ANATOMY AND PHYSIOLOGY

By

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ANATOMY AND PHYSIOLOGY

The Anatomy and Physiology module introduces the structure and function of the human body. You will read about the cells, tissues and membranes that make up our bodies and how our major systems function to help us develop and stay healthy.

In this module you will learn to:

- Describe basic human body functions and life process.
- Name the major human body systems and relate their functions.
- Describe the anatomical locations, structures and physiological functions of the main components of each major system of the human body.

INTRODUCTION TO THE HUMAN BODY

Human beings are arguably the most complex organisms on this planet. Imagine billions of microscopic parts, each with its own identity, working together in an organized manner for the benefit of the total being. The human body is a single structure but it is made up of billions of smaller structures of four major kinds:

Cells

Cells have long been recognized as the simplest units of living matter that can maintain life and reproduce themselves. The human body, which is made up of numerous cells, begins as a single, newly fertilized cell.

Tissues

Tissues are somewhat more complex units than cells. By definition, a tissue is an organization of a great many similar cells with varying amounts and kinds of nonliving, intercellular substance between them.

Organs

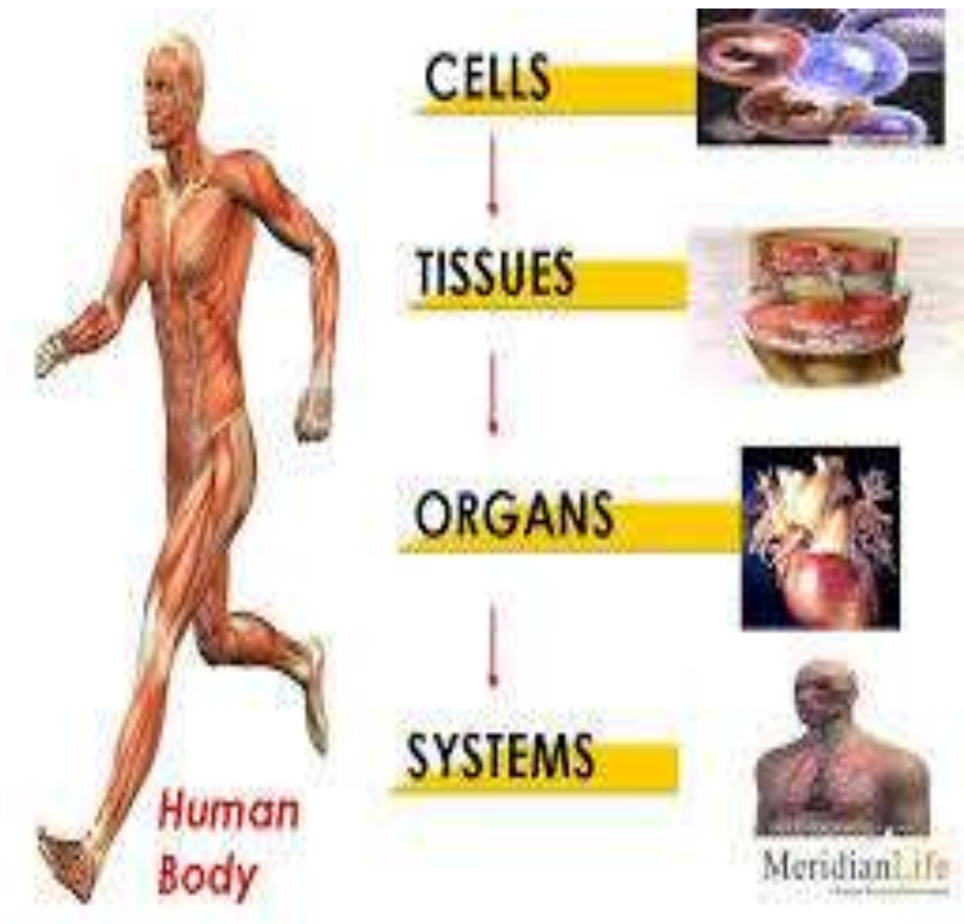
Organs are more complex units than tissues. An organ is an organization of several different kinds of tissues so arranged that together they can perform a special function. For example, the stomach is an organization of muscle, connective, epithelial, and nervous tissues. Muscle and connective tissues form its wall, epithelial and connective tissues form its lining, and nervous tissue extends throughout both its wall and its lining.

Systems

Systems are the most complex of the component units of the human body. A system is an organization of varying numbers and kinds of organs so arranged that together they can perform complex functions for the body. Ten major systems compose the human body:

- Skeletal
- Muscular
- Nervous
- Endocrine
- Cardiovascular
- Lymphatic
- Respiratory
- Digestive

- Urinary
- Reproductive



Anatomy is the study of the structure and relationship between body parts. Physiology is the study of the function of body parts and the body as a whole.

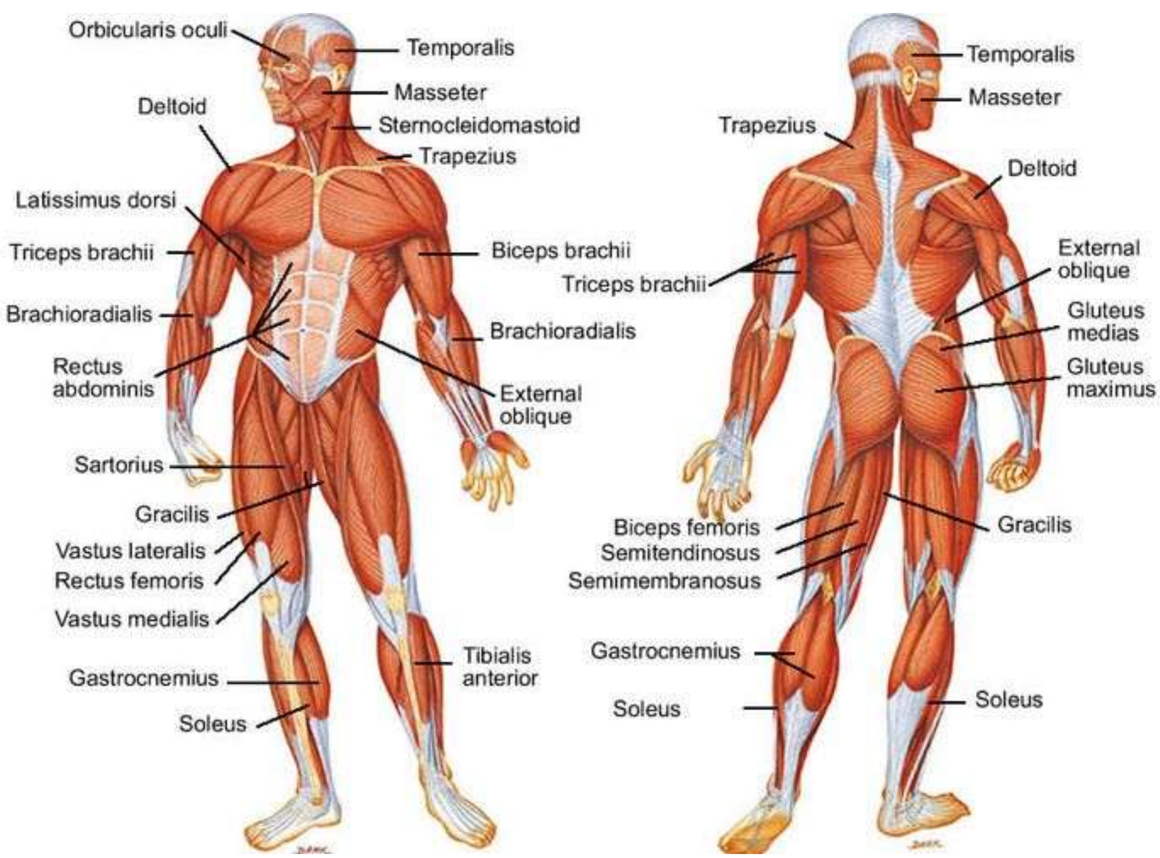
The structure of an organism or any of its parts. The scientific study of the shape and structure of organisms and their parts. **Anatomy Definition**. The structure of an animal or plant; also, the study of this structure through techniques such as microscopic observation and dissection.

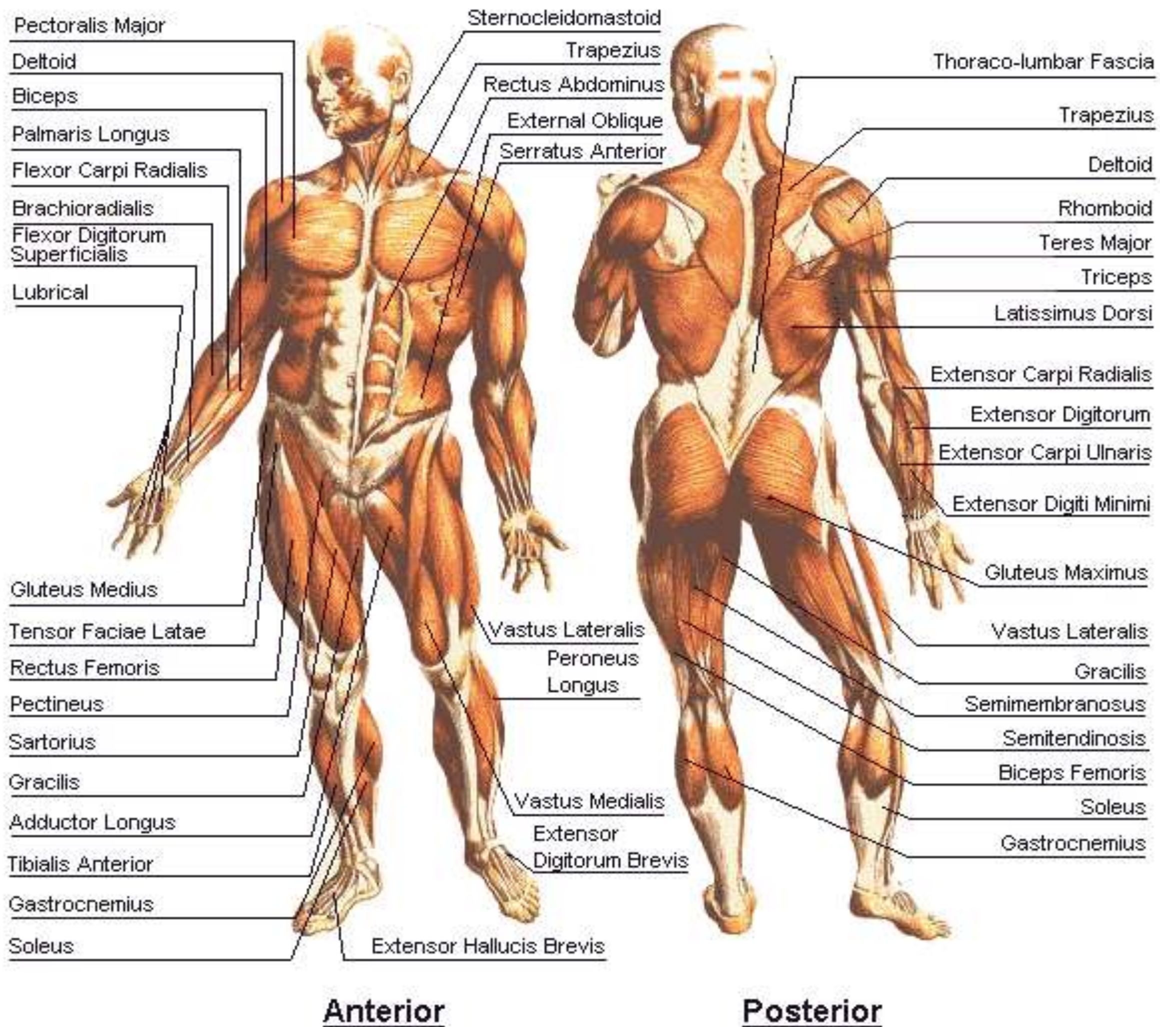
Anatomy is the branch of biology concerned with the study of the structure of organisms and their parts. In some of its facets, anatomy is related to embryology and comparative anatomy, which itself is closely related to evolutionary biology and phylogeny. Human anatomy is one of the basic essential sciences of medicine.

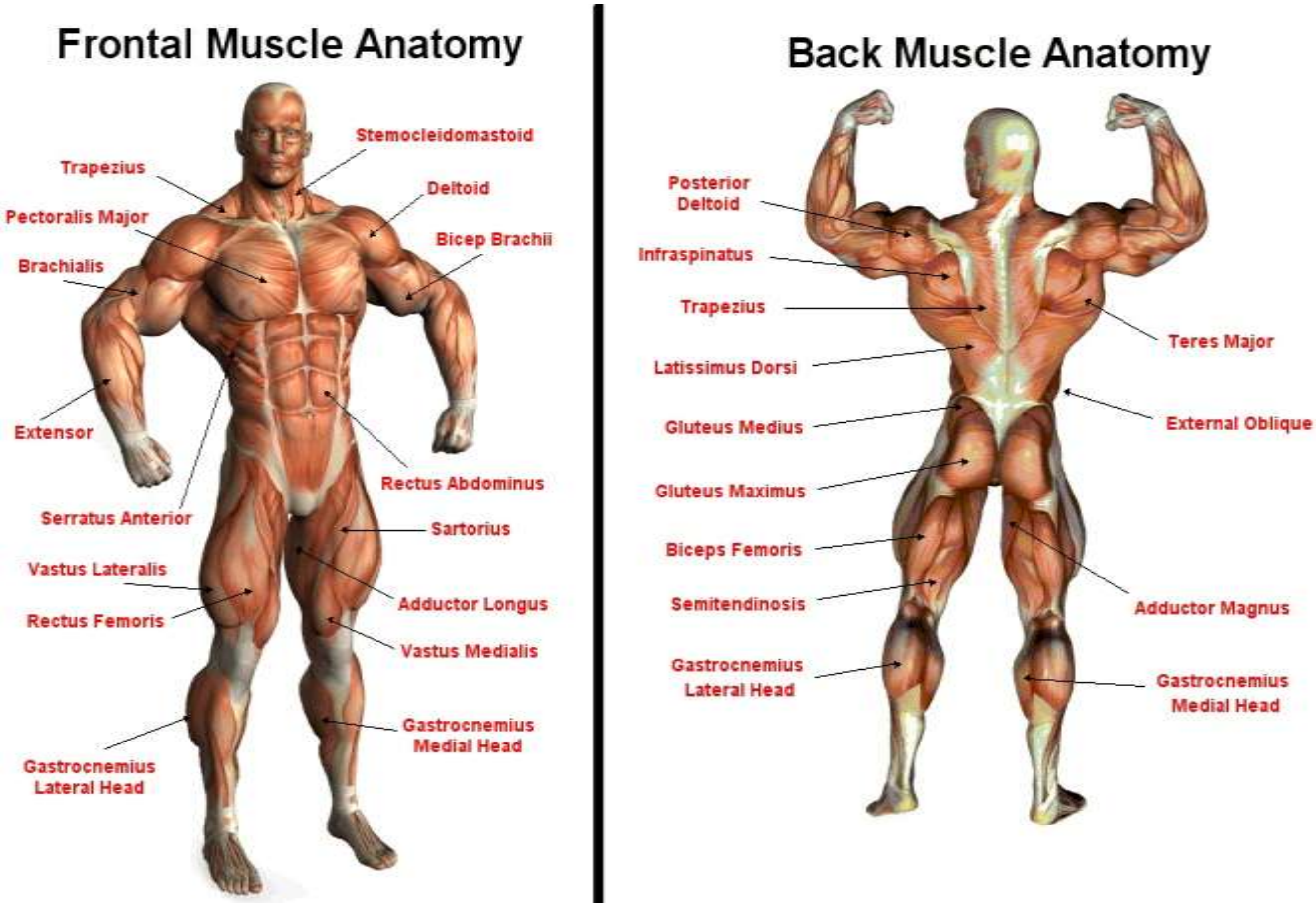
The history of anatomy is characterized by a progressive understanding of the functions of the organs and structures of the human body. Methods have also improved dramatically, advancing from the examination of animals by dissection of carcasses and cadavers (corpses) to 20th century medical imaging techniques including X-ray, ultrasound, and magnetic resonance imaging.

Anatomy and physiology, which study (respectively) the structure and function of organisms and their parts, make a natural pair of related disciplines, and they are often studied together.

Anatomy is the scientific study of the structure of organisms including their systems, organs and tissues. It includes the appearance and position of the various parts, the materials from which they are composed, their locations and their relationships with other parts. Anatomy is quite distinct from physiology and biochemistry, which deal respectively with the functions of those parts and the chemical processes involved. For example, an anatomist is concerned with the shape, size, position, structure, blood supply and innervation of an organ such as the liver; while a physiologist is interested in the production of bile, the role of the liver in nutrition and the regulation of bodily functions




Pectoralis Major
Deltoid
Biceps
Palmaris Longus
Flexor Carpi Radialis
Brachioradialis
Flexor Digitorum Superficialis
Lubrical
Gluteus Medius
Tensor Faciae Latae
Rectus Femoris
Pectineus
Sartorius
Gracilis
Adductor Longus
Tibialis Anterior
Gastrocnemius
Soleus
Sternocleidomastoid
Trapezius
Rectus Abdominus
External Oblique
Serratus Anterior
Vastus Lateralis
Peroneus Longus
Vastus Medialis
Extensor Digitorum Brevis
Extensor Hallucis Brevis
Thoraco-lumbar Fascia
Trapezius
Deltoid
Rhomboid
Teres Major
Triceps
Latissimus Dorsi
Extensor Carpi Radialis
Extensor Digitorum
Extensor Carpi Ulnaris
Extensor Digiti Minimi
Gluteus Maximus
Vastus Lateralis
Gracilis
Semimembranosus
Semitendinosis
Biceps Femoris
Soleus
Gastrocnemius
Anterior
Posterior



Anatomical Structure of human body

BODY FUNCTIONS & LIFE PROCESS

Body Functions

Body functions are the physiological or psychological functions of body systems. The body's functions are ultimately its cells' functions. Survival is the body's most important business. Survival depends on the body's maintaining or restoring homeostasis, a state of relative constancy, of its internal environment.

More than a century ago, French physiologist, Claude Bernard (1813-1878), made a remarkable observation. He noted that body cells survived in a healthy condition only when the temperature, pressure, and chemical composition of their environment remained relatively constant. Later, an American physiologist, Walter B. Cannon (1871-1945), suggested the name homeostasis for the relatively constant states maintained by the body. Homeostasis is a key word in modern physiology. It comes from two Greek words - "homeo," meaning the same, and "stasis," meaning standing. "Standing or staying the same" then is the literal meaning of homeostasis. However, as Cannon emphasized, homeostasis does not mean something set and immobile that stays exactly the same all the time. In his words, homeostasis "means a condition that may vary, but which is relatively constant."

Homeostasis depends on the body's ceaselessly carrying on many activities. Its major activities or functions are responding to changes in the body's environment, exchanging materials between the environment and cells, metabolizing foods, and integrating all of the body's diverse activities.

The body's ability to perform many of its functions changes gradually over the years. In general, the body performs its functions least well at both ends of life - in infancy and in old age. During childhood, body functions gradually become more and more efficient and effective. During late maturity and old age the opposite is true. They gradually become less and less efficient and effective. During young adulthood, they normally operate with maximum efficiency and effectiveness.

Life Process

All living organisms have certain characteristics that distinguish them from non-living forms. The basic processes of life include organization, metabolism, responsiveness, movements, and reproduction. In humans, who represent the most complex form of life, there are additional requirements such as growth, differentiation, respiration, digestion, and excretion. All of these processes are interrelated. No part of the body, from the smallest cell to a complete body system, works in isolation. All function together, in fine-tuned balance, for the well being of the individual and to maintain life. Disease such as cancer and death represent a disruption of the balance in these processes.

The following are a brief description of the life process:

Organization

At all levels of the organizational scheme, there is a division of labor. Each component has its own job to perform in cooperation with others. Even a single cell, if it loses its integrity or organization, will die.

Metabolism

Metabolism is a broad term that includes all the chemical reactions that occur in the body. One phase of metabolism is catabolism in which complex substances are broken down into simpler building blocks and energy is released.

Responsiveness

Responsiveness or irritability is concerned with detecting changes in the internal or external environments and reacting to that change. It is the act of sensing a stimulus and responding to it.

Movement

There are many types of movement within the body. On the cellular level, molecules move from one place to another. Blood moves from one part of the body to another. The diaphragm moves with every breath. The ability of muscle fibers to shorten and thus to produce movement is called contractility.

Reproduction

For most people, reproduction refers to the formation of a new person, the birth of a baby. In this way, life is transmitted from one generation to the next through reproduction of the organism. In a broader sense, reproduction also refers to the formation of new cells for the replacement and repair of old cells as well as for growth. This is cellular reproduction. Both are essential to the survival of the human race.

Growth

Growth refers to an increase in size either through an increase in the number of cells or through an increase in the size of each individual cell. In order for growth to occur, anabolic processes must occur at a faster rate than catabolic processes.

Differentiation

Differentiation is a developmental process by which unspecialized cells change into specialized cells with distinctive structural and functional characteristics. Through differentiation, cells develop into tissues and organs.

Respiration

Respiration refers to all the processes involved in the exchange of oxygen and carbon dioxide between the cells and the external environment. It includes ventilation, the diffusion of oxygen and carbon dioxide, and the transport of the gases in the blood. Cellular respiration deals with the cell's utilization of oxygen and release of carbon dioxide in its metabolism.

Digestion

Digestion is the process of breaking down complex ingested foods into simple molecules that can be absorbed into the blood and utilized by the body.

Excretion

Excretion is the process that removes the waste products of digestion and metabolism from the body. It gets rid of by-products that the body is unable to use, many of which are toxic and incompatible with life.

The ten life processes described above are not enough to ensure the survival of the individual. In addition to these processes, life depends on certain physical factors from the environment. These include water, oxygen, nutrients, heat, and pressure.

ANATOMICAL TERMINOLOGY

Before we get into the following learning units, which will provide more detailed discussion of topics on different human body systems, it is necessary to learn some useful terms for describing body structure. Knowing these terms will make it much easier for us to understand the content of the following learning units. Three groups of terms are introduced here:

- Directional Terms
- Planes of the Body
- Body Cavities

Directional Terms

Directional terms describe the positions of structures relative to other structures or locations in the body.

Superior or cranial - toward the head end of the body; upper (example, the hand is part of the superior extremity).

Inferior or caudal - away from the head; lower (example, the foot is part of the inferior extremity).

Anterior or ventral - front (example, the kneecap is located on the anterior side of the leg).

Posterior or dorsal - back (example, the shoulder blades are located on the posterior side of the body).

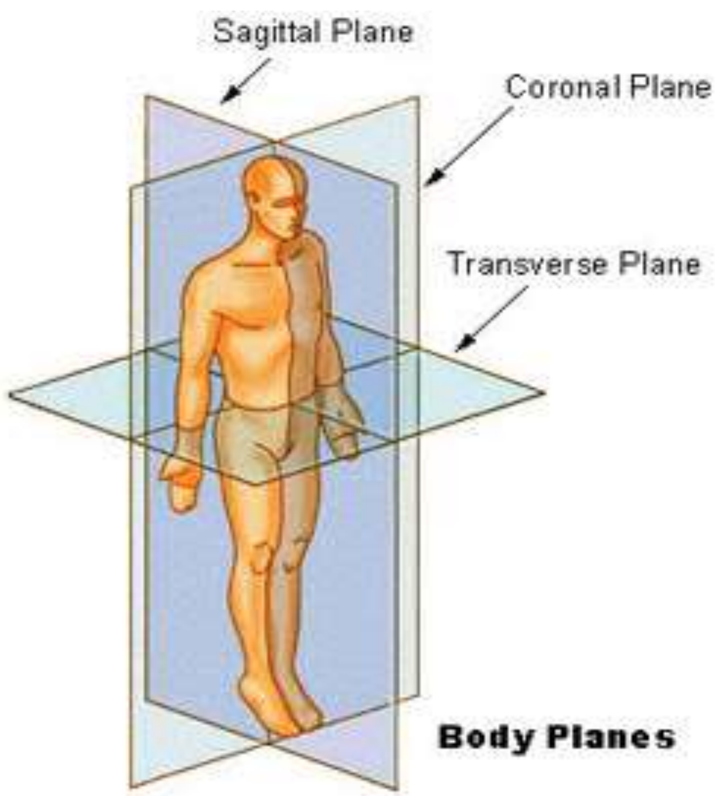
Medial - toward the midline of the body (example, the middle toe is located at the medial side of the foot).

Lateral - away from the midline of the body (example, the little toe is located at the lateral side of the foot).

Proximal - toward or nearest the trunk or the point of origin of a part (example, the proximal end of the femur joins with the pelvic bone).

Distal - away from or farthest from the trunk or the point or origin of a part (example, the hand is located at the distal end of the forearm)

Planes of the Body



Coronal Plane (Frontal Plane) - A vertical plane running from side to side; divides the body or any of its parts into anterior and posterior portions.

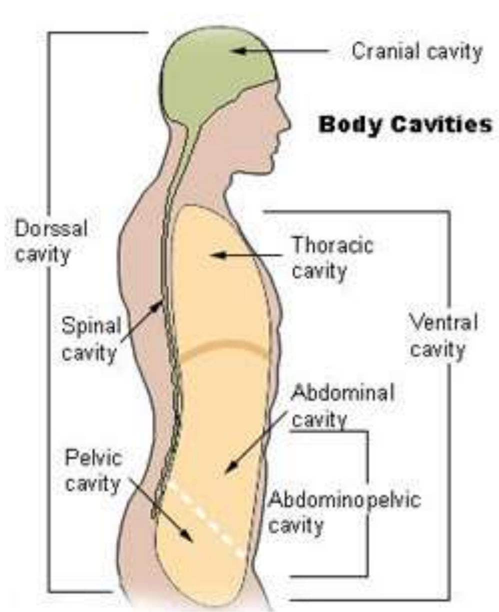
Sagittal Plane (Lateral Plane) - A vertical plane running from front to back; divides the body or any of its parts into right and left sides.

Axial Plane (Transverse Plane) - A horizontal plane; divides the body or any of its parts into upper and lower parts.

Median plane - Sagittal plane through the midline of the body; divides the body or any of its parts into right and left halves.

Body Cavaties

The cavities, or spaces, of the body contain the internal organs, or viscera. The two main cavities are called the ventral and dorsal cavities. The ventral is the larger cavity and is subdivided into two parts (thoracic and abdominopelvic cavities) by the diaphragm, a dome-shaped respiratory muscle.



Thoracic cavity

The upper ventral, thoracic, or chest cavity contains the heart, lungs, trachea, esophagus, large blood vessels, and nerves. The thoracic cavity is bound laterally by the ribs (covered by costal pleura) and the diaphragm caudally (covered by diaphragmatic pleura).

Abdominal and pelvic cavity

The lower part of the ventral (abdominopelvic) cavity can be further divided into two portions: abdominal portion and pelvic portion. The abdominal cavity contains most of the gastrointestinal tract as well as the kidneys and adrenal glands. The abdominal cavity is bound cranially by the diaphragm, laterally by the body wall, and caudally by the pelvic cavity. The pelvic cavity contains most of the urogenital system as well as the rectum. The pelvic cavity is bounded cranially by the abdominal cavity, dorsally by the sacrum, and laterally by the pelvis.

Dorsal cavity

The smaller of the two main cavities is called the dorsal cavity. As its name implies, it contains organs lying more posterior in the body. The dorsal cavity, again, can be divided into two portions. The upper portion, or the cranial cavity, houses the brain, and the lower portion, or vertebral canal houses the spinal cord.

Here is what we have learned from *Introduction to the Human Body*:

- The human body is a single structure but it is made up of billions of smaller structures of four major kinds: cells, tissues, organs, and systems.
- An organ is an organization of several different kinds of tissues so arranged that together they can perform a special function.
- A system is an organization of varying numbers and kinds of organs so arranged that together they can perform complex functions for the body.
- Ten major systems include the skeletal, muscular, nervous, endocrine, cardiovascular, lymphatic, respiratory, digestive, urinary, and the reproductive system.
- Body functions are the physiological or psychological functions of body systems. Survival of the body depends on the body's maintaining or restoring homeostasis, a state of relative constancy, of its internal environment.
- Human life process includes organization, metabolism, responsiveness, movements, reproduction, growth, differentiation, respiration, digestion, and excretion. All these processes work together, in fine-tuned balance, for the well-being of the individual and to maintain life.
- Life depends on certain physical factors from the environment, which include water, oxygen, nutrients, heat, and pressure.
- Useful terms for describing body parts and activities include:
    - Directional terms
    - Terms describing planes of the body

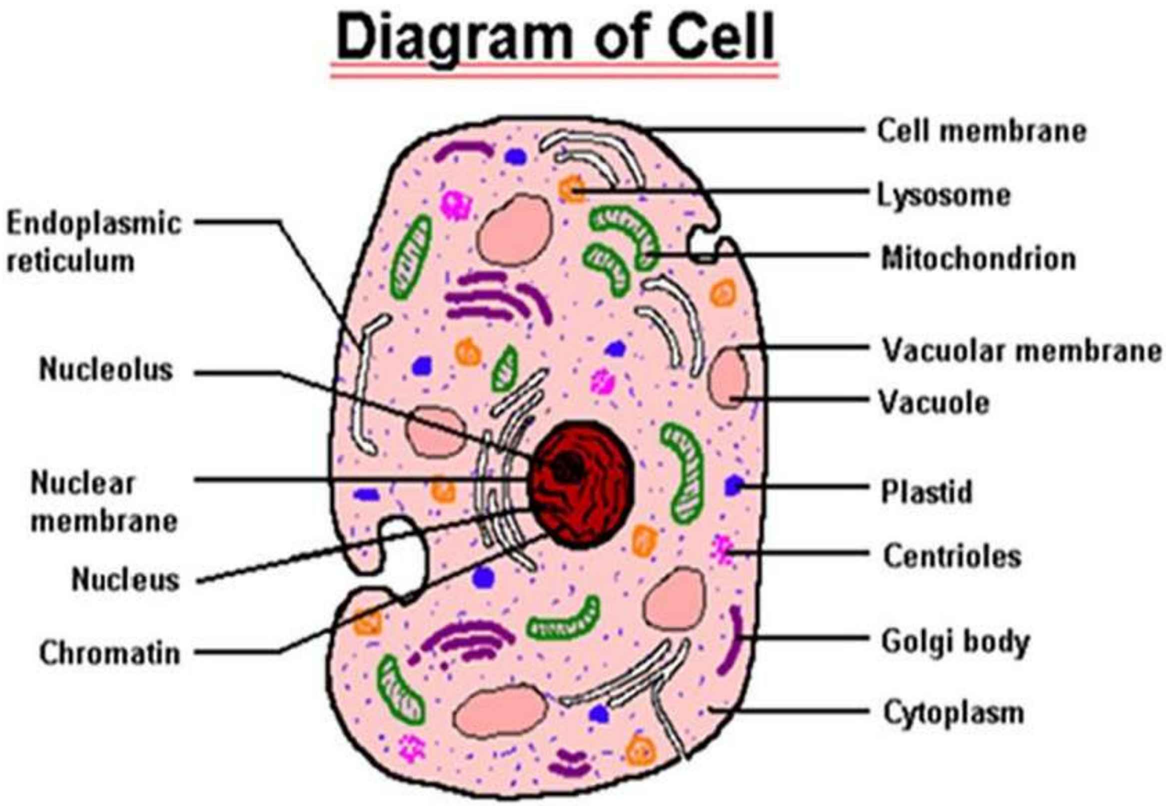
- Terms describing body cavities

Cell

The **cell** (from Latin cella, meaning "small room") is the basic structural, functional, and biological unit of all known living organisms.**Cells** is the smallest unit of life that can replicate independently, and are often called the "building blocks of life".

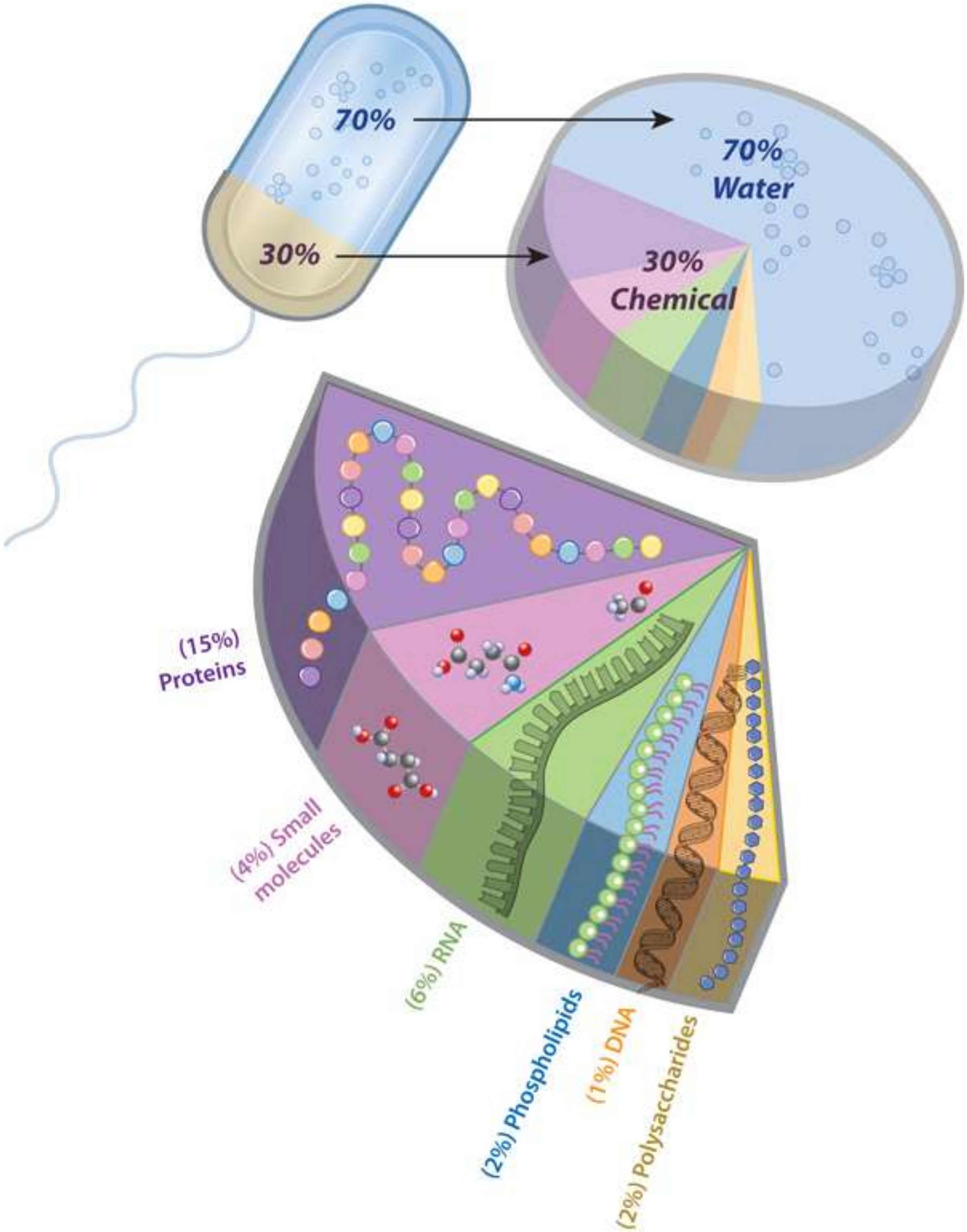
Cells, the smallest structures capable of maintaining life and reproducing, compose all living things, from single-celled plants to multibillion-celled animals. The human body, which is made up of numerous cells, begins as a single, newly fertilized cell.

Almost all human cells are microscopic in size. To give you an idea how small a cell is, one average-sized adult body, according to one estimate, consists of 100 trillion cells



Two-thirds of a cell is water, which means that **two-thirds** of your whole body is water. The rest is a mixture of molecules, mainly **proteins**, **lipids** and **carbohydrates**. Your cells turn the raw materials in the food you eat into the molecules your body needs, using thousands of different chemical reactions.

The **nucleus** is surrounded by a membrane called the nuclear envelope, which protects the **DNA** and separates the **nucleus** from the rest of the cell. Plasma membrane (illustration) the plasma membrane is the outer lining of the cell.

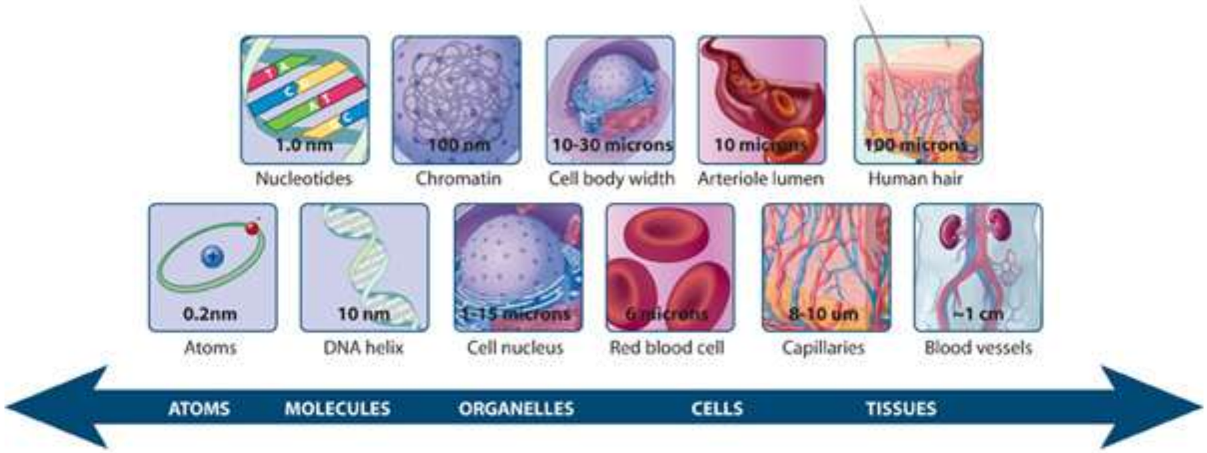

70%
30%
70%
Water
30%
Chemical
(15%) Proteins
(4%) Small molecules
(6%) RNA
(2%) Phospholipids
(1%) DNA
(2%) Polysaccharides

The **cell** (from Latin *cella*, meaning "small room") is the basic structural, functional, and biological unit of all known living organisms. Cells are the smallest unit of life that can replicate independently, and are often called the "building blocks of life". The study of cells is called cell biology.

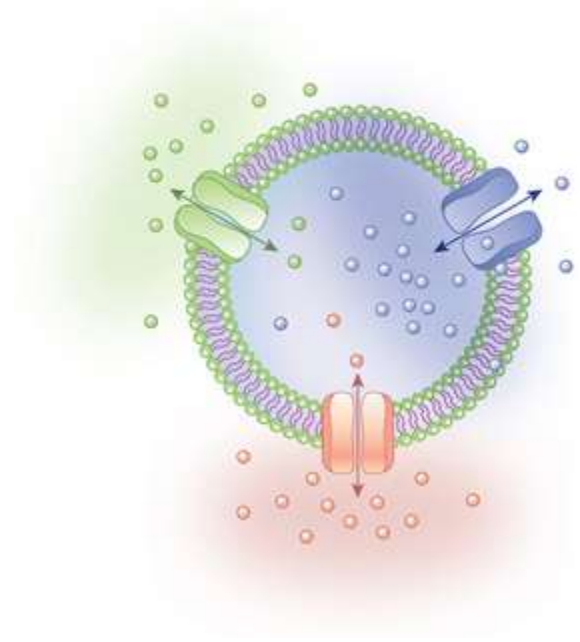
Cells consist of cytoplasm enclosed within a membrane, which contains many bimolecular such as proteins and nucleic acids. Organisms can be classified as unicellular (consisting of a single cell; including bacteria) or multi cellular (including plants and animals). While the number of cells in plants and animals varies from species to species, humans contain more than 10 trillion cells. Most plant and animal cells are visible only under the microscope, with dimensions between 1 and 100 micrometres.

The cell was discovered by Robert Hooke in 1665, who named the biological unit for its resemblance to cells inhabited by Christian monks in a monastery. Cell theory, first developed in 1839 by Matthias Jakob Schleiden and Theodor Schwann, states that all organisms are composed of one or more cells, that cells are the fundamental unit of structure and function in all living organisms, that all cells come from preexisting cells, and that all cells contain the hereditary information necessary for regulating cell functions and for transmitting information to the next generation of cells. Cells emerged on Earth at least 3.5 billion years ago.

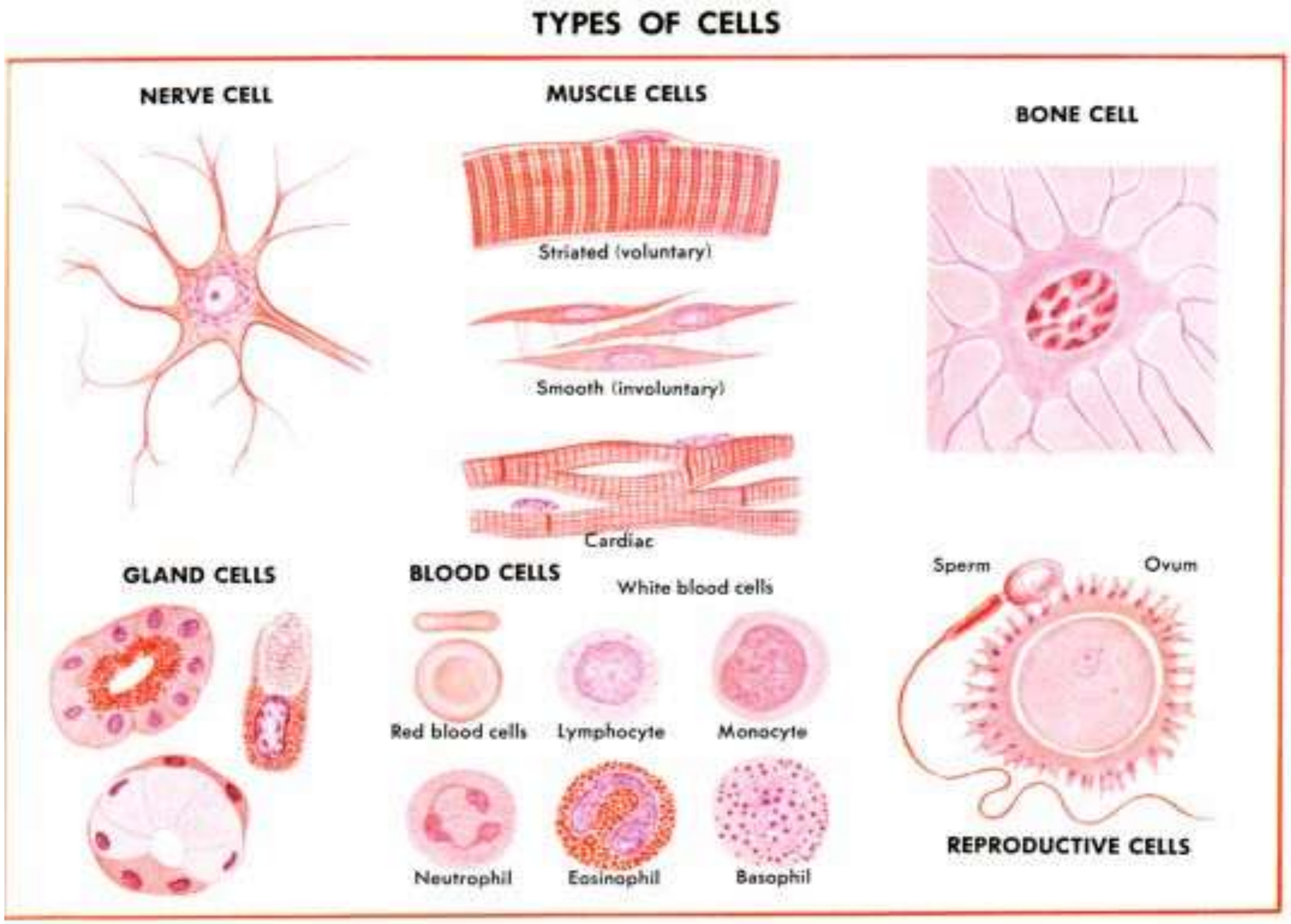
Cells are considered the basic units of life in part because they come in discrete and easily recognizable packages. That's because all cells are surrounded by a structure called the **cell membrane** — which, much like the walls of a house, serves as a clear boundary between the cell's internal and external environments. The cell membrane is sometimes also referred to as the **plasma membrane**.



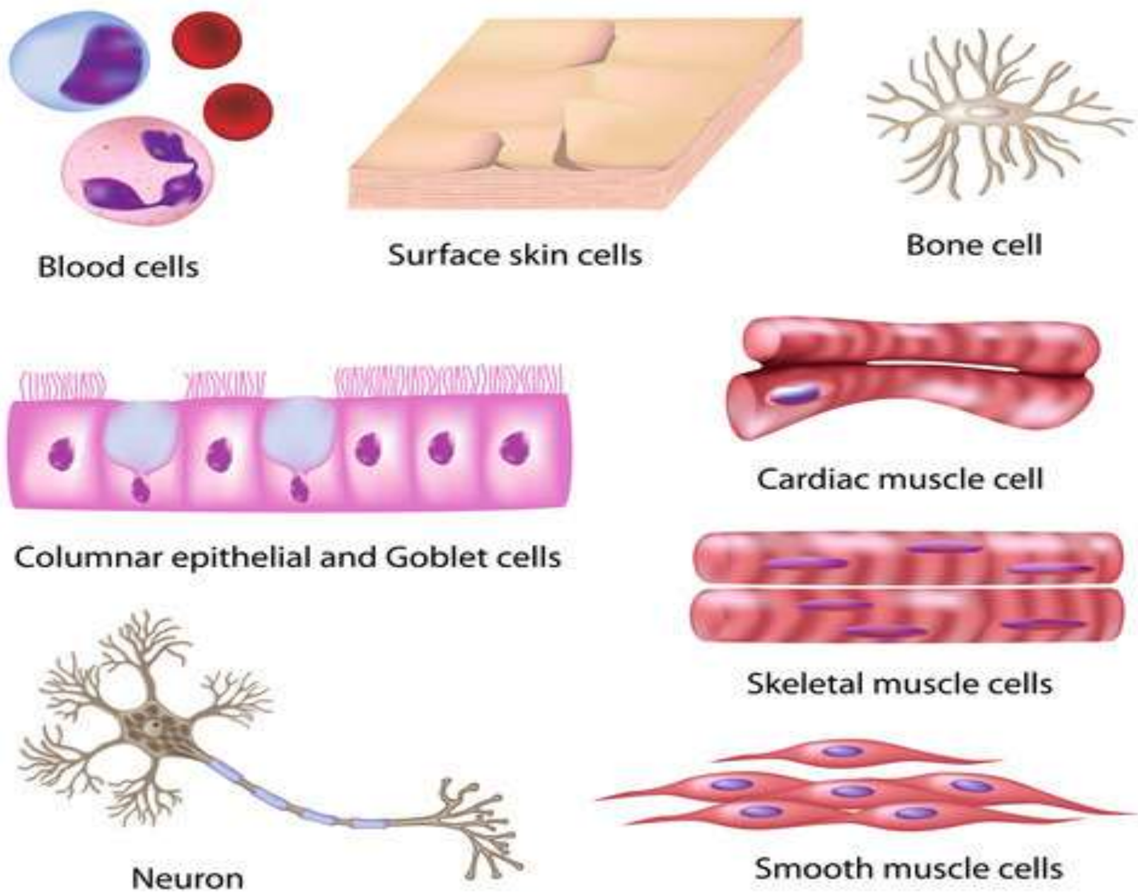
Cell membranes are based on a framework of fat-based molecules called **phospholipids**, which physically prevent water-loving, or hydrophilic, substances from entering or escaping the cell. These membranes are also studded with proteins that serve various functions. Some of these proteins act as gatekeepers, determining what substances can and cannot cross the membrane. Others function as markers, identifying the cell as part of the same organism or as foreign. Still others work like fasteners, binding cells together so they can function as a unit. Yet other membrane proteins serve as communicators, sending and receiving signals from neighboring cells and the environment — whether friendly or alarming



Cells are the smallest common denominator of life. Some cells are organisms unto themselves; others are part of multicellular organisms. All cells are made from the same major classes of organic molecules: nucleic acids, proteins, carbohydrates, and lipids. In addition, cells can be placed in two major categories as a result of ancient evolutionary events: prokaryotes, with their cytoplasmic genomes, and eukaryotes, with their nuclear-encased genomes and other membrane-bound organelles. Though they are small, cells have evolved into a vast variety of shapes and sizes. Together they form tissues that themselves form organs, and eventually entire organisms

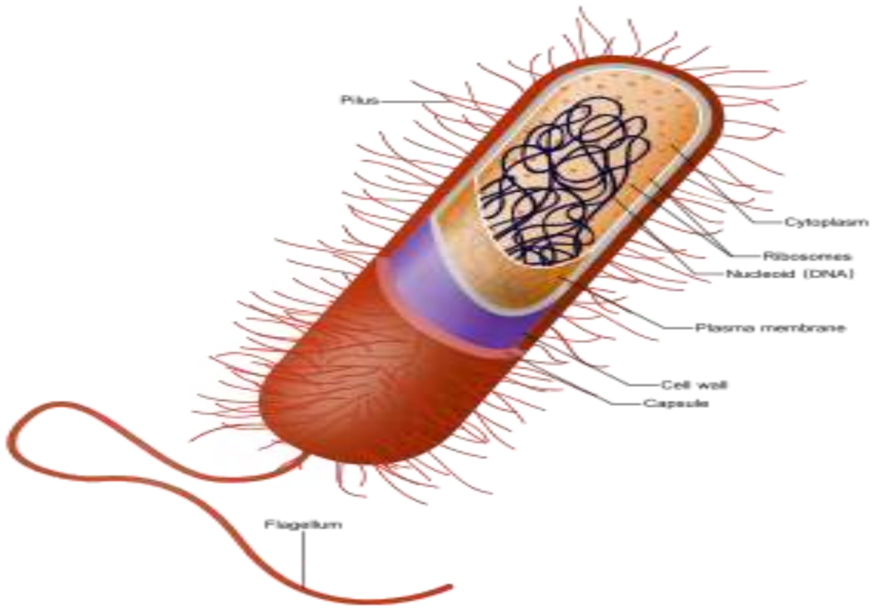


Cells are of two types, eukaryotic, which contain a nucleus, and prokaryotic, which do not. Prokaryotes are single-celled organisms, while eukaryotes can be either single-celled or multicellular.



Prokaryotic cells

Prokaryotic cells were the first form of life on Earth, characterized by having vital biological processes including cell signaling and being self-sustaining. They are simpler and smaller than eukaryotic cells, and lack membrane-bound organelles such as the nucleus. Prokaryotes include two of the domains of life, bacteria and archaea. The DNA of a prokaryotic cell consists of a single chromosome that is in direct contact with the cytoplasm. The nuclear region in the cytoplasm is called the nucleoid. Most prokaryotes are the smallest of all organisms ranging from 0.5 to 2.0 μm in diameter.



A prokaryotic cell has three architectural regions:

- Enclosing the cell is the cell envelope – generally consisting of a plasma membrane covered by a cell wall which, for some bacteria, may be further covered by a third layer called a capsule. Though most prokaryotes have both a cell membrane and a cell wall, there are exceptions such as *Mycoplasma* (bacteria) and *Thermoplasma* (archaea) which only possess the cell membrane layer. The envelope gives rigidity to the cell and separates the interior of the cell from its environment, serving as a protective filter. The cell wall consists of peptidoglycan in bacteria, and acts as an additional barrier against exterior forces. It also prevents the cell from expanding and bursting (cytolysis) from osmotic pressure due to a hypotonic environment. Some eukaryotic cells (plant cells and fungal cells) also have a cell wall.
- Inside the cell is the cytoplasmic region that contains the genome (DNA), ribosome and various sorts of inclusions. The genetic material is freely

found in the cytoplasm. Prokaryotes can carry extra chromosomal DNA elements called plasmids, which are usually circular. Linear bacterial plasmids have been identified in several species of spirochetebacteria, including members of the genus Borrelia notably *Borrelia burgdorferi*, which causes Lyme disease.[13] Though not forming a *nucleus*, the DNA is condensed in a *nucleoid*. Plasmids encode additional genes, such as antibiotic resistance genes.

- On the outside, flagella and pili project from the cell's surface. These are structures (not present in all prokaryotes) made of proteins that facilitate movement and communication between cells.

Eukaryotic cells

Plants, animals, fungi, slime moulds, protozoa, and algae are all eukaryotic. These cells are about fifteen times wider than a typical prokaryote and can be as much as a thousand times greater in volume. The main distinguishing feature of eukaryotes as compared to prokaryotes is compartmentalization: the presence of membrane-bound organelles (compartments) in which specific metabolic activities take place. Most important among these is a cell nucleus, an organelle that houses the cell's DNA. This nucleus gives the eukaryote its name, which means "true kernel (nucleus)". Other differences include:

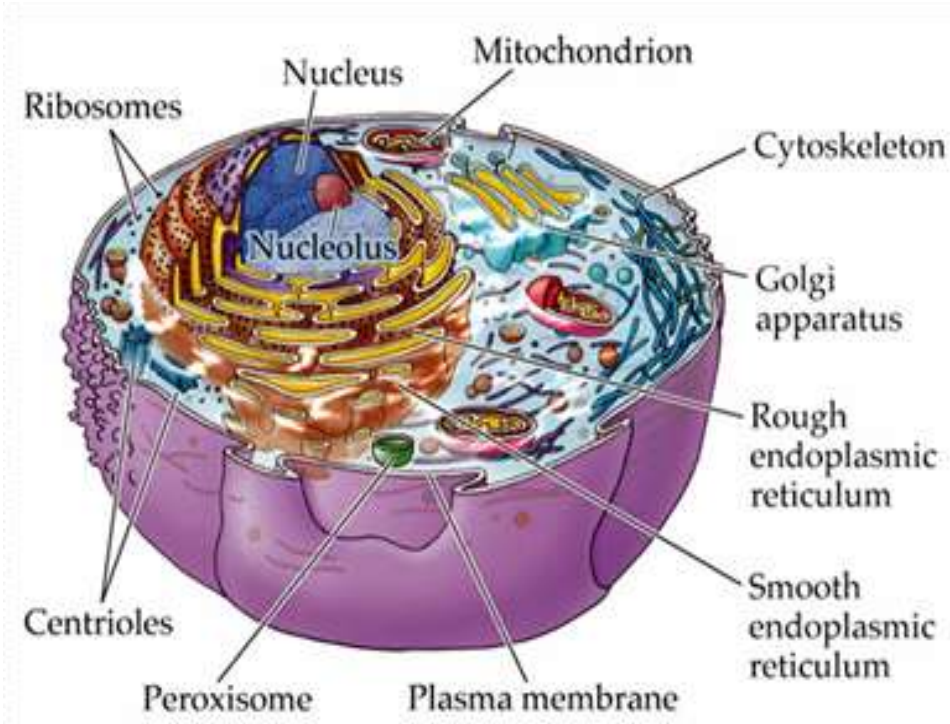
- The plasma membrane resembles that of prokaryotes in function, with minor differences in the setup. Cell walls may or may not be present.

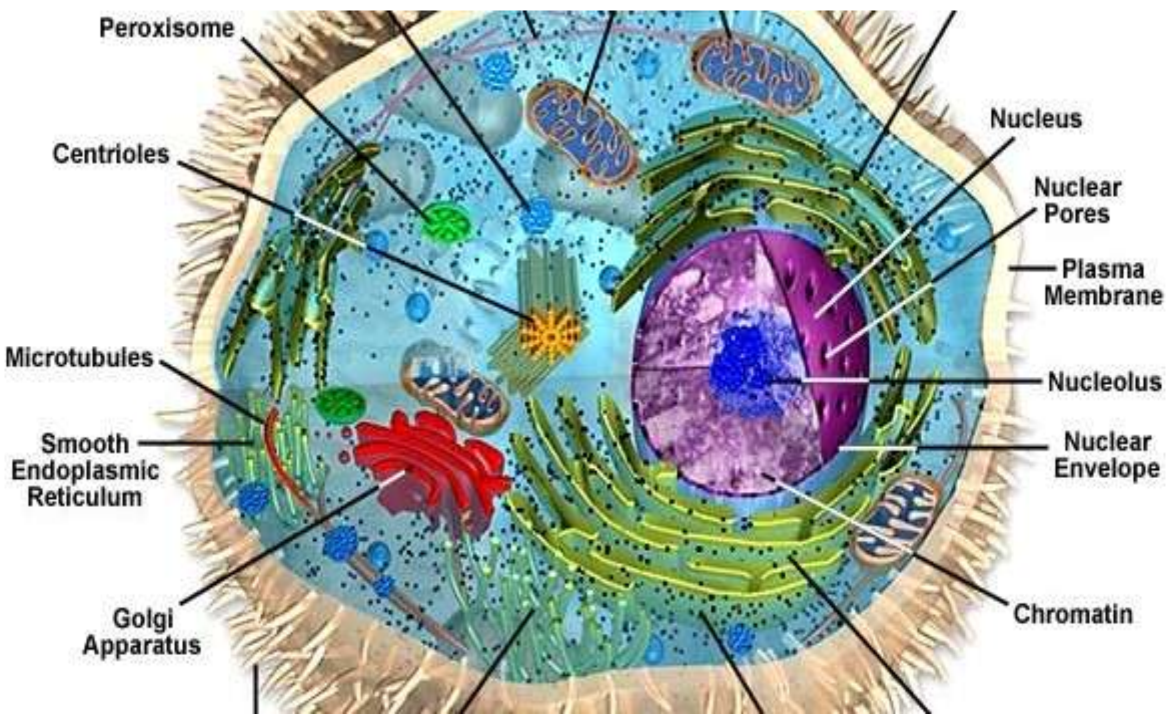
- The eukaryotic DNA is organized in one or more linear molecules, called chromosomes, which are associated with histoneproteins. All chromosomal DNA is stored in the *cell nucleus*, separated from the cytoplasm by a membrane. Some eukaryotic organelles such as mitochondria also contain some DNA.

- Many eukaryotic cells are ciliated with *primary cilia*. Primary cilia play important roles in chemosensation,mechanosensation, and thermo sensation. Cilia may thus be "viewed as a sensory cellular antennae that coordinates a large number of cellular signaling pathways, sometimes coupling the signaling to ciliary motility or alternatively to cell division and differentiation."

- Motile cells of eukaryotes can move using *motile cilia* or *flagella*. Motile cells are absent in conifers and flowering plants. Eukaryotic flagella are less complex than those of prokaryotes.

All cells, whether prokaryotic or eukaryotic, have a membrane that envelops the cell, regulates what moves in and out (selectively permeable), and maintains the electric potential of the cell. Inside the membrane, the cytoplasm takes up most of the cell's volume. All cells (except red blood cells which lack a cell nucleus and most organelles to accommodate maximum space for hemoglobin) possess DNA, the hereditary material of genes, and RNA, containing the information necessary to build various proteins such as enzymes, the cell's primary machinery. There are also other kinds of bimolecular in cells. This article lists these primary components of the cell, then briefly describes their function.


Nucleus
Mitochondrion
Ribosomes
Cytoskeleton
Nucleolus
Golgi
apparatus
Rough
endoplasmic
reticulum
Smooth
endoplasmic
reticulum
Centrioles
Peroxisome
Plasma membrane


Peroxisome
Centrioles
Nucleus
Nuclear
Pores
Plasma
Membrane
Microtubules
Nucleolus
Smooth
Endoplasmic
Reticulum
Nuclear
Envelope
Golgi
Apparatus
Chromatin

Membrane

The cell membrane, or plasma membrane, is a biological membrane that surrounds the cytoplasm of a cell. In animals, the plasma membrane is the outer boundary of the cell, while in plants and prokaryotes it is usually covered by a cell wall. This membrane serves to separate and protect a cell from its surrounding environment and is made mostly from a double layer of phospholipids, which are amphiphilic (partly hydrophobic and partly hydrophilic). Hence, the layer is called a phospholipids bilayer, or sometimes a fluid mosaic membrane. Embedded within this membrane is a variety of protein molecules that act as channels and pumps that move different molecules into and out of the cell. The membrane is said to be 'semi-permeable', in that it can either let a substance (molecule or ion) pass through freely, pass through to a limited extent or not pass through at all. Cell surface membranes also contain receptor proteins that allow cells to detect external signaling molecules such as hormones.

Genetic material

Two different kinds of genetic material exist: deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). Cells use DNA for their long-term information storage. The biological information contained in an organism is encoded in its DNA sequence. RNA is used for information transport (e.g., mRNA) and enzymatic functions (e.g., ribosomal RNA). Transfer RNA (tRNA) molecules are used to add amino acids during protein translation.

Prokaryotic genetic material is organized in a simple circular DNA molecule (the bacterial chromosome) in the nucleoid region of the cytoplasm. Eukaryotic genetic material is divided into different, linear molecules called chromosomes inside a discrete nucleus, usually with additional genetic material in some organelles like mitochondria andchloroplasts (see endosymbiotic theory).

A human cell has genetic material contained in the cell nucleus (the nuclear genome) and in the mitochondria (the mitochondrial genome). In humans the nuclear genome is divided into 46 linear DNA molecules called chromosomes, including 22 homologous chromosome pairs and a pair of sex chromosomes. The mitochondrial genome is a circular DNA molecule distinct from the nuclear DNA. Although the mitochondrial DNA is very small compared to nuclear chromosomes, it codes for 13 proteins involved in mitochondrial energy production and specific RNAs.

Foreign genetic material (most commonly DNA) can also be artificially introduced into the cell by a process called transfection. This can be transient, if the DNA is not inserted into the cell's genome, or stable, if it is. Certain viruses also insert their genetic material into the genome.

Cells, the smallest structures capable of maintaining life and reproducing, compose all living things, from single-celled plants to multibillion-celled animals. The human body, which is made up of numerous cells, begins as a single, newly fertilized cell.

Almost all human cells are microscopic in size. To give you an idea how small a cell is, one average-sized adult body, according to one estimate, consists of 100 trillion cells!

CELL FUNCTION

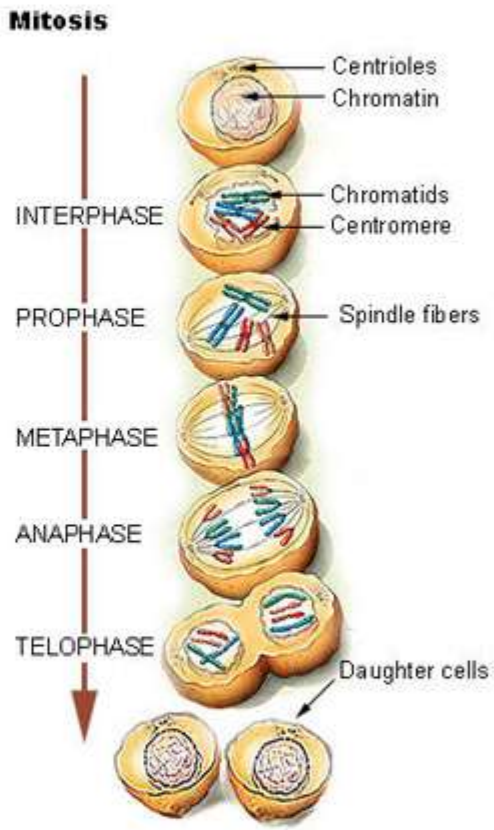
The structural and functional characteristics of different types of cells are determined by the nature of the proteins present. Cells of various types have different functions because cell structure and function are closely related. It is apparent that a cell that is very thin is not well suited for a protective function. Bone cells do not have an appropriate structure for nerve impulse conduction. Just as there are many cell types, there are varied cell functions. The generalized cell functions include movement of substances across the cell membrane, cell division to make new cells, and protein synthesis.

Movement of substances across the cell membrane

The survival of the cell depends on maintaining the difference between extracellular and intracellular material. Mechanisms of movement across the cell membrane include simple diffusion, osmosis, filtration, active transport, endocytosis, andexocytosis.

Simple diffusion is the movement of particles (solutes) from a region of higher solute concentration to a region of lower solute concentration. Osmosis is the diffusion of solvent or water molecules through a selectively permeable membrane. Filtration utilizes pressure to push substances through a membrane. Active transport moves substances against a concentration gradient from a region of lower concentration to a region of higher concentration. It requires a carrier molecule and uses energy. Endocytosis refers to the formation of vesicles to transfer particles and droplets from outside to inside the cell. Secretory vesicles are moved from the inside to the outside of the cell by exocytosis.

Cell division



Cell division is the process by which new cells are formed for growth, repair, and replacement in the body. This process includes division of the nuclear material and division of the cytoplasm. All cells in the body (somatic cells), except those that give rise to the eggs and sperm (gametes), reproduce by mitosis. Egg and sperm cells are produced by a special type of nuclear division called meiosis in which the number of chromosomes is halved. Division of the cytoplasm is called cytokinesis.

Somatic cells reproduce by mitosis, which results in two cells identical to the one parent cell. Interphase is the period between successive cell divisions. It is the longest part of the cell cycle. The successive stages of mitosis are prophase, metaphase, anaphase, and telophase. Cytokinesis, division of the cytoplasm, occurs during telophase.

Meiosis is a special type of cell division that occurs in the production of the gametes, or eggs and sperm. These cells have only 23 chromosomes, one-half the number found in somatic cells, so that when fertilization takes place the resulting cell will again have 46 chromosomes, 23 from the egg and 23 from the sperm.

DNA replication and protein synthesis

Proteins that are synthesized in the cytoplasm function as structural materials, enzymes that regulate chemical reactions, hormones, and other vital substances. DNA in the nucleus directs protein synthesis in the cytoplasm. A gene is the portion of a DNA molecule that controls the synthesis of one specific protein molecule. Messenger RNA carries the genetic information from the DNA in the nucleus to the sites of protein synthesis in the cytoplasm.

There are many different types, sizes, and shapes of cells in the body. For descriptive purposes, the concept of a "generalized cell" is introduced. It includes features from all cell types. A cell consists of three parts: the cell membrane, the nucleus, and, between the two, the cytoplasm. Within the cytoplasm lie intricate arrangements of fine fibers and hundreds or even thousands of miniscule but distinct structures called organelles.

Cell membrane

Every cell in the body is enclosed by a cell (Plasma) membrane. The cell membrane separates the material outside the cell, extracellular, from the material inside the cell, intracellular. It maintains the integrity of a cell and controls passage of materials into and out of the cell. All materials within a cell must have access to the cell membrane (the cell's boundary) for the needed exchange.

The cell membrane is a double layer of phospholipid molecules. Proteins in the cell membrane provide structural support, form channels for passage of materials, act as receptor sites, function as carrier molecules, and provide identification markers.

Nucleus and Nucleolus

The nucleus, formed by a nuclear membrane around a fluid nucleoplasm, is the control center of the cell. Threads of chromatin in the nucleus contain deoxyribonucleic acid (DNA), the genetic material of the cell. The nucleolus is a dense region of ribonucleic acid (RNA) in the nucleus and is the site of ribosome formation. The nucleus determines how the cell will function, as well as the basic structure of that cell.

Cytoplasm

The cytoplasm is the gel-like fluid inside the cell. It is the medium for chemical reaction. It provides a platform upon which other organelles can operate within the cell. All of the functions for cell expansion, growth and replication are carried out in the cytoplasm of a cell. Within the cytoplasm, materials move by diffusion, a physical process that can work only for short distances.

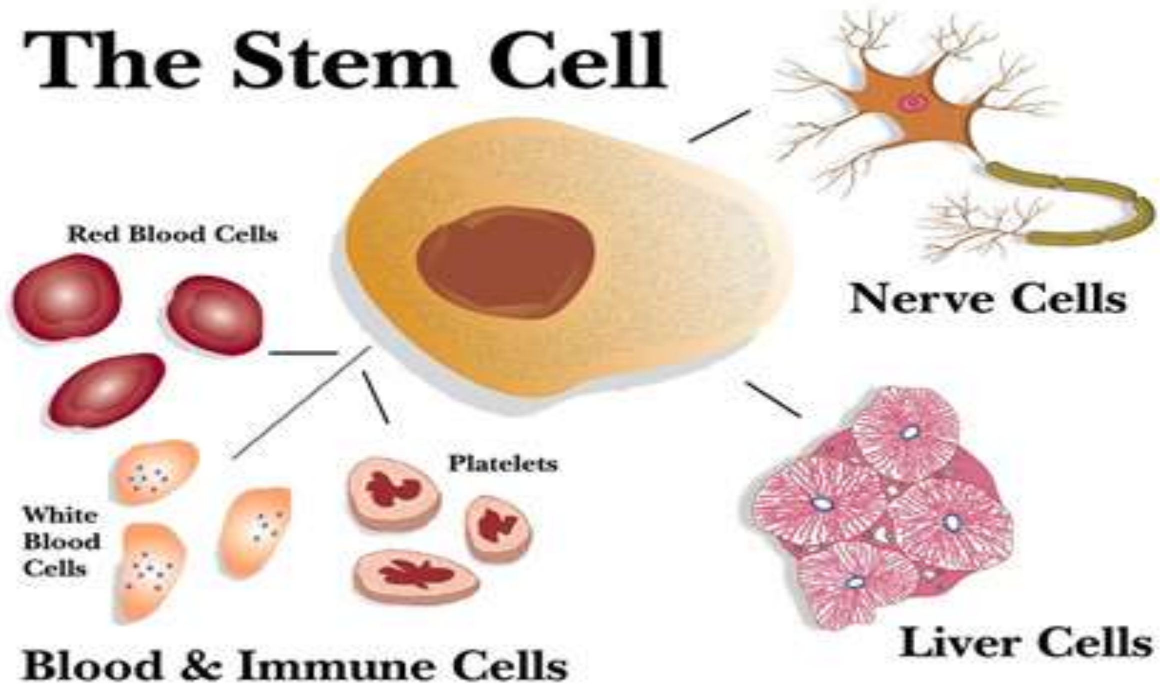
Cytoplasmic organelles

Cytoplasmic organelles are "little organs" that are suspended in the cytoplasm of the cell. Each type of organelle has a definite structure and a specific role in the function of the cell. Examples of cytoplasmic organelles are mitochondrion, ribosomes,endoplasmic reticulum, golgi apparatus, and lysosomes.

Organelles

Organelles are parts of the cell which are adapted and/or specialized for carrying out one or more vital functions, analogous to the organs of the human body (such as the heart, lung, and kidney, with each organ performing a different function). Both eukaryotic and prokaryotic cells have organelles, but prokaryotic organelles are generally simpler and are not membrane-bound.

There are several types of organelles in a cell. Some (such as the nucleus and golgi apparatus) are typically solitary, while others (such as mitochondria, chloroplasts,peroxisomes and lysosomes) can be numerous (hundreds to thousands). The cytosol is the gelatinous fluid that fills the cell and surrounds the organelles.



Eukaryotic

- **Cell nucleus**: A cell's information center, the cell nucleus is the most conspicuous organelle found in a eukaryotic cell. It houses the cell's chromosomes, and is the place where almost all DNA replication and RNA synthesis (transcription) occur. The nucleus is spherical and separated from the cytoplasm by a double membrane called the nuclear envelope. The nuclear envelope isolates and protects a cell's DNA from various molecules that could accidentally damage its structure or interfere with its processing. During processing, DNA is transcribed, or copied into a special RNA, called messenger RNA (mRNA). This mRNA is then transported out of the nucleus, where it is translated into a specific protein molecule. The nucleolus is a specialized region within the nucleus where ribosome subunits are assembled. In prokaryotes, DNA processing takes place in the cytoplasm.

- **Mitochondria and Chloroplasts**: generate energy for the cell. Mitochondria are self-replicating organelles that occur in various numbers, shapes, and sizes in the cytoplasm of all eukaryotic cells. Respiration occurs in the cell mitochondria, which generate the cell's energy by oxidative phosphorylation, using oxygen to release energy stored in cellular nutrients (typically pertaining to glucose) to generate ATP. Mitochondria multiply by binary fission, like prokaryotes. Chloroplasts can only be found in plants and algae, and they capture the sun's energy to make carbohydrates through photosynthesis.

- **Endoplasmic reticulum**: The endoplasmic reticulum (ER) is a transport network for molecules targeted for certain modifications and specific destinations, as compared to molecules that float freely in the cytoplasm. The ER has two forms: the rough ER, which has ribosomes on its surface that secrete proteins into the ER, and the smooth ER, which lacks ribosomes. The smooth ER plays a role in calcium sequestration and release.
- **Golgi apparatus**: The primary function of the Golgi apparatus is to process and package the macromolecules such as proteins andlipids that are synthesized by the cell.
- **Lysosomes and Peroxisomes**: Lysosomes contain digestive enzymes (acid hydrolases). They digest excess or worn-outorganelles, food particles, and engulfed viruses or bacteria. Peroxisomes have enzymes that rid the cell of toxic peroxides. The cell could not house

these destructive enzymes if they were not contained in a membrane-bound system.

- **Centrosome**: the cytoskeleton organiser: The centrosome produces the microtubules of a cell – a key component of thecytoskeleton. It directs the transport through the ER and the Golgi apparatus. Centrosomes are composed of two centrioles, which separate during cell division and help in the formation of the mitotic spindle. A single centrosome is present in the animal cells. They are also found in some fungi and algae cells.

- **Vacuoles**: Vacuoles sequester waste products and in plant cells store water. They are often described as liquid filled space and are surrounded by a membrane. Some cells, most notably *Amoeba*, have contractile vacuoles, which can pump water out of the cell if there is too much water. The vacuoles of plant cells and fungal cells are usually larger than those of animal cells.

Eukaryotic and prokaryotic

- **Ribosomes**: The ribosome is a large complex of RNA and protein molecules. They each consist of two subunits, and act as an assembly line where RNA from the nucleus is used to synthesise proteins from amino acids. Ribosomes can be found either floating freely or bound to a membrane (the rough endoplasmatic reticulum in eukaryotes, or the cell membrane in prokaryotes).

TISSUES

BODY TISSUES

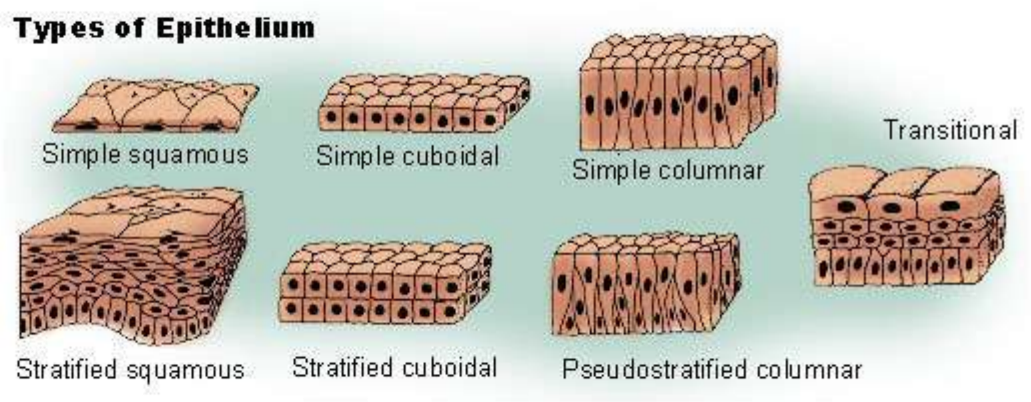
Tissue is a group of cells that have similar structure and that function together as a unit. A nonliving material, called the intercellular matrix, fills the spaces between the cells. This may be abundant in some tissues and minimal in others. The intercellular matrix may contain special substances such as salts and fibers that are unique to a specific tissue and gives that tissue distinctive characteristics. There are four main tissue types in the body: epithelial, connective, muscle, and nervous. Each is designed for specific functions.

EPITHELIAL TISSUE

Epithelial tissues are widespread throughout the body. They form the covering of all body surfaces, line body cavities and hollow organs, and are the major tissue in glands. They perform a variety of functions that include protection, secretion, absorption, excretion, filtration, diffusion, and sensory reception.

The cells in epithelial tissue are tightly packed together with very little intercellular matrix. Because the tissues form coverings and linings, the cells have one free surface that is not in contact with other cells. Opposite the free surface, the cells are attached to underlying connective tissue by a non-cellular basement membrane. This membrane is a mixture of carbohydrates and proteins secreted by the epithelial and connective tissue cells.

Epithelial cells may be squamous, cuboidal, or columnar in shape and may be arranged in single or multiple layers.

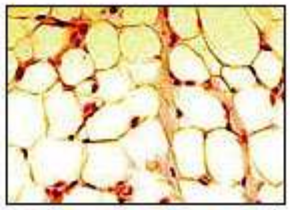


Simple cuboidal epithelium is found in glandular tissue and in the kidney tubules. Simple columnar epithelium lines the stomach and intestines. Pseudostratified columnar epithelium lines portions of the respiratory tract and some of the tubes of the male reproductive tract. Transitional epithelium can be distended or stretched. Glandular epithelium is specialized to produce and secrete substances.

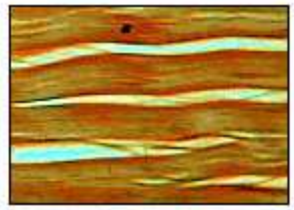
CONNECTIVE TISSUE

Connective tissues bind structures together, form a framework and support for organs and the body as a whole, store fat, transport substances, protect against disease, and help repair tissue damage. They occur throughout the body. Connective tissues are characterized by an abundance of intercellular matrix with relatively few cells. Connective tissue cells are able to reproduce but not as rapidly as epithelial cells. Most connective tissues have a good blood supply but some do not.

Areolar connective tissue

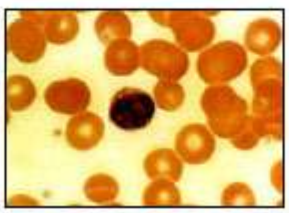


Adipose tissue



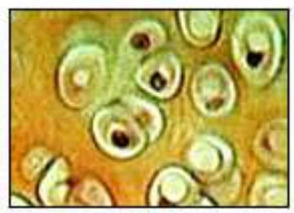
Fibrous connective tissue

Numerous cell types are found in connective tissue. Three of the most common are the fibroblast, macrophage, and mast cell. The types of connective tissue include loose connective tissue, adipose tissue, dense fibrous connective tissue, elastic connective tissue, cartilage, osseous tissue (bone), and blood.



Blood

Osseous tissue



Hyaline cartilage

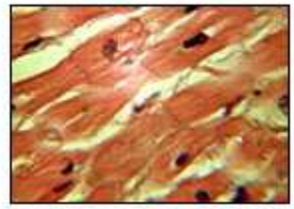
MUSCLE TISSUE

Muscle tissue is composed of cells that have the special ability to shorten or contract in order to produce movement of the body parts. The tissue is highly cellular and is well supplied with blood vessels. The cells are long and slender so they are sometimes called muscle fibers, and these are usually arranged in bundles or layers that are surrounded by connective tissue. Actin and myosin are contractile proteins in muscle tissue.

Muscle tissue can be categorized into skeletal muscle tissue, smooth muscle tissue, and cardiac muscle tissue.


Skeletal muscle


Smooth muscle


Cardiac muscle

Skeletal muscle fibers are cylindrical, multinucleated, striated, and under voluntary control. Smooth muscle cells are spindle shaped, have a single, centrally located nucleus, and lack striations. They are called involuntary muscles. Cardiac muscle has branching fibers, one nucleus per cell, striations, and intercalated disks. Its contraction is not under voluntary control.

NERVOUS TISSUE

Nervous tissue is found in the brain, spinal cord, and nerves. It is responsible for coordinating and controlling many body activities. It stimulates muscle contraction, creates an awareness of the environment, and plays a major role in emotions, memory, and reasoning. To do all these things, cells in nervous tissue need to be able to communicate with each other by way of electrical nerve impulses. The cells in nervous tissue that generate and conduct impulses are called neurons or nerve cells. These cells have three principal parts: the dendrites, the cell body, and one axon. The main part of the cell, the part that carries on the general functions, is the cell body. Dendrites are extensions, or processes, of the cytoplasm that carry impulses to the cell body. An extension or process called an axon carries impulses away from the cell body.

Nervous tissue also includes cells that do not transmit impulses, but instead support the activities of the neurons. These are the glial cells (neuroglial cells), together termed the neuroglia. Supporting, or glia, cells bind neurons together and insulate the neurons. Some are phagocytic and protect against bacterial invasion, while others provide nutrients by binding blood vessels to the neurons.

MEMBRANES

Body membranes are thin sheets of tissue that cover the body, line body cavities, and cover organs within the cavities in hollow organs. They can be categorized into epithelial and connective tissue membrane.

Epithelial Membranes

Epithelial membranes consist of epithelial tissue and the connective tissue to which it is attached. The two main types of epithelial membranes are the mucous membranes and serous membranes.

Mucous Membranes

Mucous membranes are epithelial membranes that consist of epithelial tissue that is attached to an underlying loose connective tissue. These membranes, sometimes called mucosae, line the body cavities that open to the outside. The entire digestive tract is lined with mucous membranes. Other examples include the respiratory, excretory, and reproductive tracts.

Serous Membranes

Serous membranes line body cavities that do not open directly to the outside, and they cover the organs located in those cavities. Serous membranes are covered by a thin layer of serous fluid that is secreted by the epithelium. Serous fluid lubricates the membrane and reduces friction and abrasion when organs in the thoracic or abdomen pelvic cavity move against each other or the cavity wall. Serous membranes have special names given according to their location. For example, the serous membrane that lines the thoracic cavity and covers the lungs is called pleura.

Connective Tissue Membranes

Connective tissue membranes contain only connective tissue. Synovial membranes and meninges belong to this category.

Synovial Membranes

Synovial membranes are connective tissue membranes that line the cavities of the freely movable joints such as the shoulder, elbow, and knee. Like serous membranes, they line cavities that do not open to the outside. Unlike serous membranes, they do not have a layer of epithelium. Synovial membranes secrete synovial fluid into the joint cavity, and this lubricates the cartilage on the ends of the bones so that they can move freely and without friction.

Meninges

The connective tissue covering on the brain and spinal cord, within the dorsal cavity, are called meninges. They provide protection for these vital structures.

Skeletal System Anatomy

The skeletal system includes all of the bones and joints in the body. Each bone is a complex living organ that is made up of many cells, protein fibers, and minerals. The skeleton acts as a scaffold by providing support and protection for the soft tissues that make up the rest of the body. The skeletal system also provides attachment points for muscles to allow movements at the joints. New blood cells are produced by the red bone marrow inside of our bones. New blood cells are produced by the red bone marrow inside of our bones. Bones act as the body’s warehouse for calcium, iron, and energy in the form of fat. Finally, the skeleton grows throughout childhood and provides a framework for the rest of the body to grow along with it.

The skeletal system in an adult body is made up of 206 individual bones. These bones are arranged into two major divisions: the *axial skeleton* and the *appendicular skeleton*. The axial skeleton runs along the body’s midline axis and is made up of 80 bones in the following regions:

- Skull
- Hyoid
- Auditory ossicles
- Ribs
- Sternum
- Vertebral column

The appendicle skeleton is made up of 126 bones in the following regions:

- Upper limbs
- Lower limbs
- Pelvic girdle
- Pectoral (shoulder) girdle

Skull

The **skull** is composed of 22 bones that are fused together except for the mandible. These 21 fused bones are separate in children to allow the skull and brain to grow, but fuse to give added strength and protection as an adult. The **mandible** remains as a movable jaw bone and forms the only movable joint in the skull with the **temporal bone**.

The bones of the superior portion of the skull are known as the cranium and protect the brain from damage. The bones of the inferior and anterior portion of the skull are known as facial bones and support the eyes, nose, and mouth.

Hyoid and Auditory Ossicles

The **hyoid** is a small, U-shaped bone found just inferior to the mandible. The hyoid is the only bone in the body that does not form a joint with any other bone—it is a floating bone. The hyoid's function is to help hold the **trachea** open and to form a bony connection for the **tongue muscles**.

The malleus, incus, and stapes—known collectively as the **auditory ossicles**—are the smallest bones in the body. Found in a small cavity inside of the temporal bone, they serve to transmit and amplify sound from the eardrum to the inner ear.

Vertebrae

Twenty-six vertebrae form the **vertebral column** of the human body. They are named by region:

- **Cervical** (neck) - 7 vertebrae
- **Thoracic** (chest) - 12 vertebrae
- **Lumbar** (lower back) - 5 vertebrae
- **Sacrum** - 1 vertebra
- **Coccyx** (tailbone) - 1 vertebra

With the exception of the singular sacrum and coccyx, each vertebra is named for the first letter of its region and its position along the superior-inferior axis. For example, the most superior thoracic vertebra is called T1 and the most inferior is called T12.

Ribs and Sternum

The sternum, or breastbone, is a thin, knife-shaped bone located along the midline of the anterior side of the **thoracic region of the skeleton**. The sternum connects to the ribs by thin bands of cartilage called the costal cartilage.

There are 12 pairs of ribs that together with the sternum form the ribcage of the thoracic region. The first seven ribs are known as “true ribs” because they connect the thoracic vertebrae directly to the sternum through their own band of costal cartilage. Ribs 8, 9, and 10 all connect to the sternum through cartilage that is connected to the cartilage of the seventh rib, so we consider these to be “false ribs.” Ribs 11 and 12 are also false ribs, but are also considered to be “floating ribs” because they do not have any cartilage attachment to the sternum at all.

Pectoral Girdle and Upper Limb

The pectoral girdle connects the **upper limb (arm) bones** to the axial skeleton and consists of the left and right clavicles and left and right scapulae.

The humerus is the bone of the upper arm. It forms the ball and socket **joint of the shoulder** with the scapula and forms the **elbow joint** with the lower arm bones. The radius and ulna are the two bones of the forearm. The ulna is on the medial side of the forearm and forms a hinge joint with the humerus at the elbow. The radius allows the forearm and hand to turn over at the wrist joint.

The lower arm bones form the wrist joint with the carpals, a group of eight small bones that give added flexibility to the wrist. The carpals are connected to the five metacarpals that form the **bones of the hand** and connect to each of the fingers. Each finger has three bones known as phalanges, except for the thumb, which only has two phalanges.

Pelvic Girdle and Lower Limb

Formed by the left and right hip bones, the pelvic girdle connects the **lower limb (leg) bones** to the axial skeleton.

The **femur** is the largest bone in the body and the only bone of the thigh (femoral) region. The femur forms the ball and socket **hip joint** with the hip bone and forms the**knee joint** with the tibia and patella. Commonly called the kneecap, the patella is special because it is one of the few bones that are not present at birth. The patella forms in early childhood to support the knee for walking and crawling.

The tibia and fibula are the bones of the lower leg. The tibia is much larger than the fibula and bears almost all of the body's weight. The fibula is mainly a muscle attachment point and is used to help maintain balance. The tibia and fibula form the ankle joint with the talus, one of the seven tarsal bones in the **foot**.

The tarsals are a group of seven small bones that form the posterior end of the foot and heel. The tarsals form joints with the five long metatarsals of the foot. Then each of the metatarsals forms a joint with one of the set of phalanges in the toes. Each toe has three phalanges, except for the big toe, which only has two phalanges.

INTRODUCTION TO THE SKELETAL SYSTEM

Humans are vertebrates, animals having a vertabral column or backbone. They rely on a sturdy internal frame that is centered on a prominent spine. The human skeletal system consists of bones, cartilage, ligaments and tendons and accounts for about 20 percent of the body weight.

The living bones in our bodies use oxygen and give off waste products in metabolism. They contain active tissues that consume nutrients, require a blood supply and change shape or remodel in response to variations in mechanical stress.

Bones provide a rigid framework, known as the skeleton, that support and protect the soft organs of the body.

The skeleton supports the body against the pull of gravity. The large bones of the lower limbs support the trunk when standing.

The skeleton also protects the soft body parts. The fused bones of the cranium surround the brain to make it less vulnerable to injury. Vertebrae surround and protect the spinal cord and bones of the rib cage help protect the heart and lungs of the thorax.

Bones work together with muscles as simple mechanical lever systems to produce body movement.

Bones contain more calcium than any other organ. The intercellular matrix of bone contains large amounts of calcium salts, the most important being calcium phosphate.

When blood calcium levels decrease below normal, calcium is released from the bones so that there will be an adequate supply for metabolic needs. When blood calcium levels are increased, the excess calcium is stored in the bone matrix. The dynamic process of releasing and storing calcium goes on almost continuously.

Hematopoiesis, the formation of blood cells, mostly takes place in the red marrow of the bones.

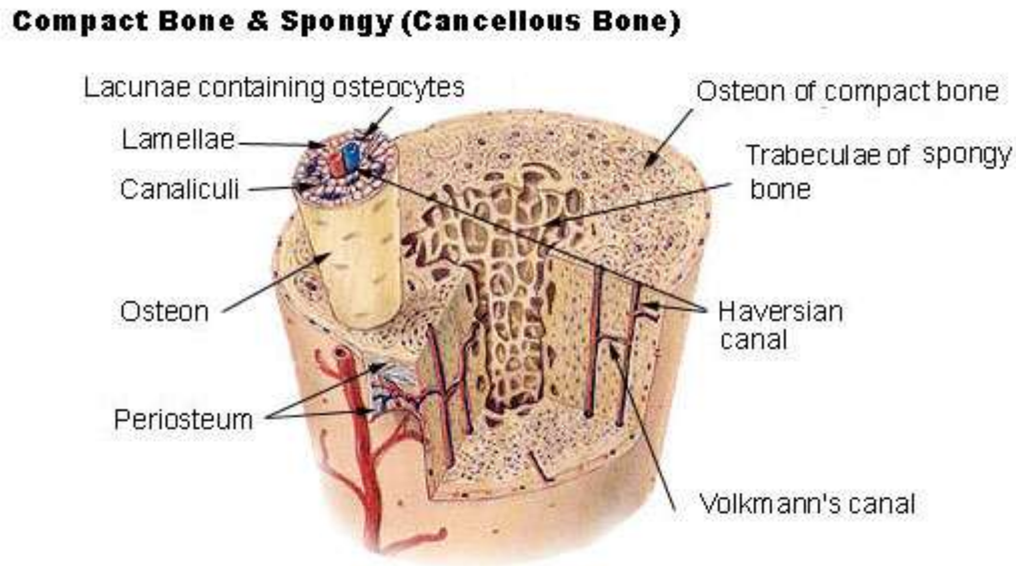
In infants, red marrow is found in the bone cavities. With age, it is largely replaced by yellow marrow for fat storage. In adults, red marrow is limited to the spongy bone in the skull, ribs, sternum, clavicles, vertebrae and pelvis. Red marrow functions in the formation of red blood cells, white blood cells and blood platelets.

STRUCTURE OF BONE TISSUE

There are two types of bone tissue: compact and spongy. The names imply that the two types differ in density, or how tightly the tissue is packed together. There are three types of cells that contribute to bone homeostasis. Osteoblasts are bone-forming cell, osteoclasts resorb or break down bone, and osteocytes are mature bone cells. An equilibrium between osteoblasts and osteoclasts maintains bone tissue.

Compact Bone

Compact bone consists of closely packed osteons or haversian systems. The osteon consists of a central canal called the osteonic (haversian) canal, which is surrounded by concentric rings (lamellae) of matrix. Between the rings of matrix, the bone cells (osteocytes) are located in spaces called lacunae. Small channels (canaliculi) radiate from the lacunae to the osteonic (haversian) canal to provide passageways through the hard matrix. In compact bone, the haversian systems are packed tightly together to form what appears to be a solid mass. The osteonic canals contain blood vessels that are parallel to the long axis of the bone. These blood vessels interconnect, by way of perforating canals, with vessels on the surface of the bone.



Spongy (Cancellous) Bone

Spongy (cancellous) bone is lighter and less dense than compact bone. Spongy bone consists of plates (trabeculae) and bars of bone adjacent to small, irregular cavities that contain red bone marrow. The canaliculi connect to the adjacent cavities, instead of a central haversian canal, to receive their blood supply. It may appear that the trabeculae are arranged in a haphazard manner, but they are organized to provide maximum strength similar to braces that are used to support a building. The trabeculae of spongy bone follow the lines of stress and can realign if the direction of stress changes.

Microscopic Structure of Bones

The skeleton makes up about 30-40% of an adult's body mass. The skeleton's mass is made up of nonliving bone matrix and many tiny bone cells. Roughly half of the bone matrix's mass is **water**, while the other half is collagen protein and solid crystals of calcium carbonate and calcium phosphate.

Living bone cells are found on the edges of bones and in small cavities inside of the bone matrix. Although these cells make up very little of the total bone mass, they have several very important roles in the functions of the skeletal system. The bone cells allow bones to:

- Grow and develop
- Be repaired following an injury or daily wear
- Be broken down to release their stored **minerals**

BONE DEVELOPMENT & GROWTH

The terms osteogenesis and ossification are often used synonymously to indicate the process of bone formation. Parts of the skeleton form during the first few weeks after conception. By the end of the eighth week after conception, the skeletal pattern is formed in cartilage and connective tissue membranes and ossification begins.

Bone development continues throughout adulthood. Even after adult stature is attained, bone development continues for repair of fractures and for remodeling to meet changing lifestyles. Osteoblasts, osteocytes and osteoclasts are the three cell types involved in the development, growth and remodeling of bones. Osteoblasts are bone-forming cells, osteocytes are mature bone cells and osteoclasts break down and reabsorb bone.

There are two types of ossification: intramembranous and endochondral.

Intramembranous

Intramembranous ossification involves the replacement of sheet-like connective tissue membranes with bony tissue. Bones formed in this manner are called intramembranous bones. They include certain flat bones of the skull and some of the irregular bones. The future bones are first formed as connective tissue membranes. Osteoblasts migrate to the membranes and deposit bony matrix around themselves. When the osteoblasts are surrounded by matrix they are called osteocytes.

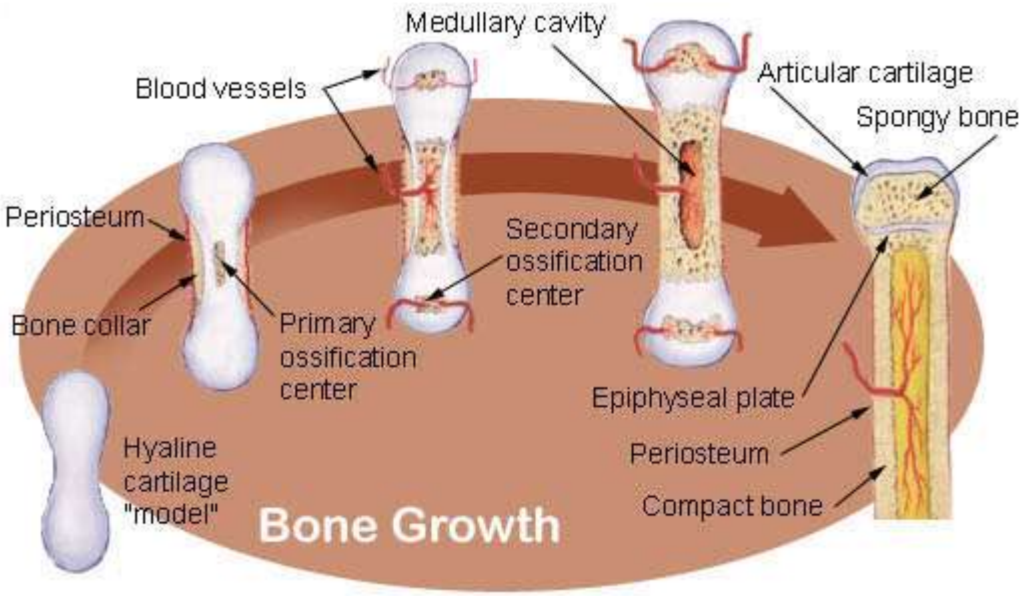
Endochondral Ossification

Endochondral ossification involves the replacement of hyaline cartilage with bony tissue. Most of the bones of the skeleton are formed in this manner. These bones are called endochondral bones. In this process, the future bones are first formed as hyaline cartilage models. During the third month after conception, the perichondriumthat surrounds the hyaline cartilage "models" becomes infiltrated with blood vessels and osteoblasts and changes into a periosteum. The osteoblasts form a collar of compact bone around the diaphysis. At the same time, the cartilage in the center of the diaphysis begins to disintegrate. Osteoblasts penetrate the disintegrating cartilage and replace it with spongy bone. This forms a primary ossification center. Ossification continues from this center toward the ends of the bones. After spongy bone is formed in the diaphysis, osteoclasts break down the newly formed bone to open up the medullary cavity.

The cartilage in the epiphyses continues to grow so the developing bone increases in length. Later, usually after birth, secondary ossification centers form in the epiphyses. Ossification in the epiphyses is similar to that in the diaphysis except that the spongy bone is retained instead of being broken down to form a medullary cavity. When secondary ossification is complete, the hyaline cartilage is totally replaced by bone except in two areas. A region of hyaline cartilage remains over the surface of the epiphysis as the articular cartilage and another area of cartilage remains between the epiphysis and diaphysis. This is the epiphyseal plate or growth region.

Bone Growth

Bones grow in length at the epiphyseal plate by a process that is similar to endochondral ossification. The cartilage in the region of the epiphyseal plate next to the epiphysis continues to grow by mitosis. The chondrocytes, in the region next to the diaphysis, age and degenerate. Osteoblasts move in and ossify the matrix to form bone. This process continues throughout childhood and the adolescent years until the cartilage growth slows and finally stops. When cartilage growth ceases, usually in the early twenties, the epiphyseal plate completely ossifies so that only a thin epiphyseal line remains and the bones can no longer grow in length. Bone growth is under the influence of growth hormone from the anterior pituitary gland and sex hormones from the ovaries and testes.



Even though bones stop growing in length in early adulthood, they can continue to increase in thickness or diameter throughout life in response to stress from increased muscle activity or to weight. The increase in diameter is called appositional growth. Osteoblasts in the periosteum form compact bone around the external bone surface. At the same time, osteoclasts in the endosteum break down bone on the internal bone surface, around the medullary cavity. These two processes together increase the diameter of the bone and, at the same time, keep the bone from becoming excessively heavy and bulky.

Types of Bones

All of the bones of the body can be broken down into five types: long, short, flat, irregular, and sesamoid.

- *Long*. Long bones are longer than they are wide and are the major bones of the limbs. Long bones grow more than the other classes of bone throughout childhood and so are responsible for the bulk of our height as adults. A hollow medullary cavity is found in the center of long bones and serves as a storage area for bone marrow. Examples of long bones include the femur, tibia, fibula, metatarsals, and phalanges.

- *Short*. Short bones are about as long as they are wide and are often cubed or round in shape. The carpal bones of the wrist and the tarsal bones of the foot are examples of short bones.

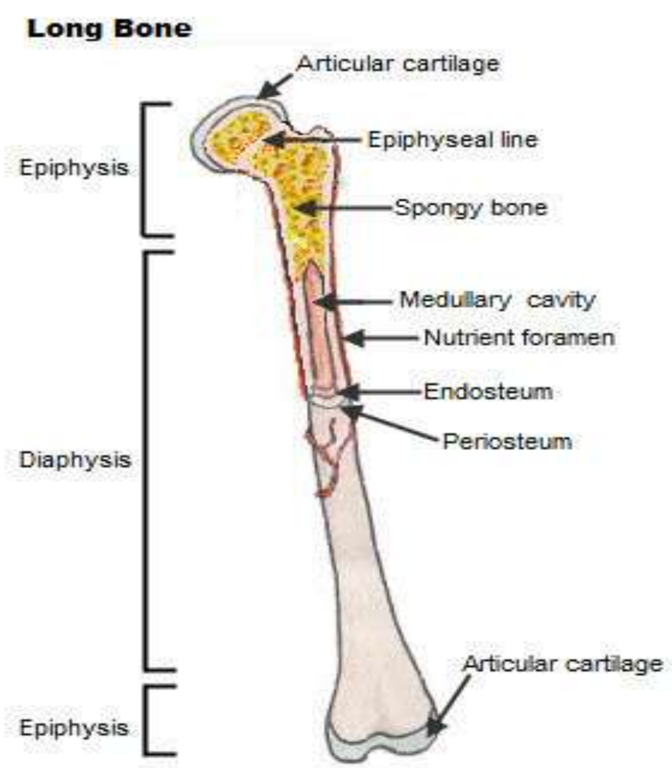
- *Flat*. Flat bones vary greatly in size and shape, but have the common feature of being very thin in one direction. Because they are thin, flat bones do not have a medullary cavity like the long bones. The frontal, parietal, and **occipital bones** of the cranium—along with the ribs and hip bones—are all examples of flat bones.

- *Irregular*. Irregular bones have a shape that does not fit the pattern of the long, short, or flat bones. The vertebrae, sacrum, and coccyx of the spine—as well as the sphenoid, ethmoid, and **zygomatic bones** of the skull—are all irregular bones.

- *Sesamoid*. The sesamoid bones are formed after birth inside of tendons that run across joints. Sesamoid bones grow to protect the tendon from stresses and strains at the joint and can help to give a mechanical advantage to muscles pulling on the tendon. The patella and the **pisiform bone** of the carpals are the only sesamoid bones that are counted as part of the 206 bones of the body. Other sesamoid bones can form in the joints of the hands and feet, but are not present in all people.

CLASSIFICATION OF BONES

Long Bones



The bones of the body come in a variety of sizes and shapes. The four principal types of bones are long, short, flat and irregular. Bones that are longer than they are wide are called long bones. They consist of a long shaft with two bulky ends or extremities. They are primarily compact bone but may have a large amount of spongy bone at the ends or extremities. Long bones include bones of the thigh, leg, arm, and forearm.

Short Bones

Short bones are roughly cube shaped with vertical and horizontal dimensions approximately equal. They consist primarily of spongy bone, which is covered by a thin layer of compact bone. Short bones include the bones of the wrist and ankle.

Flat Bones

Flat bones are thin, flattened, and usually curved. Most of the bones of the cranium are flat bones.

Irregular Bones

Bones that are not in any of the above three categories are classified as irregular bones. They are primarily spongy bone that is covered with a thin layer of compact bone. The vertebrae and some of the bones in the skull are irregular bones.

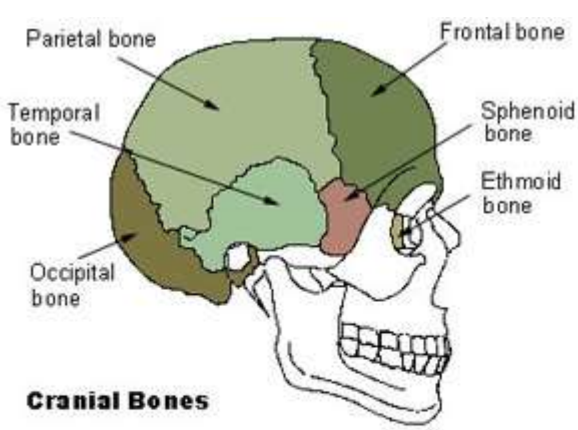
All bones have surface markings and characteristics that make a specific bone unique. There are holes, depressions, smooth facets, lines, projections and other markings. These usually represent passageways for vessels and nerves, points of articulation with other bones or points of attachment for tendons and ligaments.

DIVISIONS OF THE SKELETON

The adult human skeleton usually consists of 206 named bones. These bones can be grouped in two divisions: axial skeleton and appendicular skeleton. The 80 bones of the axial skeleton form the vertical axis of the body. They include the bones of the head, vertebral column, ribs and breastbone or sternum. The appendicular skeleton consists of 126 bones and includes the free appendages and their attachments to the axial skeleton. The free appendages are the upper and lower extremities, or limbs, and their attachments which are called girdles. The named bones of the body are listed below by category.

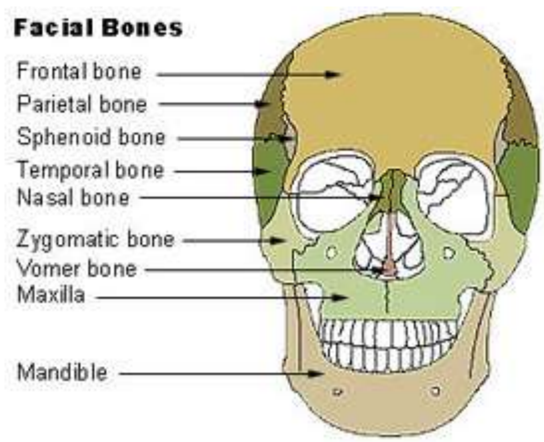
AXIAL SKELETON (80 BONES)

Skull (28)



Cranial Bones

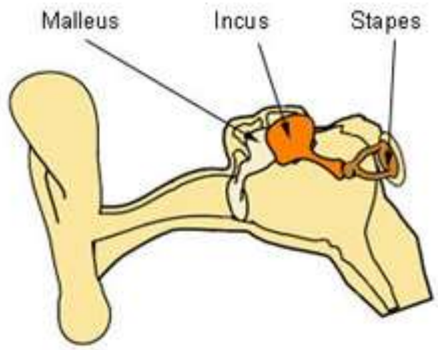
- Parietal (2)
- Temporal (2)
- Frontal (1)
- Occipital (1)
- Ethmoid (1)
- Sphenoid (1)



Facial Bones

- Maxilla (2)
- Zygomatic (2)
- Mandible (1)
- Nasal (2)
- Platine (2)
- Inferior nasal concha (2)
- Lacrimal (2)

- Vomer (1)

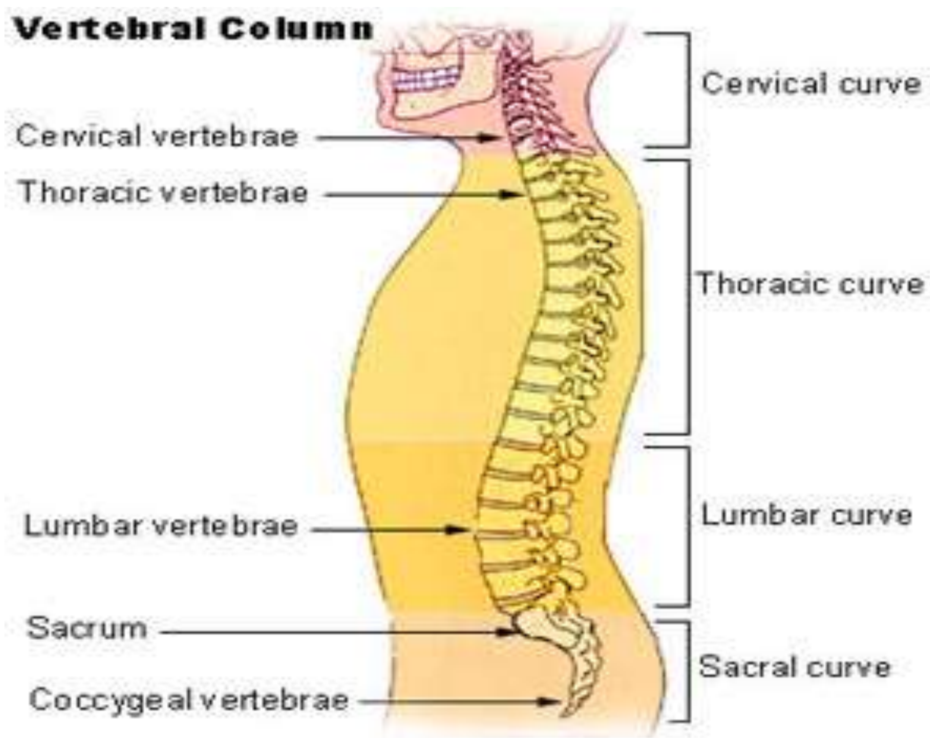


Cranial Bones

Auditory Ossicles

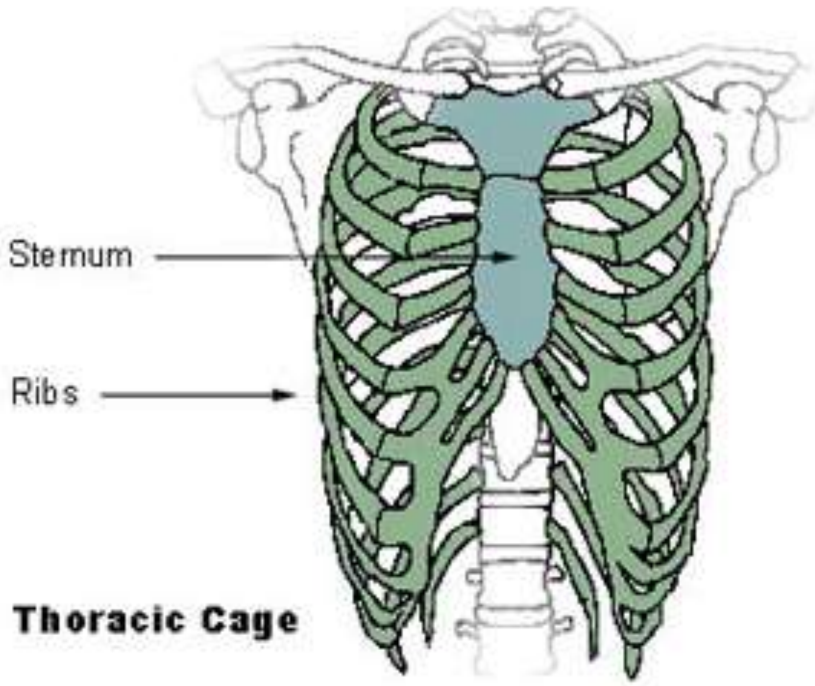
- Malleus (2)
- Incus (2)
- Stapes (2)

Hyoid (1)



Vertebral Column

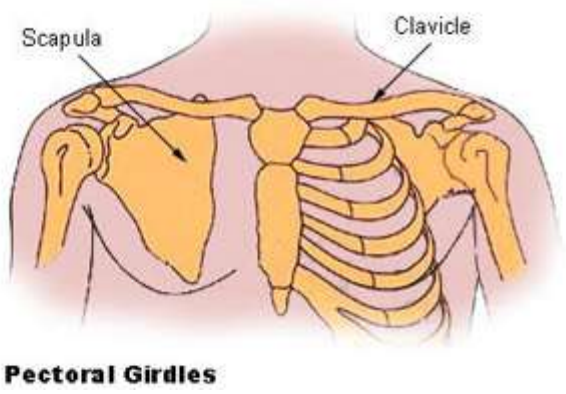
- Cervical vertebrae (7)
- Thoracic vertebrae (12)
- Lumbar vertebrae (5)
- Sacrum (1)
- Coccyx (1)



Thoracic Cage

- Sternum (1)
- Ribs (24)

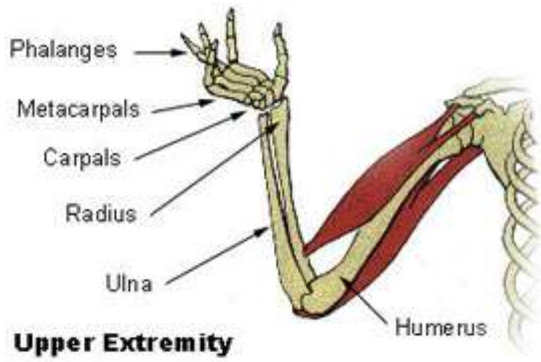
APPENDICULAR SKELETON (126 BONES)



Pectoral girdles

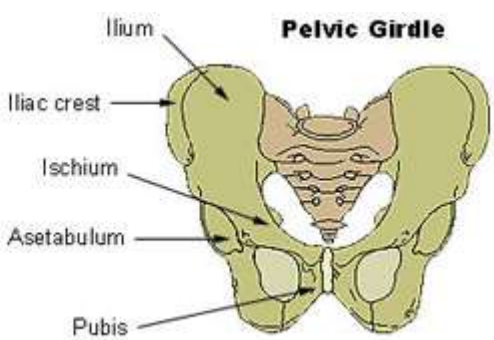
- Clavicle (2)

* Scapula (2)



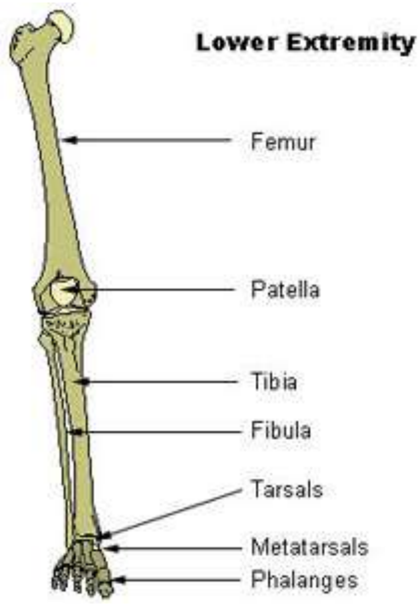
Upper Extremity

* Humerus (2)
* Radius (2)
* Ulna (2)
* Carpals (16)
* Metacarpals (10)
* Phalanges (28)



Pelvic Girdle

* Coxal, innominate, or hip bones (2)



Lower Extremity

- Femur (2)
- Tibia (2)
- Fibula (2)
- Patella (2)
- Tarsals (14)
- Metatarsals (10)
- Phalanges (28)

ARTICULATIONS

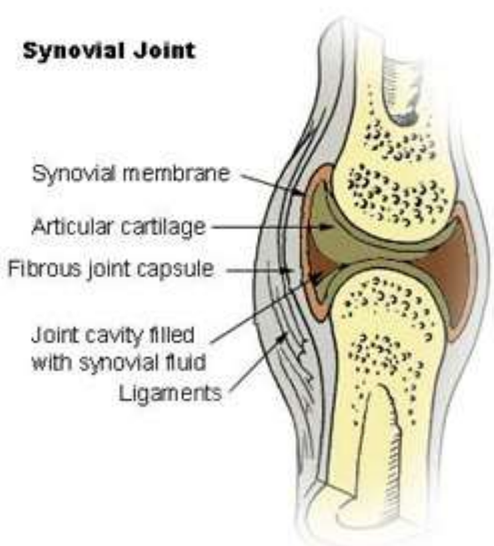
An articulation, or joint, is where two bones come together. In terms of the amount of movement they allow, there are three types of joints: immovable, slightly movable and freely movable.

Synarthroses

Synarthroses are immovable joints. The singular form is synarthrosis. In these joints, the bones come in very close contact and are separated only by a thin layer of fibrous connective tissue. The sutures in the skull are examples of immovable joints.

Amphiarthroses

Slightly movable joints are called amphiarthroses. The singular form is amphiarthrosis. In this type of joint, the bones are connected by hyaline cartilage or fibrocartilage. The ribs connected to the sternum by costal cartilages are slightly movable joints connected by hyaline cartilage. The symphysis pubis is a slightly movable joint in which there is a fibrocartilage pad between the two bones. The joints between the vertebrae and the intervertebral disks are also of this type.



Diarthroses

Most joints in the adult body are diarthroses, or freely movable joints. The singular form is diarthrosis. In this type of joint, the ends of the opposing bones are covered with hyaline cartilage, the articular cartilage, and they are separated by a space called the joint cavity. The components of the joints are enclosed in a dense fibrous joint capsule. The outer layer of the capsule consists of the ligaments that hold the bones together. The inner layer is the synovial membrane that secretes synovial fluid into the joint cavity for lubrication. Because all of these joints have a synovial membrane, they are sometimes called synovial joints.

Parts of Bones

The long bones of the body contain many distinct regions due to the way in which they develop. At birth, each long bone is made of three individual bones separated by hyaline cartilage. Each end bone is called an **epiphysis** (epi = on; physis = to grow) while the middle bone is called a diaphysis (dia = passing through). The epiphyses and diaphysis grow towards one another and eventually fuse into one bone. The region of growth and eventual fusion in between the epiphysis and diaphysis is called the metaphysis (meta = after). Once the long bone parts have fused together, the only hyaline cartilage left in the bone is found as articular cartilage on the ends of the bone that form joints with other bones. The **articular cartilage** acts as a shock absorber and gliding surface between the bones to facilitate movement at the joint.

Looking at a bone in cross section, there are several distinct layered regions that make up a bone. The outside of a bone is covered in a thin layer of dense irregular connective tissue called the periosteum. The periosteum contains many strong collagen fibers that are used to firmly anchor tendons and muscles to the bone for movement. Stem cells and osteoblast cells in the periosteum are involved in the growth and repair of the outside of the bone due to stress and injury. Blood vessels present in the periosteum provide energy to the cells on the surface of the bone and penetrate into the bone itself to nourish the cells inside of the bone. The periosteum also contains nervous tissue and many nerve endings to give bone its sensitivity to pain when injured.

Deep to the periosteum is the compact bone that makes up the hard, mineralized portion of the bone. Compact bone is made of a matrix of hard mineral salts reinforced with tough collagen fibers. Many tiny cells called osteocytes live in small spaces in the matrix and help to maintain the strength and integrity of the compact bone.

Deep to the compact bone layer is a region of spongy bone where the bone tissue grows in thin columns called trabeculae with spaces for red bone marrow in between. The trabeculae grow in a specific pattern to resist outside stresses with the least amount of mass possible, keeping bones light but strong. Long bones have a spongy bone on their ends but have a hollow medullary cavity in the middle of the diaphysis. The medullary cavity contains red bone marrow during childhood, eventually turning into yellow bone marrow after puberty.

Articulations

An articulation, or joint, is a point of contact between bones, between a bone and cartilage, or between a bone and a tooth. Synovial joints are the most common type of articulation and feature a small gap between the bones. This gap allows a free range of motion and space for synovial fluid to lubricate the joint. Fibrous joints exist where bones are very tightly joined and offer little to no movement between the bones. Fibrous joints also hold **teeth** in their bony sockets. Finally, cartilaginous joints are formed where bone meets cartilage or where there is a layer of cartilage between two bones. These joints provide a small amount of flexibility in the joint due to the gel-like consistency of cartilage.

Support and Protection

The skeletal system's primary function is to form a solid framework that supports and protects the body's organs and anchors the skeletal muscles. The bones of the axial skeleton act as a hard shell to protect the internal organs—such as the **brain** and the **heart**—from damage caused by external forces. The bones of the appendicle skeleton provide support and flexibility at the joints and anchor the muscles that move the limbs.

Movement

The bones of the skeletal system act as attachment points for the skeletal muscles of the body. Almost every skeletal muscle works by pulling two or more bones either closer together or further apart. Joints act as pivot points for the movement of the bones. The regions of each bone where muscles attach to the bone grow larger and stronger to support the additional force of the muscle. In addition, the overall mass and thickness of a bone increase when it is under a lot of stress from lifting weights or supporting body weight.

Hematopoiesis

Red bone marrow produces red and white blood cells in a process known as hematopoietic. Red bone marrow is found in the hollow space inside of bones known as the **medullary cavity**. Children tend to have more red bone marrow compared to their body size than adults do, due to their body's constant growth and development. The amount of red bone marrow drops off at the end of puberty, replaced by yellow bone marrow.

Storage

The skeletal system stores many different types of essential substances to facilitate growth and repair of the body. The skeletal system's cell matrix acts as our calcium bank by storing and releasing calcium ions into the blood as needed. Proper levels of calcium ions in the blood are essential to the proper function of the nervous and muscular systems. Bone cells also release osteocalcin, a hormone that helps regulate blood sugar and fat deposition. The yellow bone marrow inside of our hollow long bones is used to store energy in the form of lipids. Finally, red bone marrow stores some iron in the form of the molecule ferritin and uses this iron to form hemoglobin in red blood cells.

Growth and Development

The skeleton begins to form early in fetal development as a flexible skeleton made of hyaline cartilage and dense irregular fibrous connective tissue. These tissues act as a soft, growing framework and placeholder for the bony skeleton that will replace them. As development progresses, blood vessels begin to grow into the soft fetal skeleton, bringing stem cells and nutrients for bone growth. Osseous tissue slowly replaces the cartilage and fibrous tissue in a process called calcification. The calcified areas spread out from their blood vessels replacing the old tissues until they reach the border of another bony area. At birth, the skeleton of a newborn has more than 300 bones; as a person ages, these bones grow together and fuse into larger bones, leaving adults with only 206 bones.

Flat bones follow the process of intramembranous ossification where the young bones grow from a primary ossification center in fibrous membranes and leave a small region of fibrous tissue in between each other. In the skull these soft spots are known as fontanels, and give the skull flexibility and room for the bones to grow. Bone slowly replaces the fontanels until the individual bones of the skull fuse together to form a rigid adult skull.

Long bones follow the process of endochondral ossification where the diaphysis grows inside of cartilage from a primary ossification center until it forms most of the bone. The epiphyses then grow from secondary ossification centers on the ends of the bone. A small band of hyaline cartilage remains in between the bones as a growth plate. As we grow through childhood, the growth plates grow under the influence of growth and sex hormones, slowly separating the bones. At the same time the bones grow larger by growing back into the growth plates. This process continues until the end of puberty, when the growth plate stops growing and the bones fuse permanently into a single bone. The vast difference in height and limb length between birth and adulthood are mainly the result of endochondral ossification in the long bones.

Here is what we have learned from *Introduction to the Skeletal System*:

- The human skeleton is well-adapted for the functions it must perform. Functions of bones include support, protection, movement, mineral storage, and formation of blood cells.
- There are two types of bone tissue: compact and spongy. Compact bone consists of closely packed osteons, or haversian system. Spongy

bone consists of plates of bone, called trabeculae, around irregular spaces that contain red bone marrow.

- Osteogenesis is the process of bone formation. Three types of cells, osteoblasts, osteocytes, and osteoclasts, are involved in bone formation and remodeling.
- In intramembranous ossification, connective tissue membranes are replaced by bone. This process occurs in the flat bones of the skull. In endochondral ossification, bone tissue replaces hyaline cartilage models. Most bones are formed in this manner.
- Bones grow in length at the epiphyseal plate between the diaphysis and the epiphysis. When the epiphyseal plate completely ossifies, bones no longer increase in length.
- Bones may be classified as long, short, flat, or irregular. The diaphysis of a long bone is the central shaft. There is an epiphysis at each end of the diaphysis.
- The adult human skeleton usually consists of 206 named bones and these bones can be grouped in two divisions: axial skeleton and appendicular skeleton.
- The bones of the skeleton are grouped in two divisions: axial skeleton and appendicular skeleton.
- There are three types of joints in terms of the amount of movement they allow: synarthroses (immovable), amphiarthroses (slightly movable), and diarthroses (freely movable).

Anatomical Structure of human body

INTRODUCTION TO THE MUSCULAR SYSTEM

The muscular system is composed of specialized cells called muscle fibers. Their predominant function is contractibility. Muscles, attached to bones or internal organs and blood vessels, are responsible for movement. Nearly all movement in the body is the result of muscle contraction. Exceptions to this are the action of cilia, the flagellumon sperm cells, and amoeboid movement of some white blood cells.

The integrated action of joints, bones, and skeletal muscles produces obvious movements such as walking and running. Skeletal muscles also produce more subtle movements that result in various facial expressions, eye movements, and respiration.

In addition to movement, muscle contraction also fulfills some other important functions in the body, such as posture, joint stability, and heat production. Posture, such as sitting and standing, is maintained as a result of muscle contraction. The skeletal muscles are continually making fine adjustments that hold the body in stationary positions. The tendons of many muscles extend over joints and in this way contribute to joint stability. This is particularly evident in the knee and shoulder joints, where muscle tendons are a major factor in stabilizing the joint. Heat production, to maintain body temperature, is an important by-product of muscle metabolism. Nearly 85 percent of the heat produced in the body is the result of muscle contraction.

Muscular System

The muscular system is responsible for the movement of the human body. Attached to the bones of the skeletal system are about 700 named muscles that make up roughly half of a person's body weight. Each of these muscles is a discrete organ constructed of skeletal muscle tissue, blood vessels, tendons, and nerves. Muscle tissue is also found inside of the heart, digestive organs, and blood vessels. In these organs, muscles serve to move substances throughout the body.

Muscle Types

There are three types of muscle tissue: Visceral, cardiac, and skeletal.

1. ***Visceral Muscle*****.** Visceral muscle is found inside of organs like the **stomach**, intestines, and blood vessels. The weakest of all muscle tissues, visceral muscle makes organs contract to move substances through the organ. Because visceral muscle is controlled by the unconscious part of the brain, it is known as involuntary muscle—it cannot be directly controlled by the conscious mind. The term "smooth muscle" is often used to describe visceral muscle because it has a very smooth, uniform appearance when viewed under a microscope. This smooth appearance starkly contrasts with the banded appearance of cardiac and skeletal muscles.

2. ***Cardiac Muscle*****.** Found only in the **heart**, cardiac muscle is responsible for pumping blood throughout the body. Cardiac muscle tissue cannot be controlled consciously, so it is an involuntary muscle. While hormones and signals from the **brain** adjust the rate of contraction, cardiac muscle stimulates itself to contract. The natural pacemaker of the heart is made of cardiac muscle tissue that stimulates other cardiac muscle cells to contract. Because of its self-stimulation, cardiac muscle is considered to be auto rhythmic or intrinsically controlled.

   The cells of cardiac muscle tissue are striated—that is, they appear to have light and dark stripes when viewed under a light microscope. The arrangement of protein fibers inside of the cells causes these light and dark bands. Striations indicate that a muscle cell is very strong, unlike visceral muscles.

The cells of cardiac muscle are branched X or Y shaped cells tightly connected together by special junctions called intercalated disks. Intercalated disks are made up of fingerlike projections from two neighboring cells that interlock and provide a strong bond between the cells. The branched structure and intercalated disks allow the muscle cells to resist high blood pressures and the strain of pumping blood throughout a lifetime. These features also help to spread electrochemical signals quickly from cell to cell so that the heart can beat as a unit.

3. ***Skeletal Muscle.*** Skeletal muscle is the only voluntary muscle tissue in the human body—it is controlled consciously. Every physical action that a person consciously performs (e.g. speaking, walking, or writing) requires skeletal muscle. The function of skeletal muscle is to contract to move parts of the body closer to the bone that the muscle is attached to. Most skeletal muscles are attached to two bones across a joint, so the muscle serves to move parts of those bones closer to each other.

Skeletal muscle cells form when many smaller progenitor cells lump themselves together to form long, straight, multinucleated fibers. Striated just like cardiac muscle, these skeletal muscle fibers are very strong. Skeletal muscle derives its name from the fact that these muscles always connect to the skeleton in at least one place.

MUSCLE TYPES

In the body, there are three types of muscle: skeletal (striated), smooth, and cardiac.

Skeletal Muscle

Skeletal muscle, attached to bones, is responsible for skeletal movements. The peripheral portion of the central nervous system (CNS) controls the skeletal muscles. Thus, these muscles are under conscious, or voluntary, control. The basic unit is the muscle fiber with many nuclei. These muscle fibers are striated (having transverse streaks) and each acts independently of neighboring muscle fibers.

Smooth Muscle

Smooth muscle, found in the walls of the hollow internal organs such as blood vessels, the gastrointestinal tract, bladder, and uterus, is under control of the autonomic nervous system. Smooth muscle cannot be controlled consciously and thus acts involuntarily. The non-striated (smooth) muscle cell is spindle-shaped and has one central nucleus. Smooth muscle contracts slowly and rhythmically.

Cardiac Muscle

Cardiac muscle, found in the walls of the heart, is also under control of the autonomic nervous system. The cardiac muscle cell has one central nucleus, like smooth muscle, but it also is striated, like skeletal muscle. The cardiac muscle cell is rectangular in shape. The contraction of cardiac muscle is involuntary, strong, and rhythmical.

Smooth and cardiac muscle will be discussed in detail with respect to their appropriate systems. This unit mainly covers the skeletal muscular system.

MUSCLE GROUPS

There are more than 600 muscles in the body, which together account for about 40 percent of a person's weight.

Most skeletal muscles have names that describe some feature of the muscle. Often several criteria are combined into one name. Associating the muscle's characteristics with its name will help you learn and remember them. The following are some terms relating to muscle features that are used in naming muscles.

- **Size:** vastus (huge); maximus (large); longus (long); minimus (small); brevis (short).
- **Shape:** deltoid (triangular); rhomboid (like a rhombus with equal and parallel sides); latissimus (wide); teres (round); trapezius (like a trapezoid, a four-sided figure with two sides parallel).
- **Direction of fibers:** rectus (straight); transverse (across); oblique (diagonally); orbicularis (circular).
- **Location:** pectoralis (chest); gluteus (buttock or rump); brachii (arm); supra- (above); infra- (below); sub- (under or beneath); lateralis (lateral).

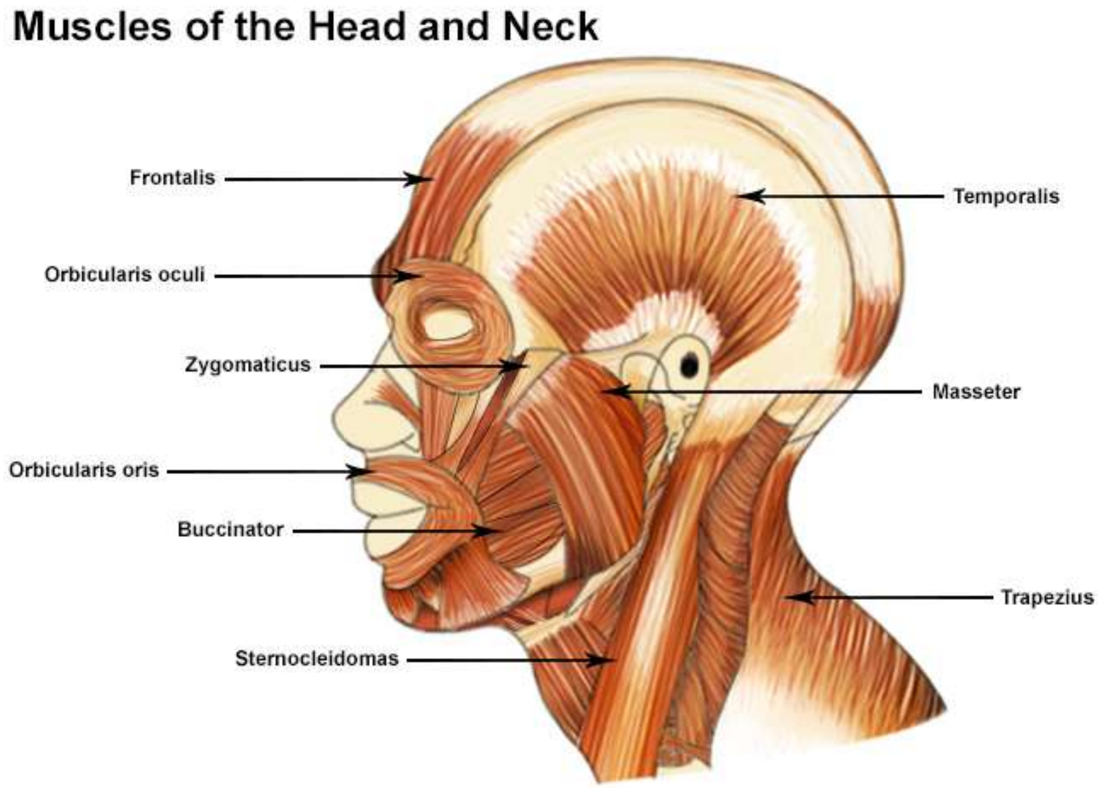
- **Number of origins:** biceps (two heads); triceps (three heads); quadriceps (four heads).

- **Origin and insertion:** sternocleidomastoideus (origin on the sternum and clavicle, insertion on the mastoid process); brachioradialis (origin on the brachium or arm, insertion on the radius).

- **Action:** abductor (to abduct a structure); adductor (to adduct a structure); flexor (to flex a structure); extensor (to extend a structure); levator (to lift or elevate a structure); masseter (a chewer).

MUSCLES OF THE HEAD AND NECK

Humans have well-developed muscles in the face that permit a large variety of facial expressions. Because the muscles are used to show surprise, disgust, anger, fear, and other emotions, they are an important means of nonverbal communication. Muscles of facial expression include frontalis, orbicularis oris, laris oculi, buccinator, and zygomaticus.These muscles of facial expressions are identified in the illustration below.

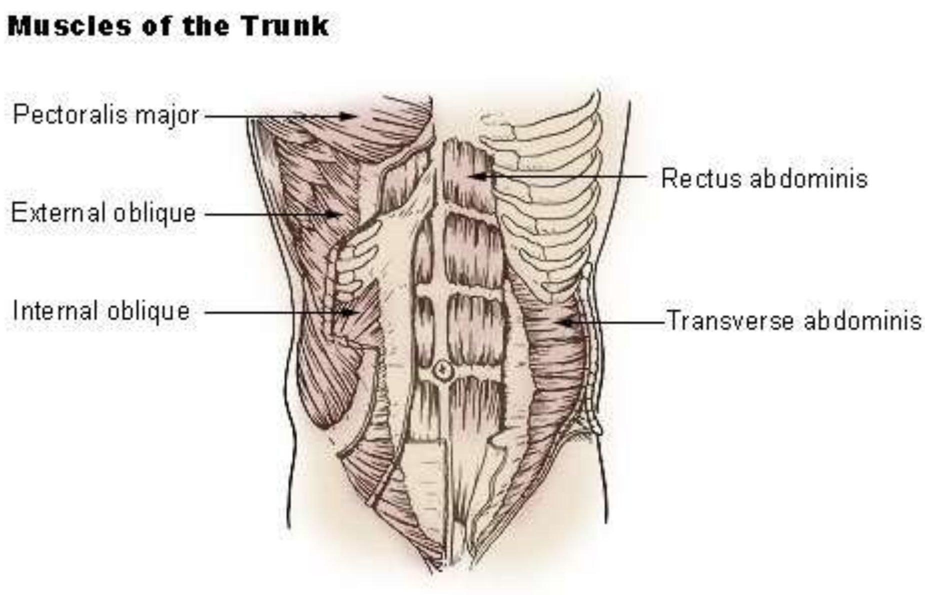


There are four pairs of muscles that are responsible for chewing movements or mastication. All of these muscles connect to the mandible and they are some of the strongest muscles in the body. Two of the muscles, temporalis and masseter, are identified in the illustration above.

There are numerous muscles associated with the throat, the hyoid bone and the vertebral column; only two of the more obvious and superficial neck muscles are identified in the illustration: sternocleidomastoid and trapezius.

MUSCLES OF THE TRUNK

The muscles of the trunk include those that move the vertebral column, the muscles that form the thoracic and abdominal walls, and those that cover the pelvic outlet.



The erector spinae group of muscles on each side of the vertebral column is a large muscle mass that extends from the sacrum to the skull. These muscles are primarily responsible for extending the vertebral column to maintain erect posture. The deep back muscles occupy the space between the spinous and transverse processes of adjacent vertebrae.

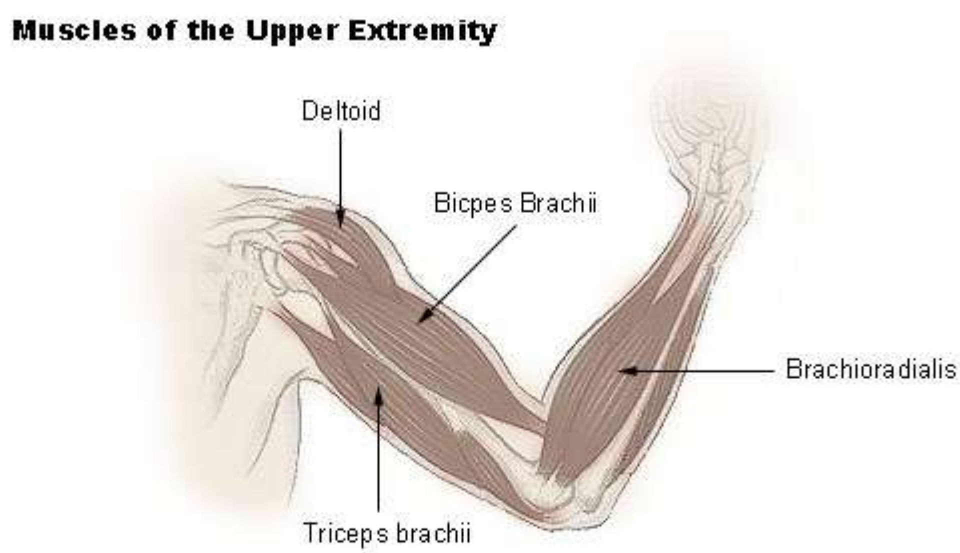
The muscles of the thoracic wall are involved primarily in the process of breathing. The intercostal muscles are located in spaces between the ribs. They contract during forced expiration. External intercostal muscles contract to elevate the ribs during the inspiration phase of breathing. The diaphragm is a dome-shaped muscle that forms a partition between the thorax and the abdomen. It has three openings in it for structures that have to pass from the thorax to the abdomen.

The abdomen, unlike the thorax and pelvis, has no bony reinforcements or protection. The wall consists entirely of four muscle pairs, arranged in layers, and the fascia that envelops them. The abdominal wall muscles are identified in the illustration below.

The pelvic outlet is formed by two muscular sheets and their associated fascia.

MUSCLES OF THE UPPER EXTREMITY

The muscles of the upper extremity include those that attach the scapula to the thorax and generally move the scapula, those that attach the humerus to the scapula and generally move the arm, and those that are located in the arm or forearm that move the forearm, wrist, and hand. The illustration below shows some of the muscles of the upper extremity.



Muscles that move the shoulder and arm include the trapezius and serratus anterior. The pectoralis major, latissimus dorsi, deltoid, and rotator cuff muscles connect to the humerus and move the arm.

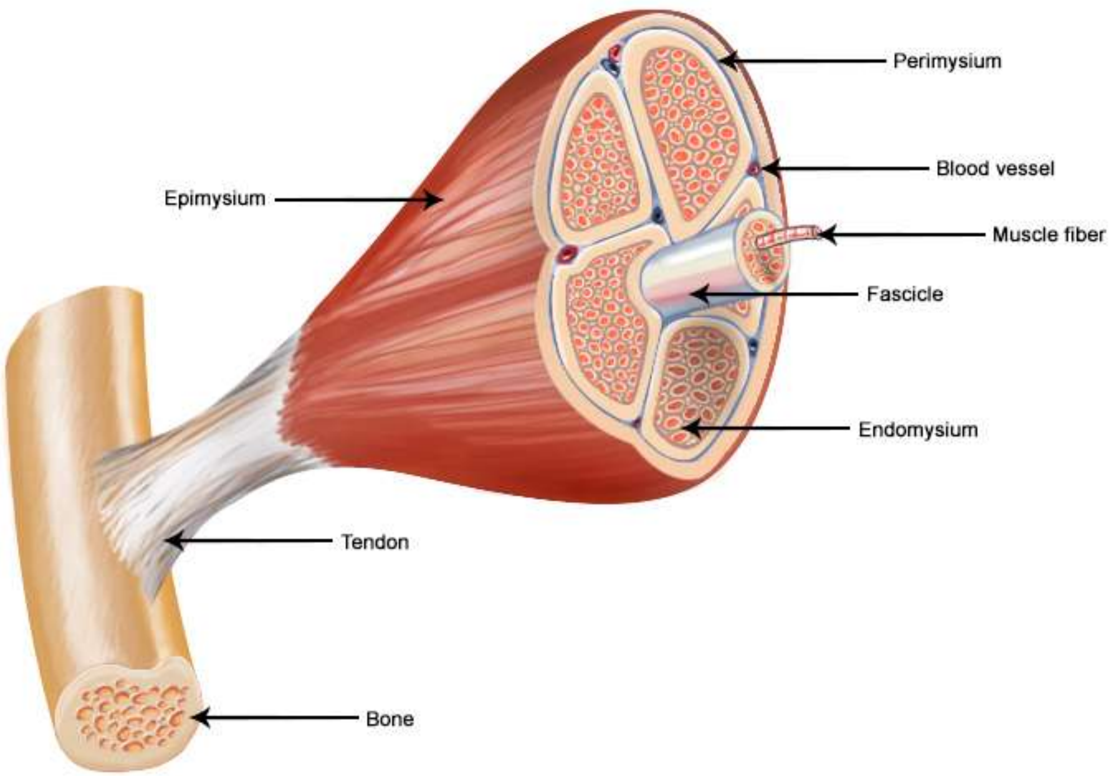
The muscles that move the forearm are located along the humerus, which include the triceps brachii, biceps brachii, brachialis, and brachioradialis. The 20 or more muscles that cause most wrist, hand, and finger movements are located along the forearm.

STRUCTURE OF SKELETAL MUSCLE

A whole skeletal muscle is considered an organ of the muscular system. Each organ or muscle consists of skeletal muscle tissue, connective tissue, nerve tissue, and blood or vascular tissue.

Skeletal muscles vary considerably in size, shape, and arrangement of fibers. They range from extremely tiny strands such as the stapedium muscle of the middle ear to large masses such as the muscles of the thigh. Some skeletal muscles are broad in shape and some narrow. In some muscles the fibers are parallel to the long axis of the muscle; in some they converge to a narrow attachment; and in some they are oblique.

Structure of a Skeletal Muscle



Each skeletal muscle fiber is a single cylindrical muscle cell. An individual skeletal muscle may be made up of hundreds, or even thousands, of muscle fibers bundled together and wrapped in a connective tissue covering. Each muscle is surrounded by a connective tissue sheath called the epimysium. Fascia, connective tissue outside the epimysium, surrounds and separates the muscles. Portions of the epimysium project inward to divide the muscle into compartments. Each compartment contains a bundle of muscle fibers. Each bundle of muscle fiber is called a fasciculus and is surrounded by a layer of connective tissue called the perimysium. Within the fasciculus, each individual muscle cell, called a muscle fiber, is surrounded by connective tissue called the endomysium.

Skeletal muscle cells (fibers), like other body cells, are soft and fragile. The connective tissue covering furnish support and protection for the delicate cells and allow them to withstand the forces of contraction. The coverings also provide pathways for the passage of blood vessels and nerves.

Commonly, the epimysium, perimysium, and endomysium extend beyond the fleshy part of the muscle, the belly or gaster, to form a thick ropelike tendon or a broad, flat sheet-like aponeurosis. The tendon and aponeurosis form indirect attachments from muscles to the periosteum of bones or to the connective tissue of other muscles. Typically a muscle spans a joint and is attached to bones by tendons at both ends. One of the bones remains relatively fixed or stable while the other end moves as a result of muscle contraction.

Skeletal muscles have an abundant supply of blood vessels and nerves. This is directly related to the primary function of skeletal muscle, contraction. Before a skeletal muscle fiber can contract, it has to receive an impulse from a nerve cell. Generally, an artery and at least one vein accompany each nerve that penetrates the epimysium of a skeletal muscle. Branches of the nerve and blood vessels follow the connective tissue components of the muscle of a nerve cell and with one or more minute blood vessels called capillaries.

Gross Anatomy of a Skeletal Muscle

Most skeletal muscles are attached to two bones through tendons. Tendons are tough bands of dense regular connective tissue whose strong collagen fibers firmly attach muscles to bones. Tendons are under extreme stress when muscles pull on them, so they are very strong and are woven into the coverings of both muscles and bones.

Muscles move by shortening their length, pulling on tendons, and moving bones closer to each other. One of the bones is pulled towards the other bone, which remains stationary. The place on the stationary bone that is connected via tendons to the muscle is called the origin. The place on the moving bone that is connected to the muscle via tendons is called the insertion. The belly of the muscle is the fleshy part of the muscle in between the tendons that does the actual contraction.

Names of Skeletal Muscles

Skeletal muscles are named based on many different factors, including their location, origin and insertion, number of origins, shape, size, direction, and function.

- *Location*. Many muscles derive their names from their anatomical region. The rectus abdominis and transverse abdominis, for example, are found in the**abdominal region**. Some muscles, like the **tibialis anterior**, are named after the part of the bone (the anterior portion of the **tibia**) that they are attached to. Other muscles use a hybrid of these two, like the brachioradialis, which is named after a region (brachial) and a bone (**radius**).

- *Origin and Insertion*. Some muscles are named based upon their connection to a stationary bone (origin) and a moving bone (insertion). These muscles become very easy to identify once you know the names of the bones that they are attached to. Examples of this type of muscle include the **sternocleidomastoid** (connecting the**sternum** and **clavicle** to the mastoid process of the skull) and the occipitofrontalis (connecting the **occipital bone** to the **frontal bone**).

- *Number of Origins*. Some muscles connect to more than one bone or to more than one place on a bone, and therefore have more than one origin. A muscle with two origins is called a biceps. A muscle with three origins is a triceps muscle. Finally, a muscle with four origins is a quadriceps muscle.

- *Shape, Size, and Direction*. We also classify muscles by their shapes. For example, the **deltoids** have a delta or triangular shape. The serratus muscles feature a serrated or saw-like shape. The rhomboid major is a rhombus or diamond shape. The size of the muscle can be used to distinguish between two muscles found in the same region. The gluteal region contains three muscles differentiated by size—the gluteus maximus (large), gluteus medius (medium), and gluteus minimus (smallest). Finally, the direction in which the muscle fibers run can be used to identify a muscle. In the abdominal region, there are several sets of wide, flat muscles. The muscles whose fibers run straight up and down are the **rectus abdominis**, the ones running transversely (left to right) are the transverse abdominis, and the ones running at an angle are the obliques.

- *Function*. Muscles are sometimes classified by the type of function that they perform. Most of the muscles of the forearms are named based on their function because they are located in the same region and have similar shapes and sizes. For example, the flexor group of the forearm flexes the wrist and the fingers. The **supinator** is a muscle that supinates the wrist by rolling it over to face palm up. In the leg, there are muscles called adductors whose role is to adduct (pull together) the legs.

Groups Action in Skeletal Muscle

Skeletal muscles rarely work by themselves to achieve movements in the body. More often they work in groups to produce precise movements. The muscle that produces any particular movement of the body is known as an agonist or prime mover. The agonist always pairs with an antagonist muscle that produces the opposite effect on the same bones. For example, the biceps brachii muscle flexes the arm at the **elbow**. As the antagonist for this motion, the triceps brachii muscle extends the arm at the elbow. When the triceps is extending the arm, the biceps would be considered the antagonist.

In addition to the agonist/antagonist pairing, other muscles work to support the movements of the agonist. Synergists are muscles that help to stabilize a movement and reduce extraneous movements. They are usually found in regions near the agonist and often connect to the same bones. Because skeletal muscles move the insertion closer to the immobile origin, fixator muscles assist in movement by holding the origin stable. If you lift something heavy with your arms, fixators in the trunk region hold your body upright and immobile so that you maintain your balance while lifting.

Skeletal Muscle Histology

Skeletal muscle fibers differ dramatically from other tissues of the body due to their highly specialized functions. Many of the organelles that make up muscle fibers are unique to this type of cell.

The sarcolemma is the cell membrane of muscle fibers. The sarcolemma acts as a conductor for electrochemical signals that stimulate muscle cells. Connected to the sarcolemma are transverse tubules (T-tubules) that help carry these electrochemical signals into the middle of the muscle fiber. The sarcoplasmic reticulum serves as a storage facility for calcium ions (Ca2+) that are vital to muscle contraction. Mitochondria, the "power houses" of the cell, are abundant in muscle cells to break down sugars and provide energy in the form of ATP to active muscles. Most of the muscle fiber's structure is made up of myofibrils, which are the contractile structures of the cell. Myofibrils are made up of many proteins fibers arranged into repeating subunits called sarcomeres. The sarcomere is the functional unit of muscle fibers. (See *Macronutrients* for more information about the roles of sugars and proteins.)

Sarcomere Structure

Sarcomeres are made of two types of protein fibers: thick filaments and thin filaments.

- *Thick filaments*. Thick filaments are made of many bonded units of the protein myosin. Myosin is the protein that causes muscles to contract.
- *Thin filaments*. Thin filaments are made of three proteins:

1. *Actin*. Actin forms a helical structure that makes up the bulk of the thin filament mass. Actin contains myosin-binding sites that allow myosin to connect to and move actin during muscle contraction.
2. *Tropomyosin*. Tropomyosin is a long protein fiber that wraps around actin and covers the myosin binding sites on actin.
3. *Troponin*. Bound very tightly to tropomyosin, troponin moves tropomyosin away from myosin binding sites during muscle contraction.

Function of Muscle Tissue

The main function of the muscular system is movement. Muscles are the only tissue in the body that has the ability to contract and therefore move the other parts of the body.

Related to the function of movement is the muscular system's second function: the maintenance of posture and body position. Muscles often contract to hold the body still or in a particular position rather than to cause movement. The muscles responsible for the body's posture have the greatest endurance of all muscles in the body—they hold up the body throughout the day without becoming tired.

Another function related to movement is the movement of substances inside the body. The cardiac and visceral muscles are primarily responsible for transporting substances like blood or food from one part of the body to another.

The final function of muscle tissue is the generation of body heat. As a result of the high metabolic rate of contracting muscle, our muscular system produces a great deal of waste heat. Many small muscle contractions within the body produce our natural body heat. When we exert ourselves more than normal, the extra muscle contractions lead to a rise in body temperature and eventually to sweating.

Skeletal Muscles as Levers

Skeletal muscles work together with bones and joints to form lever systems. The muscle acts as the effort force; the joint acts as the fulcrum; the bone that the muscle moves acts as the lever; and the object being moved acts as the load.

There are three classes of levers, but the vast majority of the levers in the body are third class levers. A third class lever is a system in which the fulcrum is at the end of the lever and the effort is between the fulcrum and the load at the other end of the lever. The third class levers in the body serve to increase the distance moved by the load compared to the distance that the muscle contracts.

The tradeoff for this increase in distance is that the force required to move the load must be greater than the mass of the load. For example, the biceps brachia of the arm pulls on the radius of the forearm, causing flexion at the **elbow joint** in a third class lever system. A very slight change in the length of the biceps causes a much larger movement of the forearm and hand, but the force applied by the biceps must be higher than the load moved by the muscle.

Motor Units

Nerve cells called motor neurons control the skeletal muscles. Each motor neuron controls several muscle cells in a group known as a motor unit. When a motor neuron receives a signal from the brain, it stimulates all of the muscles cells in its motor unit at the same time.

The size of motor units varies throughout the body, depending on the function of a muscle. Muscles that perform fine movements—like those of the **eyes** or fingers—have very few muscle fibers in each motor unit to improve the precision of the brain's control over these structures. Muscles that need a lot of strength to perform their function—like leg or arm muscles—have many muscle cells in each motor unit. One of the ways that the body can control the strength of each muscle is by determining how many motor units to activate for a given function. This explains why the same muscles that are used to pick up a pencil are also used to pick up a bowling ball.

Contraction Cycle

Muscles contract when stimulated by signals from their motor neurons. Motor neurons contact muscle cells at a point called the Neuromuscular Junction (NMJ). Motor neurons release neurotransmitter chemicals at the NMJ that bond to a special part of the sarcolemma known as the motor end plate. The motor end plate contains many ion channels that open in response to neurotransmitters and allow positive ions to enter the muscle fiber. The positive ions form an electrochemical gradient to form inside of the cell, which spreads throughout the sarcolemma and the T-tubules by opening even more ion channels.

When the positive ions reach the sarcoplasmic reticulum, Ca^{2+} ions are released and allowed to flow into the myofibrils. Ca^{2+} ions bind to troponin, which causes the troponin molecule to change shape and move nearby molecules of tropomyosin. Tropomyosin is moved away from myosin binding sites on actin molecules, allowing actin and myosin to bind together.

ATP molecules power myosin proteins in the thick filaments to bend and pull on actin molecules in the thin filaments. Myosin proteins act like oars on a boat, pulling the thin filaments closer to the center of a sarcomere. As the thin filaments are pulled together, the sarcomere shortens and contracts. Myofibrils of muscle fibers are made of many sarcomeres in a row, so that when all of the sarcomeres contract, the muscle cells shortens with a great force relative to its size.

Muscles continue contraction as long as they are stimulated by a neurotransmitter. When a motor neuron stops the release of the neurotransmitter, the process of contraction reverses itself. Calcium returns to the sarcoplasmic reticulum; troponin and tropomyosin return to their resting positions; and actin and myosin are prevented from binding. Sarcomeres return to their elongated resting state once the force of myosin pulling on actin has stopped.

Types of Muscle Contraction

The strength of a muscle's contraction can be controlled by two factors: the number of motor units involved in contraction and the amount of stimulus from the nervous system. A single nerve impulse of a motor neuron will cause a motor unit to contract briefly before relaxing. This small contraction is known as a twitch contraction. If the motor neuron provides several signals within a short period of time, the strength and duration of the muscle contraction increases. This phenomenon is known as temporal summation. If the motor neuron provides many nerve impulses in rapid succession, the muscle may enter the state of tetanus, or complete and lasting contraction. A muscle will remain in tetanus until the nerve signal rate slows or until the muscle becomes too fatigued to maintain the tetanus.

Not all muscle contractions produce movement. Isometric contractions are light contractions that increase the tension in the muscle without exerting enough force to move a body part. When people tense their bodies due to stress, they are performing an isometric contraction. Holding an object still and maintaining posture are also the result of isometric contractions. A contraction that does produce movement is an isotonic contraction. Isotonic contractions are required to develop muscle mass through weight lifting.

Muscle tone is a natural condition in which a skeletal muscle stays partially contracted at all times. Muscle tone provides a slight tension on the muscle to prevent damage to the muscle and joints from sudden movements, and also helps to maintain the body’s posture. All muscles maintain some amount of muscle tone at all times, unless the muscle has been disconnected from the central nervous system due to nerve damage.

Functional Types of Skeletal Muscle Fibers

Skeletal muscle fibers can be divided into two types based on how they produce and use energy: Type I and Type II.

1. Type I fibers are very slow and deliberate in their contractions. They are very resistant to fatigue because they use aerobic respiration to produce energy from sugar. We find Type I fibers in muscles throughout the body for stamina and posture. Near the **spine** and neck regions, very high concentrations of Type I fibers hold the body up throughout the day.

2. Type II fibers are broken down into two subgroups: Type II A and Type II B.

- Type II A fibers are faster and stronger than Type I fibers, but do not have as much endurance. Type II A fibers are found throughout the body, but especially in the legs where they work to support your body throughout a long day of walking and standing.

- Type II B fibers are even faster and stronger than Type II A, but have even less endurance. Type II B fibers are also much lighter in color than Type I and Type II A due to their lack of myoglobin, an oxygen-storing pigment. We find Type II B fibers throughout the body, but particularly in the upper body where they give speed and strength to the arms and chest at the expense of stamina.

Muscle Metabolism and Fatigue

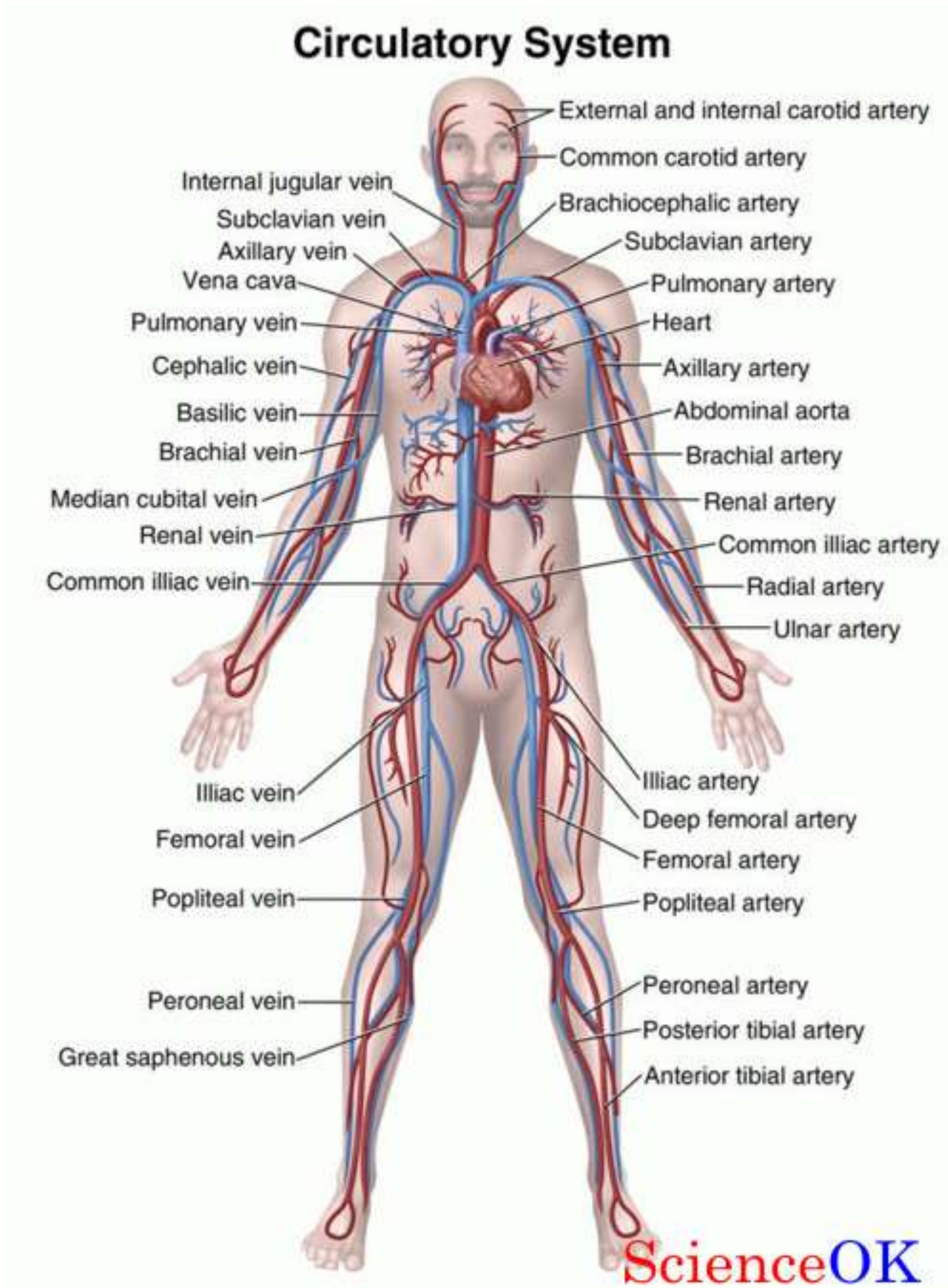
Muscles get their energy from different sources depending on the situation that the muscle is working in. Muscles use aerobic respiration when we call on them to produce a low to moderate level of force. Aerobic respiration requires oxygen to produce about 36-38 ATP molecules from a molecule of glucose. Aerobic respiration is very efficient, and can continue as long as a muscle receives adequate amounts of oxygen and glucose to keep contracting. When we use muscles to produce a high level of force, they become so tightly contracted that oxygen carrying blood cannot enter the muscle. This condition causes the muscle to create energy using lactic acid fermentation, a form of anaerobic respiration. Anaerobic respiration is much less efficient than aerobic respiration—only 2 ATP are produced for each molecule of glucose. Muscles quickly tire as they burn through their energy reserves under anaerobic respiration.

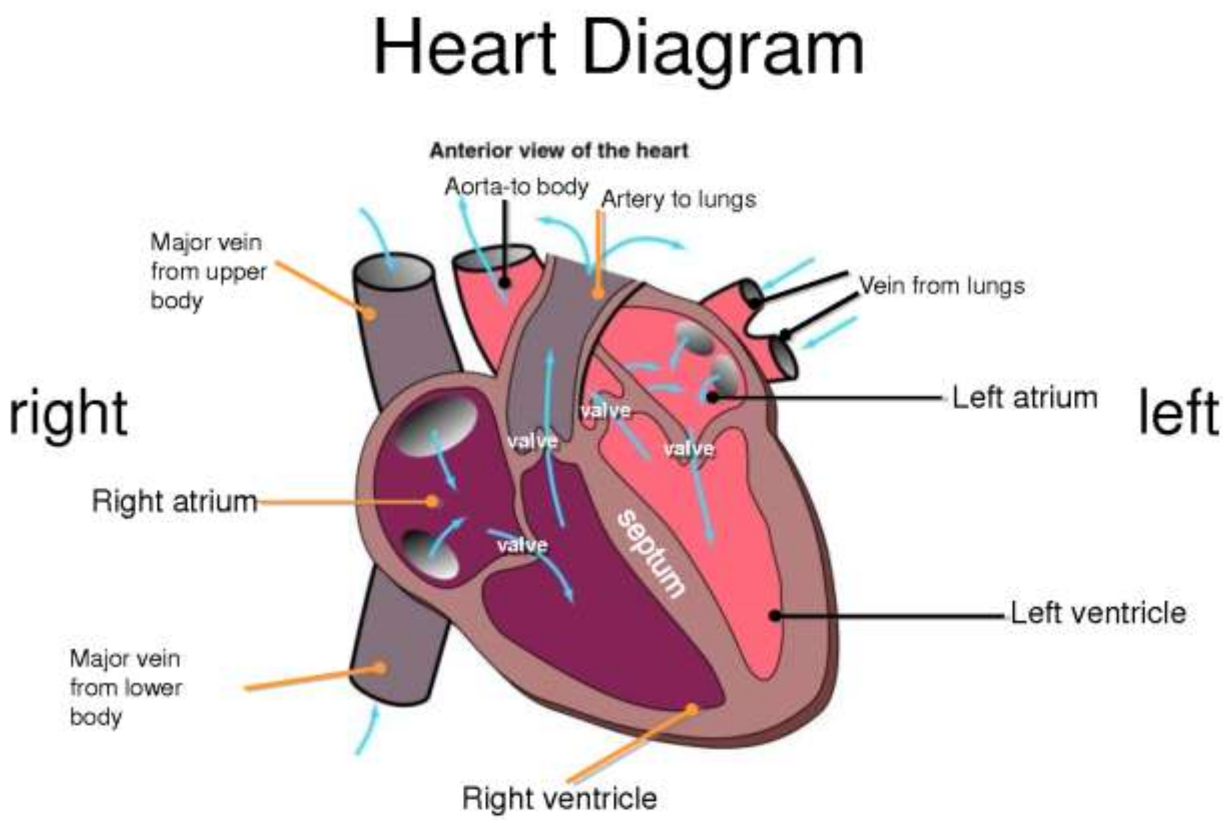
To keep muscles working for a longer period of time, muscle fibers contain several important energy molecules. Myoglobin, a red pigment found in muscles, contains iron and stores oxygen in a manner similar to hemoglobin in the blood. The oxygen from myoglobin allows muscles to continue aerobic respiration in the absence of oxygen. Another chemical that helps to keep muscles working is cretin phosphate. Muscles use energy in the form of ATP, converting ATP to ADP to release its energy. Cretin phosphate donates its phosphate group to ADP to turn it back into ATP in order to provide extra energy to the muscle. Finally, muscle fibers contain energy-storing glycogen, a large macromolecule made of many linked glucoses. Active muscles break glucoses off of glycogen molecules to provide an internal fuel supply.

When muscles run out of energy during either aerobic or anaerobic respiration, the muscle quickly tires and loses its ability to contract. This condition is known as muscle fatigue. A fatigued muscle contains very little or no oxygen, glucose or ATP, but instead has many waste products from respiration, like lactic acid and ADP. The body must take in extra oxygen after exertion to replace the oxygen that was stored in myoglobin in the muscle fiber as well as to power the aerobic respiration that will rebuild the energy supplies inside of the cell. Oxygen debt (or recovery oxygen uptake) is the name for the extra oxygen that the body must take in to restore the muscle cells to their resting state. This explains why you feel out of breath for a few minutes after a strenuous activity—your body is trying to restore itself to its normal state.

Cardiovascular System

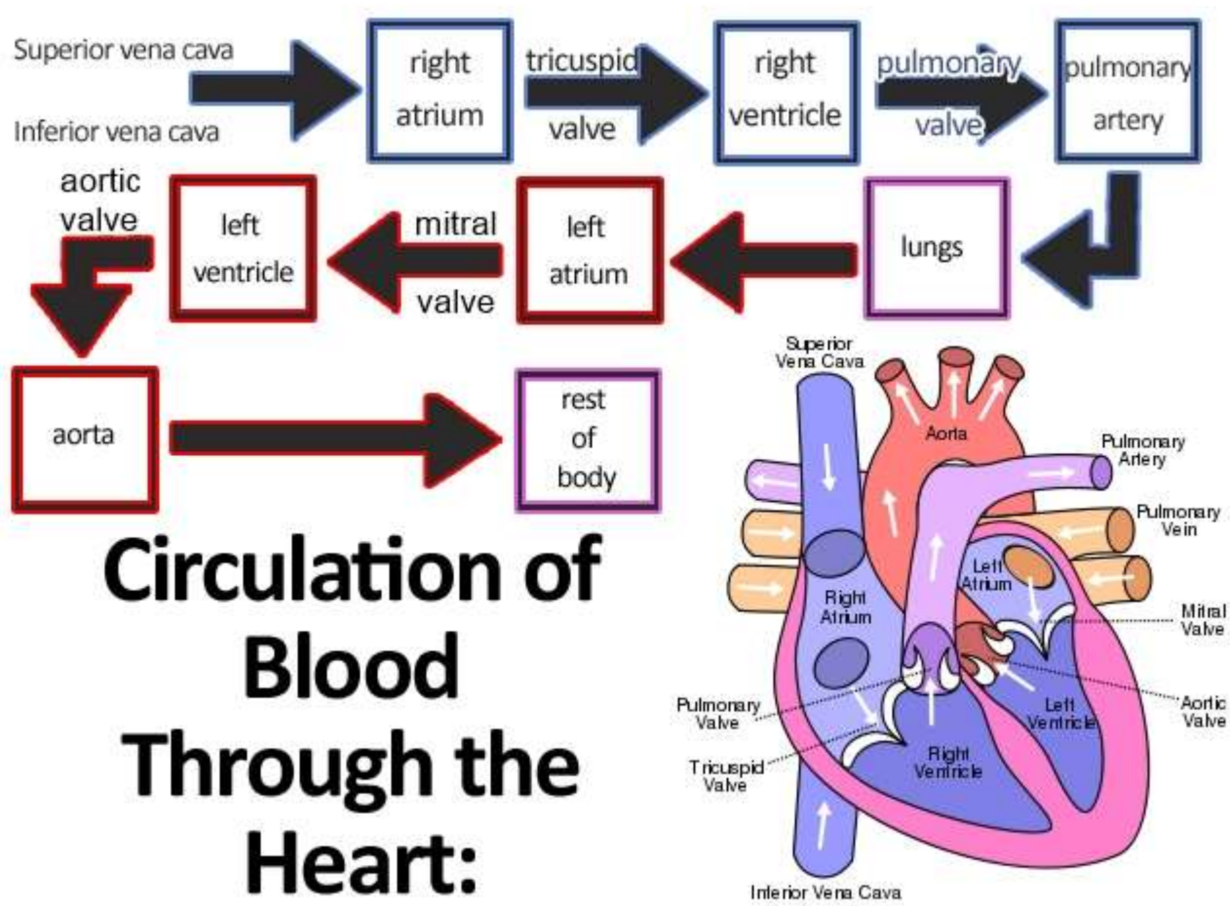
The cardiovascular system consists of the heart, blood vessels, and the approximately 5 liters of blood that the blood vessels transport. Responsible for transporting oxygen, nutrients, hormones, and cellular waste products throughout the body, the cardiovascular system is powered by the body's hardest-working organ — the heart, which is only about the size of a closed fist. Even at rest, the average heart easily pumps over 5 liters of blood throughout the body every minute.





The Heart

The **heart** is a muscular pumping organ located medial to the lungs along the body's midline in the thoracic region. The bottom tip of the heart, known as its apex, is turned to the left, so that about 2/3 of the heart is located on the body's left side with the other 1/3 on right. The top of the heart, known as the heart's base, connects to the great blood vessels of the body: the **aorta**, vena cava, pulmonary trunk, and pulmonary veins.



The Heart

The heart is a hollow muscular organ which beats over 100,000 times a day to pump blood around the body's 60,000 miles of blood vessels. The right side of the heart receives blood and sends it to the lungs to be oxygenated, while the left side receives oxygenated blood from the lungs and sends it out to the tissues of the body.

The Heart has three layers; the ENDOCARDIUM (inner layer), the EPICARDIUM (middle layer), and MYOCARDIUM (outer layer).

The heart is protected by the PERICARDIUM which the protective membrane is surrounding it.

The heart has FOUR CHAMBERS, in the lower heart the right and left Ventricles, and in the upper heart the right and left Atria. In a normal heart beat the atria contract while the ventricles relax, then the ventricles contract while the atria relax. There are VALVES through which blood passes between ventricle and atrium, these close in such a way that blood does not backwash during the pauses between ventricular contractions. The right and left ventricles are divided by a thick wall (the VENTRICULAR SEPTUM), babies born with "hole in the heart" have a small gap here, which is a problem since oxygenated and deoxygenated can blood mix. The walls of the left ventricle are thicker as it has to pump blood to all the tissues, compared to the right ventricle which only pumps blood as far as the lungs.

The spleen

This is a large flat oval organ located below the diaphragm, it's main function is to STORE BLOOD. The size of the spleen can vary, for example it may enlarge when the body is fighting infection also it's size tends to decrease with age. It is a non-vital organ and it is possible to survive after removal of the spleen.

Perinicious anaemia is a Vitamin B12 deficiency resulting in a reduction in number of erythrocytes.

Aplastic anemia is a failure of the bone marrow to produce the enough red blood cells.

Septicaemia - bacterial toxins in blood.

Circulatory Loops

There are 2 primary circulatory loops in the human body: the *pulmonary circulation loop* and the *systemic circulation loop*.

1. Pulmonary circulation transports deoxygenated blood from the right side of the heart to the **lungs**, where the blood picks up oxygen and returns to the left side of the heart. The pumping chambers of the heart that support the pulmonary circulation loop are the right atrium and right ventricle.
2. Systemic circulation carries highly oxygenated blood from the left side of the heart to all of the tissues of the body (with the exception of the heart and lungs). Systemic circulation removes wastes from body tissues and returns deoxygenated blood to the right side of the heart. The left atrium and left ventricle of the heart are the pumping chambers for the systemic circulation loop.

Blood Vessels

Blood vessels are the body's highways that allow blood to flow quickly and efficiently from the heart to every region of the body and back again. The size of blood vessels corresponds with the amount of blood that passes through the vessel. All blood vessels contain a hollow area called the lumen through which blood is able to flow. Around the lumen is the wall of the vessel, which may be thin in the case of capillaries or very thick in the case of arteries.

ARTERIES carry oxygenated blood away from the heart. They are thick hollow tubes which are highly ELASTIC which allows them to DILATE (widen) and constrict (narrow) as blood is forced down them by the heart. Arteries branch and re-branch, becoming smaller until they become small ARTERIOLES which are even more elastic. Arterioles feed oxygenated blood to the capillaries. The AORTA is the largest artery in the body, taking blood from the heart, branching into other arteries that send oxygenated blood to the rest of the body.

CAPILLARIES distribute the nutrients and oxygen to the body's tissues and remove deoxygenated blood and waste. They are extremely thin, the walls are only one cell thick and connect the arterioles with the venules (very small veins).

VENULES (very small veins) merge into **VEINS** which carry blood back to the heart. The vein walls are similar to arteries but thinner and less elastic. Veins carry deoxygenated blood towards the lungs where oxygen is received via the pulmonary capillaries. The PULMONARY Veins then carries this oxygenated blood back to the heart.

All **blood vessels** are lined with a thin layer of simple squamous epithelium known as the endothelium that keeps blood cells inside of the blood vessels and prevents clots from forming. The endothelium lines the entire circulatory system, all the way to the interior of the heart, where it is called the endocardium.

There are three major types of blood vessels: arteries, capillaries and veins. Blood vessels are often named after either the region of the body through which they carry blood or for nearby structures. For example, the **brachiocephalic artery** carries blood into the brachial (arm) and cephalic (head) regions. One of its branches, the subclavian artery, runs under the clavicle; hence the name subclavian. The subclavian artery runs into the axillary region where it becomes known as the axillary artery.

1. *Arteries and Arterioles*: Arteries are blood vessels that carry blood away from the heart. Blood carried by arteries is usually highly oxygenated, having just left the lungs on its way to the body's tissues.

   The pulmonary trunk and arteries of the pulmonary circulation loop provide an exception to this rule – these arteries carry deoxygenated blood from the heart to the lungs to be oxygenated.Arteries face high levels of blood pressure as they carry blood being pushed from the heart under great force. To withstand this pressure, the walls of the arteries are thicker, more elastic, and more muscular than those of other vessels. The largest arteries of the body contain a high percentage of elastic tissue that allows them to stretch and accommodate the pressure of the heart.Smaller arteries are more muscular in the structure of their walls.

   The smooth muscles of the arterial walls of these smaller arteries contract or expand to regulate the flow of blood through their lumen. In this way, the body controls how much blood flows to different parts of the body under varying circumstances.

The regulation of blood flow also affects blood pressure, as smaller arteries give blood less area to flow through and therefore increases the pressure of the blood on arterial walls.Arterioles are narrower arteries that branch off from the ends of arteries and carry blood to capillaries.

They face much lower blood pressures than arteries due to their greater number, decreased blood volume, and distance from the direct pressure of the heart. Thus arteriole walls are much thinner than those of arteries. Arterioles, like arteries, are able to use smooth muscle to control their aperture and regulate blood flow and blood pressure.

2. *Capillaries*: Capillaries are the smallest and thinnest of the blood vessels in the body and also the most common. They can be found running throughout almost every tissue of the body and border the edges of the body's a vascular tissues. Capillaries connect to arterioles on one end and venules on the other.Capillaries carry blood very close to the cells of the tissues of the body in order to exchange gases, nutrients, and waste products. The walls of capillaries consist of only a thin layer of endothelium so that there is the minimum amount of structure possible between the blood and the tissues. The endothelium acts as a filter to keep blood cells inside of the vessels while allowing liquids, dissolved gases, and other chemicals to diffuse along their concentration gradients into or out of tissues. Precapillary sphincters are bands of smooth muscle found at the arteriole ends of capillaries. These sphincters regulate blood flow into the capillaries. Since there is a limited supply of blood, and not all tissues have the same energy and oxygen

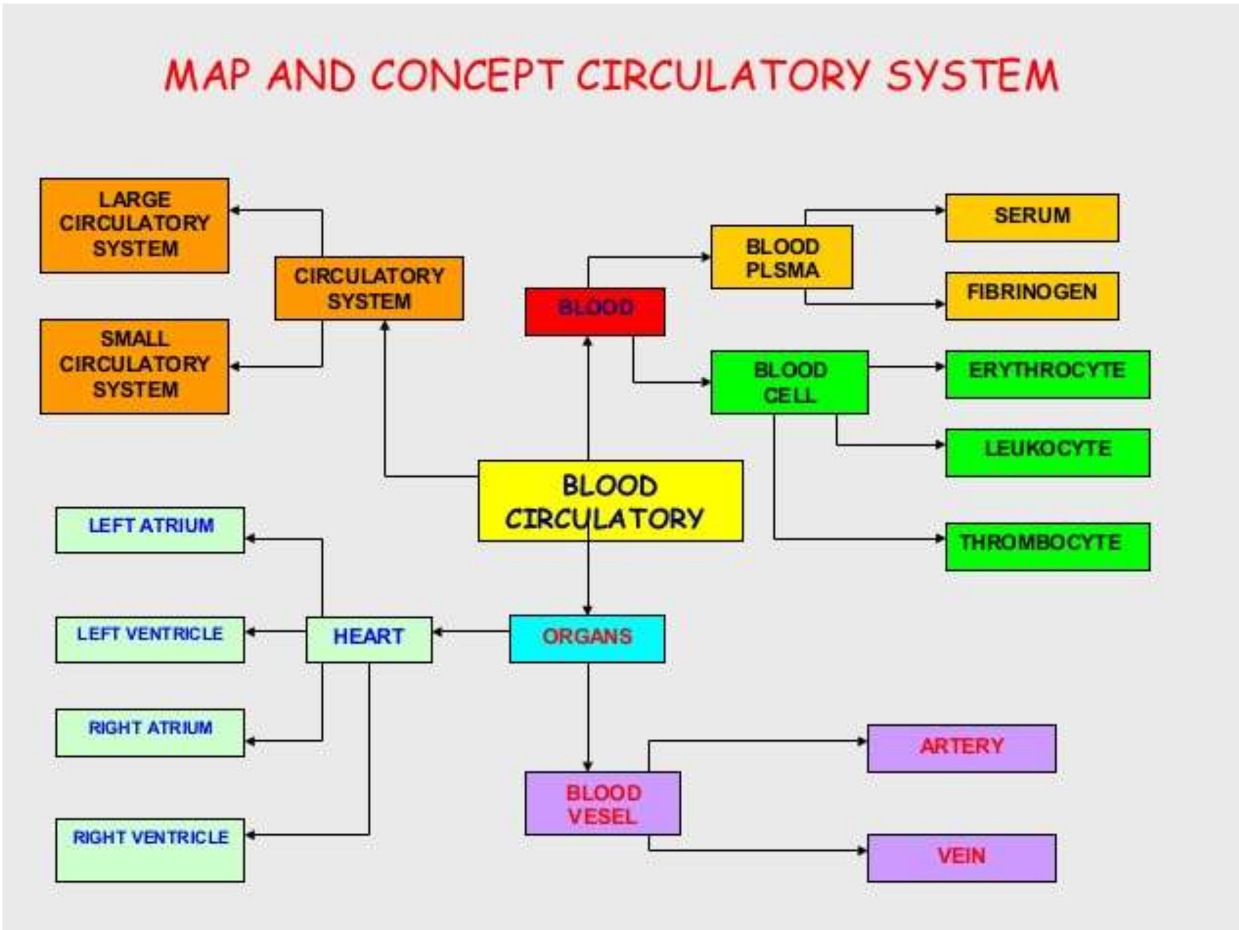
requirements, the precapillary sphincters reduce blood flow to inactive tissues and allow free flow into active tissues.

Capillaries contain small holes in their structure that allow oxygen and other nutrients to pass through into organs and tissues. Specific types of capillaries are determined by their functions, which affects their number and placement in the body. Capillaries are the smallest types of blood vessels in the body and operate as a network of many blood vessels woven together. They are most numerous in areas of the body that require a higher amount of oxygen and nutrient exchange

3. *Veins and Venules*: Veins are the large return vessels of the body and act as the blood return counterparts of arteries. Because the arteries, arterioles, and capillaries absorb most of the force of the heart's contractions, veins and venules are subjected to very low blood pressures. This lack of pressure allows the walls of veins to be much thinner, less elastic, and less muscular than the walls of arteries.

Veins rely on gravity, inertia, and the force of skeletal muscle contractions to help push blood back to the heart. To facilitate the movement of blood, some veins contain many one-way valves that prevent blood from flowing away from the heart. As skeletal muscles in the body contract, they squeeze nearby veins and push blood through valves closer to the heart.

When the muscle relaxes, the valve traps the blood until another contraction pushes the blood closer to the heart. Venules are similar to arterioles as they are small vessels that connect capillaries, but unlike arterioles, venules connect to veins instead of arteries. Venules pick up blood from many capillaries and deposit it into larger veins for transport back to the heart.



Coronary Circulation

The heart has its own set of blood vessels that provide the myocardium with the oxygen and nutrients necessary to pump blood throughout the body. The left and right coronary arteries branch off from the aorta and provide blood to the left and right sides of the heart. The coronary sinus is a vein on the posterior side of the heart that returns deoxygenated blood from the myocardium to the vena cava.

Hepatic Portal Circulation

The veins of the stomach and intestines perform a unique function: instead of carrying blood directly back to the heart, they carry **blood to the liver** through the **hepatic portal vein**. Blood leaving the digestive organs is rich in nutrients and other chemicals absorbed from food. The **liver** removes toxins, stores sugars, and processes the products of digestion before they reach the other body tissues. Blood from the liver then returns to the heart through the inferior vena cava.

Blood

The average human body contains about 4 to 5 liters of blood. As a liquid connective tissue, it transports many substances through the body and helps to maintain homeostasis of nutrients, wastes, and gases. Blood is made up of red blood cells, white blood cells, platelets, and liquid plasma.

- *Red Blood Cells*: Red blood cells, also known as erythrocytes, are by far the most common type of blood cell and make up about 45% of blood volume. Erythrocytes are produced inside of **red bone marrow** from stem cells at the astonishing rate of about 2 million cells every second. The shape of erythrocytes is biconcave—disks with a concave curve on both sides of the disk so that the center of an erythrocyte is its thinnest part. The unique shape of erythrocytes gives these cells a high surface area to volume ratio and allows them to fold to fit into thin capillaries. Immature erythrocytes have a nucleus that is ejected from the cell when it reaches maturity to provide it with its unique shape and flexibility. The lack of a nucleus means that red blood cells contain no DNA and are not able to repair themselves once damaged.

Erythrocytes transport oxygen in the blood through the red pigment hemoglobin. Hemoglobin contains iron and proteins joined to greatly increase the oxygen carrying capacity of erythrocytes. The high surface area to volume ratio of erythrocytes allows oxygen to be easily transferred into the cell in the lungs and out of the cell in the capillaries of the systemic tissues.

- *White Blood Cells*: White blood cells, also known as leukocytes, make up a very small percentage of the total number of cells in the bloodstream, but have important functions in the body's **immune system**. There are two major classes of white blood cells: granular leukocytes and granular leukocytes.

  - General types of blood cells: (each has many different sub-types)
  - **ERYTHROCYTES**
  - (red cells) are small red disk shaped cells. They contain HAEMOGLOBIN, which combines with oxygen in the lungs and is then transported to the body's cells. The haemoglobin then returns carbon dioxide waste to the lungs. Erythrocytes are formed in the bone marrow in the knobby ends of bones.
  - **LEUKOCYTES**
  - (white cells) help the body fight bacteria and infection. When a tissue is damaged or has an infection the number of leukocytes increases.

Leukocytes are formed in the small ends of bones. Leukocytes can be classed as granular or non granular. There are three types of granular leukocytes (eosinophils, neutrophils, and basophils), and three types of non-granular (monocytes, T-cell lymphocytes, and B-cell lymphocytes). See also the

THROMBOCYTES

- (platelets) aid the formation of blood CLOTS by releasing various protein substances. When the body is injured thrombocytes disintegrate and cause a chemical reaction with the proteins found in plasma, which eventually create a thread like substance called FIBRIN. The fibrin then "catches" other blood cells which form the clot, preventing further loss of blood and forms the basis of healing.

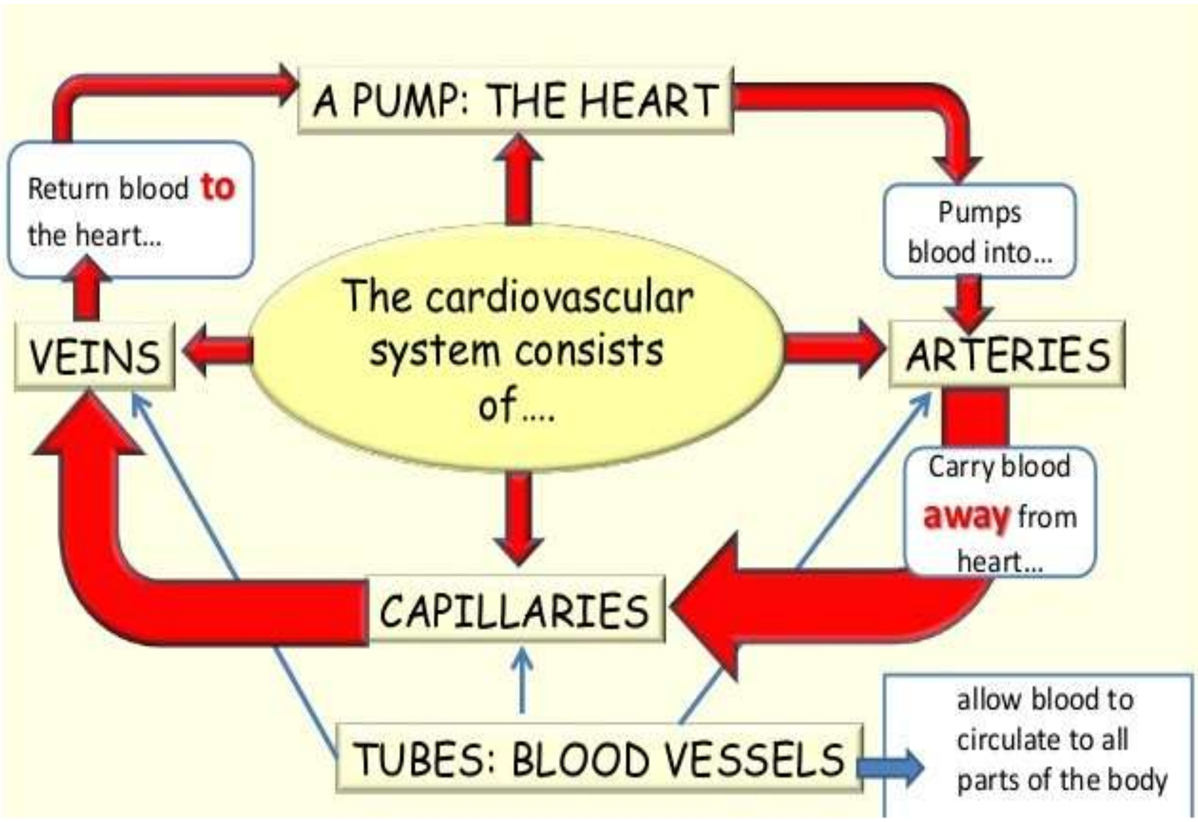
- *Platelets*: Also known as thrombocytes, platelets are small cell fragments responsible for the clotting of blood and the formation of scabs. Platelets form in the red bone marrow from large megakaryocyte cells that periodically rupture and release thousands of pieces of membrane that become the platelets. Platelets do not contain a nucleus and only survive in the body for up to a week before macrophages capture and digest them.
- *Plasma*: Plasma is the non-cellular or liquid portion of the blood that makes up about 55% of the blood's volume. Plasma is a mixture of water, proteins, and dissolved substances. Around 90% of plasma is made of **water**, although the exact percentage varies depending upon the hydration levels of the individual. The **proteins** within plasma include antibodies and albumins. Antibodies are part of the immune system and bind to antigens on the surface of pathogens that infect the body. Albumins help maintain the body's osmotic balance by providing an isotonic solution for the cells of the

body. Many different substances can be found dissolved in the plasma, including glucose, oxygen, carbon dioxide, electrolytes, nutrients, and cellular waste products. The plasma functions as transportation medium for these substances as they move throughout the body.

Functions of the Cardiovascular System

Functions of the cardiovascular system. Blood circulates through a network of vessels throughout the body to provide individual cells with oxygen and nutrients and helps dispose of metabolic wastes. The **heart** pumps the blood around the blood vessels.

The cardiovascular system is composed of the heart, blood and blood vessels. It connects all parts of the body through arteries and veins, arterioles and venules, and capillaries. Through this network, the blood delivers and expels nutrients, gases, waste products and chemical messengers throughout the body. Red blood cells transport oxygen, while white blood cells detect infections and kill foreign microbes and toxins. Clotting mechanisms further protect the body from blood loss when there’s a wound. The cardiovascular system works alongside the respiratory system to deliver oxygen to the body’s tissues and to remove carbon dioxide. It also helps maintain constant body temperature through the process thermoregulation. The sweat glands, smooth muscle around arterioles, skeletal muscle and endocrine glands all work together to keep a normal body temperature. Hormones, which are essential chemical signals used by the body to communicate with itself, are transported by the cardiovascular system to other parts of the body to deliver their message. Lastly, the cardiovascular system helps maintain fluid balance, which is important to ensure efficient movement of nutrients, gases and electrolytes in the cells.



The cardiovascular system has three major functions: transportation of materials, protection from pathogens, and regulation of the body's homeostasis.

- *Transportation*: The cardiovascular system transports blood to almost all of the body's tissues. The blood delivers essential nutrients and oxygen and removes wastes and carbon dioxide to be processed or removed from the body. Hormones are transported throughout the body via the blood's liquid plasma.

- *Protection*: The cardiovascular system protects the body through its white blood cells. White blood cells clean up cellular debris and fight pathogens that have entered the body. Platelets and red blood cells form scabs to seal wounds and prevent pathogens from entering the body and liquids from leaking out. Blood also carries antibodies that provide specific immunity to pathogens that the body has previously been exposed to or has been vaccinated against.
- *Regulation*: The cardiovascular system is instrumental in the body's ability to maintain homeostatic control of several internal conditions. Blood vessels help maintain a stable body temperature by controlling the blood flow to the surface of the **skin**. Blood vessels near the skin's surface open during times of overheating to allow hot blood to dump its heat into the body's surroundings. In the case of hypothermia, these blood vessels constrict to keep blood flowing only to vital organs in the body's core. Blood also helps balance the body's pH due to the presence of bicarbonate ions, which act as a buffer solution. Finally, the albumins in blood plasma help to balance the osmotic concentration of the body's cells by maintaining an isotonic environment.

Knowing the functions of the cardiovascular system and the parts of the body that are part of it is critical in understanding the physiology of the human body. With its complex pathways of veins, arteries, and capillaries, the cardiovascular system keeps life pumping through you. The heart, blood vessels, and blood help to transport vital nutrients throughout the body as well as remove metabolic waste. They also help to protect the body and regulate body temperature.

The cardiovascular system consists of the heart, blood vessels, and blood. This system has three main functions:

Transport of nutrients, oxygen, and hormones to cells throughout the body and removal of metabolic wastes (carbon dioxide, nitrogenous wastes).

Protection of the body by white blood cells, antibodies, and complement proteins that circulate in the blood and defend the body against foreign microbes and toxins. Clotting mechanisms are also present that protect the body from blood loss after injuries.

Regulation of body temperature, fluid pH, and water content of cells.

The cardiovascular system, also known as the circulatory system, is composed of blood, blood vessels and the heart. The heart functions as a pump to move blood through the blood vessels of the body. A circulatory system is essential for large, multi-cellular organisms, such as humans and animals, and provide at least five major functions that are necessary for life.

Transporting Oxygen and Removing Carbon Dioxide

One of the most important functions of the circulatory system is to supply oxygen to all the cells in the body. Every cell in the body requires a constant supply of oxygen to stay alive. Because most of the cells are not in contact with air, the circulatory system must supply them with oxygen.

When a person inhales, air enters the lungs, and oxygen is then absorbed across the membrane of the lungs into the bloodstream. This oxygen-rich blood is pumped through the heart to smaller and smaller blood vessels throughout the body. In the tiniest blood vessels, called capillaries, oxygen diffuses out of blood and into cells. At the same time, carbon dioxide produced by the cells is absorbed back into blood, which then returns to the lungs, releases carbon dioxide and picks up more oxygen.

Transporting Nutrients and Removing Wastes

A second critical function of the circulatory system is to supply all the cells in the body with nutrients and energy. After food is digested in the stomach, it migrates through the intestines, where nutrients from food are absorbed into the bloodstream. The blood also absorbs glucose, an energy source, from the liver, which is the body's glucose distribution center. These nutrients and energy are then transported to all the cells of the body, in a manner similar to the transport of oxygen. Blood also absorbs the waste products made by cells, and transports them to the excretory organs for removal from the body.

Fighting Disease

In addition to nutrients and oxygen, the blood also carries around important disease-fighting cells. The organs of the immune system, such as the spleen, create many types of specialized cells that can kill foreign cells trying to invade the body. The circulatory system is responsible for transporting these cells from the immune system to all other parts of the body.

Transporting Hormones

Hormones are crucial chemical signals that the body uses to communicate with itself. Hormones control many things such as growth, the reproductive cycle and glucose metabolism. Hormones are created in one part of the body, such as the brain or the liver, and then must be transported to another part of the body by the cardiovascular system in order to deliver their message.

Regulating Body Temperature

The cardiovascular system also plays a role in regulating body temperature. If body temperature rises too high, blood vessels close to the skin dilate, increasing in size. The larger surface area of blood vessels close to the skin means more heat is conducted across the skin into the air. Conversely, if body temperature drops, the blood vessels constrict, decreasing in size. The smaller surface area of blood vessels next to the skin causes less heat to be lost across the skin and retains more heat in the body.

1. To transport nutrients, gases and waste products around the body

2. To protect the body from infection and blood loss

3. To help the body maintain a constant body temperature (‘thermoregulation’)

4. To help maintain fluid balance within the body

1. Transportation of nutrients, gases and waste products

The cardiovascular system acts as an internal road network, linking all parts of the body via a system of highways (arteries and veins), main roads (arterioles and venules) and streets, avenues and lanes (capillaries).

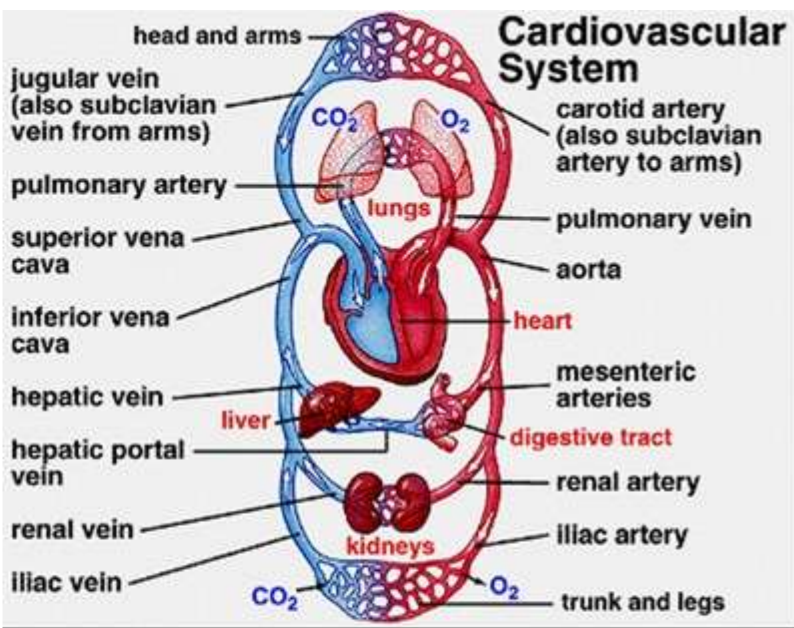
This network allows a non-stop courier system (the blood) to deliver and expel nutrients, gases, waste products and messages throughout the body.

Nutrients such as glucose from digested carbohydrate are delivered from the digestive tract to the muscles and organs that require them for energy.

Hormones (chemical messengers) from endocrine glands are transported by the cardiovascular system to their target organs, and waste products are transported to the lungs or urinary system to be expelled from the body.

The cardiovascular system works in conjunction with the respiratory system to deliver oxygen to the tissues of the body and remove carbon dioxide. In order to do this effectively the cardiovascular system is divided into two circuits, known as the pulmonary circuit and the systemic circuit.

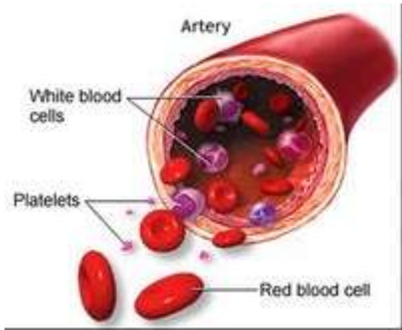
The pulmonary circuit is made up of the heart, lungs, pulmonary veins and pulmonary arteries. This circuit pumps deoxygenated (blue) blood from the heart to the lungs where it becomes oxygenated (red) and returns to the heart.



The systemic circuit is made up of the heart and all the remaining arteries, arterioles, capillaries, venules, and veins in the body.

This circuit pumps oxygenated (red) blood from the heart to all the tissues, muscles and organs in the body, to provide them with the nutrients and gases they need in order to function.

After the oxygen has been delivered the systemic circuit picks up the carbon dioxide and returns this in the now deoxygenated (blue) blood, to the lungs, where it enters the pulmonary circuit to become oxygenated again.



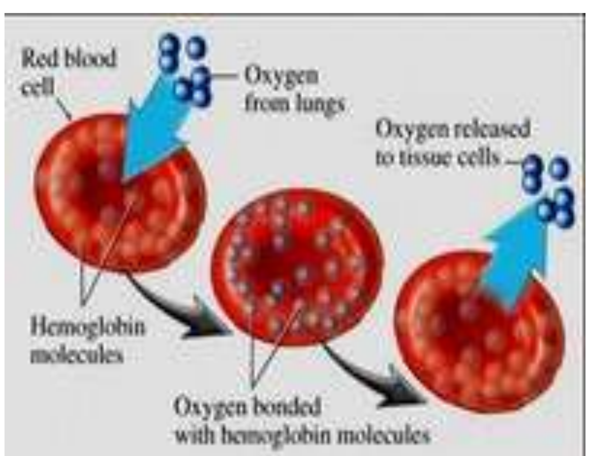
2. Protection from infection and blood loss

Blood contains three types of cells as listed below and shown in the adjacent image.

1. Red blood cells

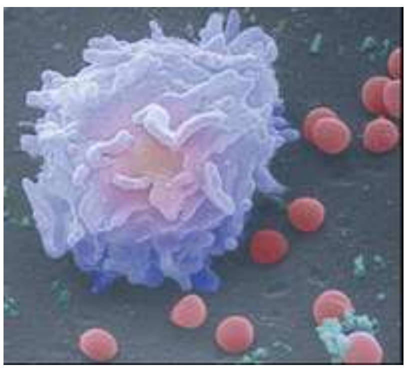
2. White blood cells

3. Platelets



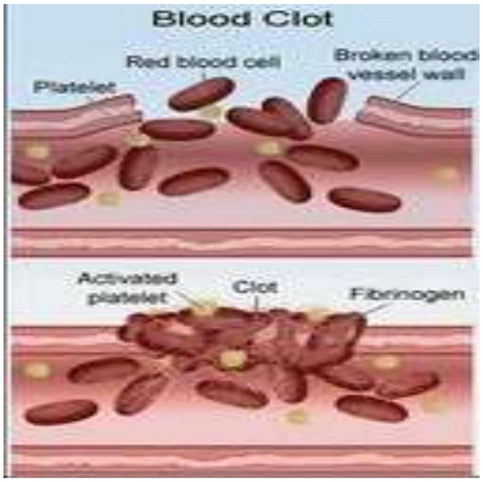
Red blood cells are responsible for transporting oxygen around the body to the tissues and organs that need it.

As oxygen enters the blood stream through the alveoli of the lungs it binds to a special protein in the red blood cells called haemoglobin. This can be seen in the adjacent image.



The job of **white blood cells** is to detect foreign bodies or infections and envelop and kill them, as seen in the below image.

When they detect and kill an infection they create antibodies for that particular infection which enables the immune system to act more quickly against foreign bodies or infections it has come into contact with previously.



Platelets are cells which are responsible for clotting the blood, they stick to foreign particles or objects such as the edges of a cut.

Platelets connect to fibrinogen (a protein which is released in the site of the cut) producing a clump that blocks the hole in the broken blood vessel. On an external wound this would become a scab.

If the body has a low level of platelets then clotting may not occur and bleeding can continue.

Excessive blood loss can be fatal – this is why people with a condition known as haemophilia (low levels or absence of platelets) need medication otherwise even minor cuts can become fatal as bleeding continues without a scab being formed.

Alternatively, if platelet levels are excessively high then clotting within blood vessels can occur, leading to a stroke and or heart attack. This is why people with a history of cardiac problems are often prescribed medication to keep their blood thin to minimise the risk of clotting within their blood vessels.

3. Maintenance of constant body temperature (thermoregulation)

The core temperature range for a healthy adult is considered to be between 36.1°C and 37.8°C, with 37°C regarded as the average ‘normal’ temperature.

If the core temperature drops below this range it is known as hypothermia and if it rises above this range it is known as hyperthermia.

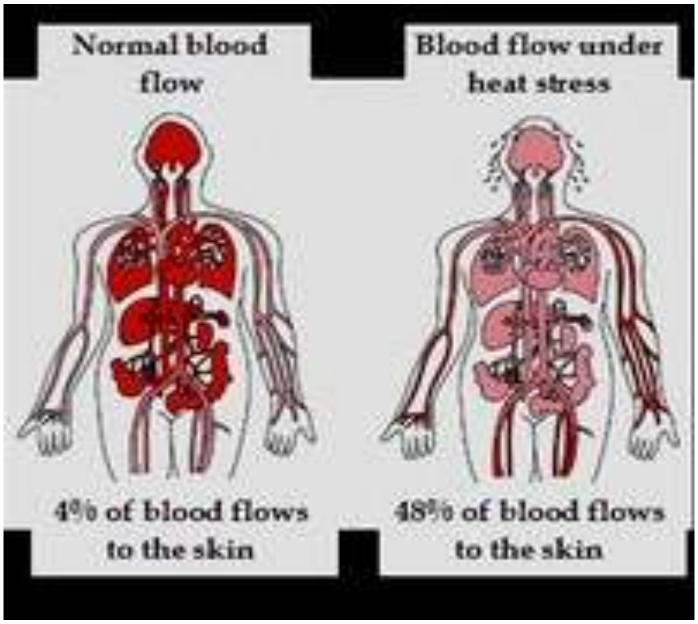
As temperatures move further into hypo or hyperthermia they become life threatening. Because of this the body works continuously to maintain its core temperature within the healthy range.

This process of temperature regulation in known as thermoregulation and the cardiovascular system plays an integral part.

Temperature changes within the body are detected by sensory receptors called thermo receptors, which in turn relay information about these changes to the hypothalamus in the brain.

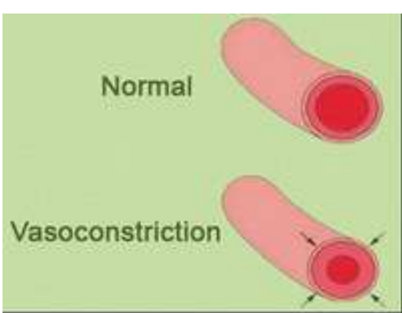
When a deviation in temperature is recorded the hypothalamus reacts by initiating certain mechanisms in order to regain a safe temperature range. There are four sites where these adjustments in temperature can occur, they are:

a. Sweat glands: These glands are instructed to secrete sweat onto the surface of the skin when either the blood or skin temperature is detected to be above a normal safe temperature. This allows heat to be lost through evaporation and cools the skin so blood that has been sent to the skin can in turn be cooled.



b. Smooth muscle around arterioles: Increases in temperature result in the smooth muscle in the walls of arterioles being stimulated to relax causing vasodilatation (increase in diameter of the vessel).

This in turn increases the volume of blood flow to the skin, allowing cooling to occur. We see this is in the adjacent diagram where blood that is normally concentrated around the core organs is shunted to the skin to cool when the body is under heat stress.



If however the thermo receptors detect a cooling of the blood or skin then the hypothalamus reacts by sending a message to the smooth muscle of the arteriole walls causing the arterioles to vasoconstrict (reduce their diameter), thus reducing the blood flow to the skin and therefore helping to maintain core body temperature.

c. Skeletal muscle: When a drop in blood temperature is recorded the hypothalamus can also react by causing skeletal muscles to start shivering. Shivering is actually lots of very fast, small muscular contractions which produce heat to help warm the blood

d. Endocrine glands: The hypothalamus may trigger the release of hormones such as thyroxin, adrenalin and noradrenalin in response to drops in blood temperature. These hormones all contribute to increasing the bodies metabolic rate (rate at which the body burns fuel) and therefore increasing the production of heat.

4. Maintaining fluid balance within the body

The cardiovascular system works in conjunction with other body systems (nervous and endocrine) to balance the body's fluid levels. Fluid balance is essential in order to ensure sufficient and efficient movement of electrolytes, nutrients and gases through the body's cells.

When the fluid levels in the body do not balance a state of dehydration or hyperhydration can occur, both of which impede normal body function and if left unchecked can become dangerous or even fatal.

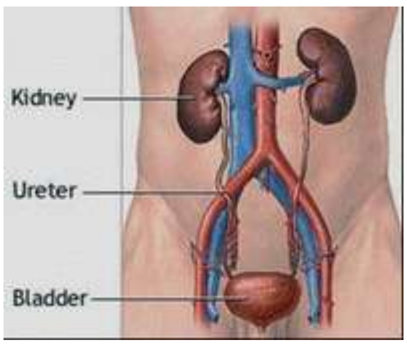
Dehydration is the excessive loss of body fluid, usually accompanied by an excessive loss of electrolytes.

The symptoms of dehydration include; headaches, cramps, dizziness, fainting and raised blood pressure (blood becomes thicker as its volume decreases requiring more force to pump it around the body).

Hyper hydration on the other hand results from an excessive intake of water which pushes the normal balance of electrolytes outside of their safe limits. This can occur through long bouts of intensive exercise where electrolytes are not replenished and excessive amounts of water are consumed.

This can result in the recently consumed fluid rushing into the body's cells, causing tissues to swell. If this swelling occurs in the brain it can put excessive pressure on the brain stem that may result in seizures, brain damage, coma or even death.

Dehydration or a loss of body fluid (through sweat, urination, bleeding etc) results in an increase in 'blood tonicity' (the concentration of substances within the blood) and a decrease in blood volume. Where as hyperhydration or a gain in body fluid (intake of water) usually results in a reduction of blood tonicity and an increase in blood volume.



Any change in blood tonicity and volume is detected by the kidneys and osmo receptors in the hypothalamus.

Osmo receptors are specialist receptors that detect changes in the dilution of the blood. Essentially they detect if we are hydrated (diluted blood) or dehydrated (less diluted blood).

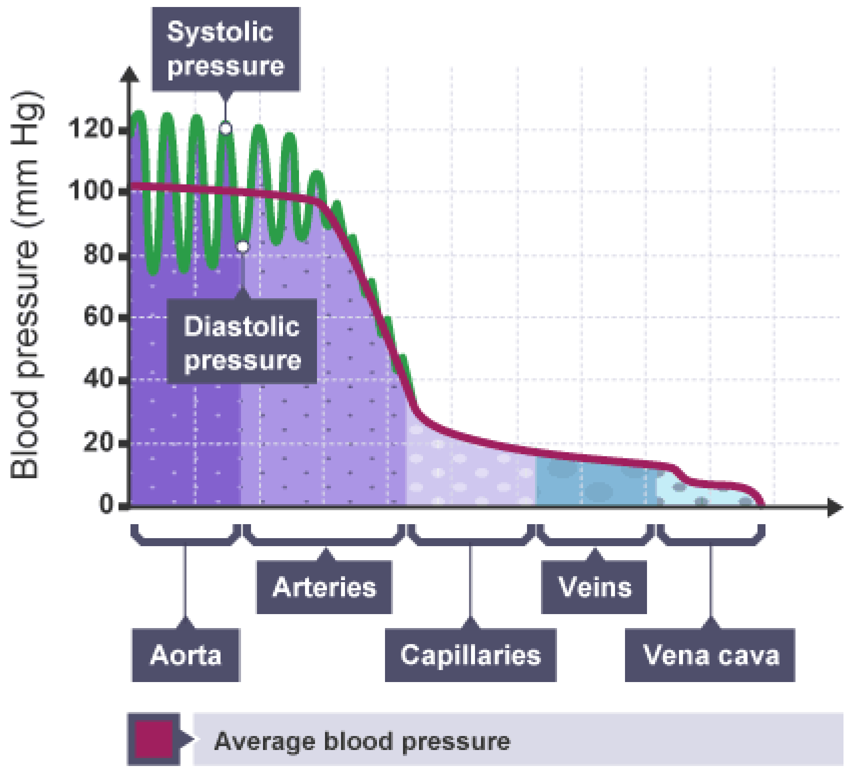
In response hormones are released and transported by the cardiovascular system (through the blood) to act on target tissues such as the kidneys to increase or decrease urine production. Another way the cardiovascular system maintains fluid balance is by either dilating (widening) or constricting (tightening) blood vessels to increase or decrease the amount of fluid that can be lost through sweat.

The Circulatory Pump

The heart is a four-chambered "double pump," where each side (left and right) operates as a separate pump. The left and right sides of the heart are separated by a muscular wall of tissue known as the septum of the heart. The right side of the heart receives deoxygenated blood from the systemic veins and pumps it to the lungs for oxygenation. The left side of the heart receives oxygenated blood from the lungs and pumps it through the systemic arteries to the tissues of the body. Each heartbeat results in the simultaneous pumping of both sides of the heart, making the heart a very efficient pump.

Blood pressure

You should be able to interpret pressure changes in arteries, capillaries and veins. The chart shows how the pressure changes in the circulatory system - starting at the *aorta* [**aorta**: *The major artery that leaves the left side of the heart, carrying oxygenated blood to the body tissues.*] leading from the left ventricle to the rest of the body, and back to the *vena cava* [**vena cava**: *The major vein that carries deoxygenated blood to the right side of the heart from the body tissues.*] leading to the right atrium.



Pressure changes in the circulatory system

Regulation of Blood Pressure

Several functions of the cardiovascular system can control blood pressure. Certain hormones along with autonomic nerve signals from the brain affect the rate and strength of heart contractions. Greater contractile force and heart rate lead to an increase in blood pressure. Blood vessels can also affect blood pressure. Vasoconstriction decreases the diameter of an artery by contracting the smooth muscle in the arterial wall. The sympathetic (fight or flight) division of the autonomic nervous system causes vasoconstriction, which leads to increases in blood pressure and decreases in blood flow in the constricted region. Vasodilatation is the expansion of an artery as the smooth muscle in the arterial wall relaxes after the fight-or-flight response wears off or under the effect of certain hormones or chemicals in the blood. The volume of blood in the body also affects blood pressure. A higher volume of blood in the body raises blood pressure by increasing the amount of blood pumped by each heartbeat. Thicker, more viscous blood from clotting disorders can also raise blood pressure.

Homeostasis

Homeostasis, or the clotting of blood and formation of scabs, is managed by the platelets of the blood. Platelets normally remain inactive in the blood until they reach damaged tissue or leak out of the blood vessels through a wound. Once active, platelets change into a spiny ball shape and become very sticky in order to latch on to damaged tissues. Platelets next release chemical clotting factors and begin to produce the protein fibrin to act as structure for the blood clot. Platelets also begin sticking together to form a platelet plug. The platelet plug will serve as a temporary seal to keep blood in the vessel and foreign material out of the vessel until the cells of the blood vessel can repair the damage to the vessel wall.

Blood groups and blood transfusion

Blood transfusion is generally the process of receiving blood products into one's circulation intravenously. Transfusions are used for various medical conditions to replace lost components of the blood. Early transfusions used whole blood, but modern medical practice commonly uses only components of the blood, such as red blood cells, white blood cells, plasma, clotting factors, and platelets.

Historically, red blood cell transfusion was considered when the hemoglobin level fell below 10 g/dL or hematocrit falls below 30% (the

"10/30 rule"). Because each unit of blood given carries risks, a trigger level lower than that at 7–8 g/dL is now usually used as it has been shown to have better patient outcomes. The administration of a single unit of blood is the standard for hospitalized people who are not bleeding, with this treatment then followed with re-assessment and consideration of symptoms and hemoglobin concentration. Patients with poor oxygen saturation may need more blood. The advisory caution to use blood transfusion only with more severe anemia is in part due to evidence that outcomes are worsened if larger amounts are given. One may consider transfusion for people with symptoms of cardiovascular disease such as chest pain or shortness of breath.[2] In cases where patients have low levels of hemoglobin but are cardiovascular stable, parenteral iron is a preferred option based on both efficacy and safety. Other blood products are given where appropriate, such as clotting deficiencies.

BLOOD

As blood moves throughout the body, it carries oxygen and nutrients to all the places they're needed. Blood also collects waste products, like carbon dioxide, and takes them to the organs responsible for making sure wastes leave the body.

Blood is a mixture of cells and liquid. Each has a specific job:

- **Red blood cells** carry oxygen to the body's tissues and remove carbon dioxide. Red blood cells make up about 40%-45% of a person's blood and live for 120 days.

- **White blood cells** are part of the immune system, and its main defense against infection. White blood cells make up less than 1% of a person's blood.
- **Platelets** are cell fragments that help blood clot, which helps to prevent and control bleeding. A person's blood has about 1 platelet for every 20 red blood cells.
- **Plasma** is a pale yellow liquid mixture of water, proteins, electrolytes, carbohydrates, cholesterol, hormones, and vitamins. About 55% of our blood is plasma.

Blood cells are made in the bone marrow (a spongy material inside many of the bones in the body). A full-grown adult has about 10 pints of blood (almost 5 liters) in his or her body.

What Is a Blood Transfusion?

A transfusion is a simple medical procedure that doctors use to make up for a loss of blood — or for any part of the blood, such as red blood cells or platelets.

A person usually gets a blood transfusion through an **intravenous line**, a tiny tube that is inserted into a vein with a small needle. The whole process takes about 1 to 4 hours, depending on how much blood is needed.

Blood from a donor needs to match the blood type of the person receiving it. There are eight main blood types:

1. O positive
2. O negative
3. A positive

4. A negative
5. B positive
6. B negative
7. AB positive
8. AB negative

In emergencies, there are exceptions to the rule that the donor's blood type must match the recipient's exactly. Blood type O negative is the only type of blood that people of all other blood types can receive. Medical teams use it in situations when patients need a transfusion but their blood type is unknown. Because of this, O negative donors are called "universal donors." People who have type AB blood are called "universal recipients" because they can safely receive any type of blood.

A blood transfusion usually isn't whole blood — it could be any one of the blood's components. For example, chemotherapy can affect how bone marrow makes new blood cells. So some people getting treatment for cancer might need a transfusion of red blood cells or platelets.

Other people might need plasma or only certain parts of plasma. People who have hemophilia, a disease that affects the blood's ability to clot, need plasma or the clotting factors contained in plasma to help their blood clot and prevent internal bleeding.

Types of Blood Transfusions

Red Blood Cell Transfusions A patient suffering from an iron deficiency or anemia, a condition where the body does not have enough red blood cells, may receive a Red Blood Cell Transfusion. This type of transfusion increases a patient's hemoglobin and iron levels, while improving the amount of oxygen in the body.

Platelet Transfusions Platelets are a component of blood that stops the body from bleeding. Often patients suffering from leukemia, or other types of cancer, have lower platelet counts as a side effect of their chemotherapy treatments. Patients who have illnesses that prevent the body from making enough platelets have to get regular transfusions to stay healthy.

Plasma Transfusions Plasma is the liquid part of the body's blood. It contains important proteins and other substances crucial to one's overall health. Plasma transfusions are used for patients with liver failure, severe infections, and serious burns.

Clotting of blood

Coagulation (also known as **clotting**) is the process by which **blood** changes from a liquid to a gel, forming a **clot**. It potentially results in homeostasis, the cessation of **blood** loss from a damaged vessel, followed by repair.

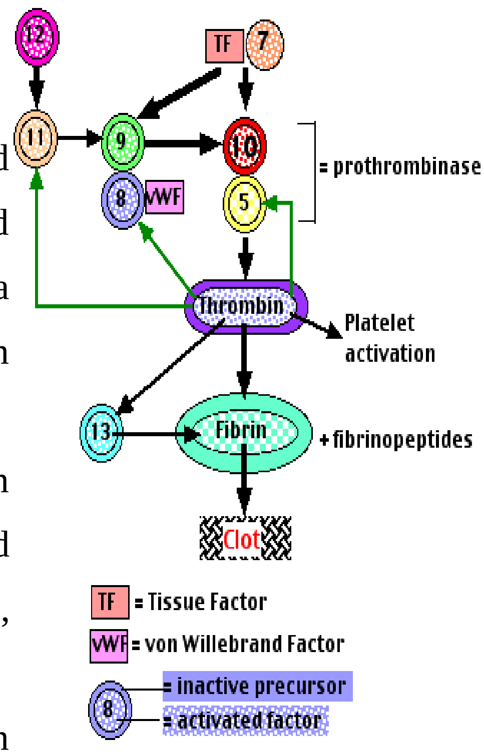
Coagulation, in physiology, the process by which a blood clot is formed. The formation of a clot is often referred to as secondary homeostasis, because it forms the second stage in the process of arresting the loss of blood from a ruptured vessel.

Platelets may stick to areas where the blood vessels are damaged and form blood clots. Vacuities also are a major **cause** of damage to the blood vessel walls. Diabetes. Diabetes external link icon increases the risk of plaque buildup in the arteries, which can **cause** dangerous blood clots.

How do you get a blood clot?

DVT occurs when **blood clots form** in the deep veins of the legs or pelvis, and is often caused by: prolonged sitting or bed rest. surgery or trauma (especially hip surgery, gynecological surgery, heart surgery) medications such as estrogen, and birth control pills with higher levels of estrogen.

Initiating the Clotting Process

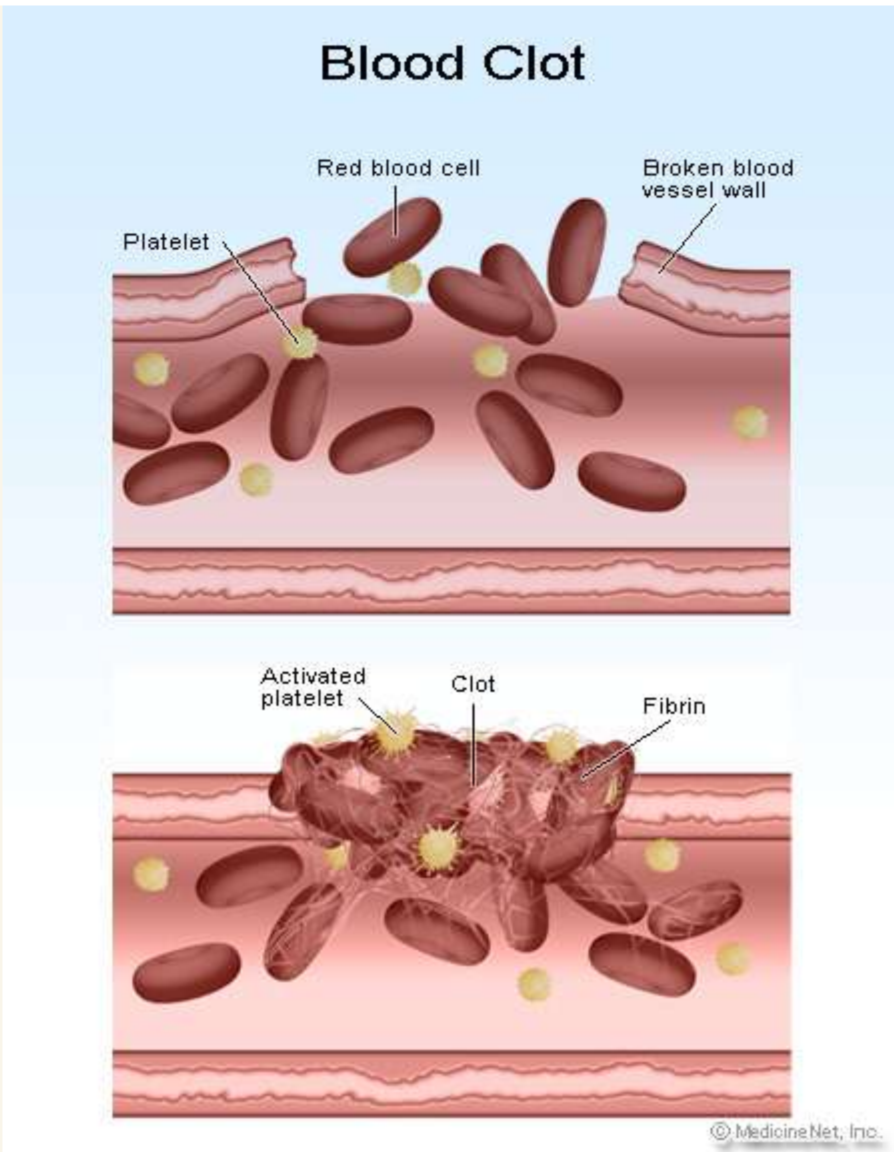


- A blood clot is a normal function of blood cells that is used to repair damaged blood vessel walls. Blood clots become a problem when the blood "clots" are in an artery or vein inappropriately.
- Risk factors for developing blood clots in arteries include high blood pressure, cholesterol, diabetes, smoking, and family history.
- Risk factors for developing blood clots in veins include prolonged immobility, including immobility after surgery, hormone therapy (including birth control pills), smoking, pregnancy, and genetic factors.
- Causes of arterial blood clots include rupture of atherosclerosis plaques, embolus from another location, and artery injury.
- Causes of venous blood blots include stasis and chemical factors that cause the blood to clot abnormally.

- Symptoms of blood clots depend upon their location and whether they occur in an artery or a vein. A blood clot in an artery that supplies blood to the heart or brain may result in
  - heart attack,
  - stroke, or
  - TIA (transient ischemic attack or mini-stroke)
- When blood clots occur in a vein, symptoms may include
  - pain,
  - swelling,
  - warmth, and
  - redness.
- If a forms in a vein in a leg or arm breaks; breaks off and travels to the lung a pulmonary embolus can occur. Symptoms of pulmonary embolism are chest pain and shortness of breath.
- Blood clots are diagnosed initially by history and physical examination. Other tests may be ordered depending upon the location of the blood clot.
- The treatment for blood clots depends upon the location, but most situations require the use of anticoagulant medications that thin the blood.
- Medications used for blood clot treatment thin or anticoagulate the blood include:
  - apixaban (Eliquis)
  - rivaroxaban (Xarelto)
  - dabigatran (Pradaxa)
  - warfarin (Coumadin)
  - enoxaparin (Lovenox)
- Complications of blood clots often depend upon their location.

- Blood clots can be prevented by remaining active especially after surgery, quitting smoking if you take birth control pills, controlling andhigh blood pressure, high cholesterol, and diabetes.
- The prognosis for a person with a blood clot depends upon the health of the person, the location of the blood clot, and how quickly medical care is accessed.

Picture of Blood Clots



Picture of blood clotting

Blood flows through the body in a continuous loop. Blood is pumped through the body by the heart, but that same blood returns back to the heart both by gravity and by muscles in the arms and legs contracting and squeezing, or milking, the blood back to the heart. If blood becomes stagnant, it may clot and cause potential life-threatening conditions.

The medical term for a blood clot is a thrombus (plural: thrombi). An embolus refers to the situation in which the clot breaks away from its original location and travels through the bloodstream to another location.

There are four potential outcomes regarding a blood clot. It will either

1. grow,
2. dissolve,
3. embolize, or
4. recannulate (a situation in which capillary blood vessels proliferate within the clot to form new channels so that blood may resume flow)

Cardiac Cycle

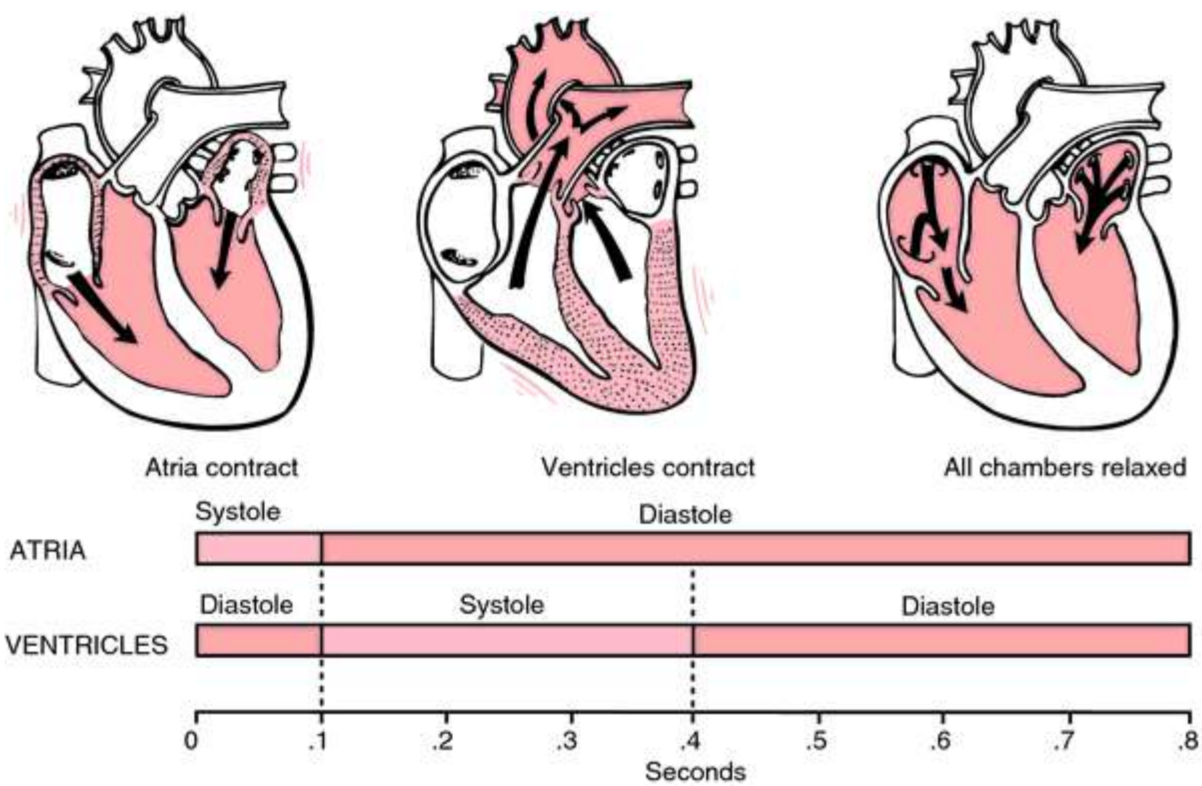
The **cardiac cycle** refers to a complete heartbeat from its generation to the beginning of the next beat, and so includes the diastole, the systole, and the intervening pause. The frequency of the **cardiac cycle** is described by the **heart** rate, which is typically expressed as beats per minute

The cardiac cycle is the sequence of events that occurs when the heart beats. There are two phases of the cardiac cycle. In the diastole phase, the heart ventricles are relaxed and the heart fills with blood. In the systole phase, the ventricles contract and pump blood to the arteries. One cardiac cycle is completed when the heart fills with blood and the blood is pumped out of the heart.

The events of the cardiac cycle described below trace the path of the blood as it enters the heart, is pumped to the lungs, travels back to the heart and is pumped out to the rest of the body. It is important to note that the events that occur in the first and second diastole phases actually happen at the same time. The same is also true for the events of the first and second systole phases.

The **cardiac cycle** refers to a complete heartbeat from its generation to the beginning of the next beat, and so includes the diastole, the systole, and the intervening pause. The frequency of the **cardiac cycle** is described by the heart rate, which is typically expressed as beats per minute.

Cardiac cycle a complete cardiac movement, or heart beat, including systole , diastole, and the intervening pause.



Cardiac Cycle: 1st Diastole Phase

During the diastole phase, the atria and ventricles are relaxed and the atrio ventricular valves are open. De-oxygenated blood from the superior and inferior vena cavae flows into the right atrium. The open atrioventricular valves allow blood to pass through to the ventricles. The SA nodecontracts triggering the atria to contract. The right atrium empties its contents into the right ventricle. The tricuspid valve prevents the blood from flowing back into the right atrium.

Cardiac Cycle: 1st Systole Phase

During the systole phase, the right ventricle receives impulses from the Purkinje fibers and contracts.

The atrioventricular valves close and the semilunar valves open. The de-oxygenated blood is pumped into the pulmonary artery. The pulmonary valve prevents the blood from flowing back into the right ventricle.

The pulmonary artery carries the blood to the lungs. There the blood picks up oxygen and is returned to the left atrium of the heart by the pulmonary veins.

Cardiac Cycle: 2nd Diastole Phase

In the next diastole period, the semi lunar valves close and the atrioventricular valves open. Blood from the pulmonary veins fills the left atrium. (Blood from the vena cava is also filling the right atrium.) The SA node contracts again triggering the atria to contract. The left atrium empties its contents into the left ventricle. The mitral valve prevents the oxygenated blood from flowing back into the left atrium.

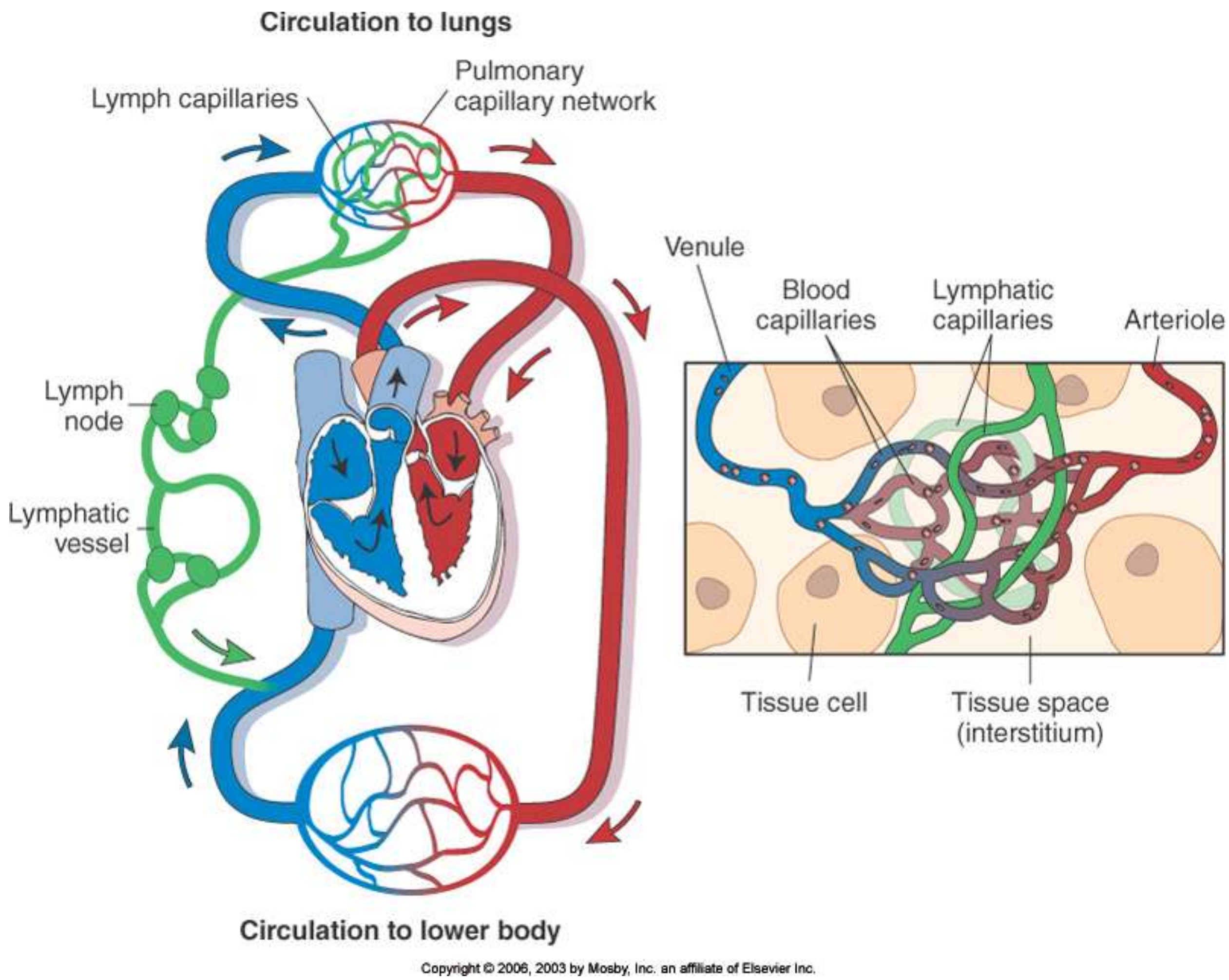
Cardiac Cycle: 2nd Systole Phase

During the following systole phase, the atrio ventricular valves close and the semi lunar valves open. The left ventricle receives impulses from the Purkinje fibers and contracts. Oxygenated blood is pumped into the aorta. The aortic valve prevents the oxygenated blood from flowing back into the left ventricle.

The aorta branches out to provide oxygenated blood to all parts of the body. The oxygen depleted blood is returned to the heart via the vena cavae.

Cardiovascular System

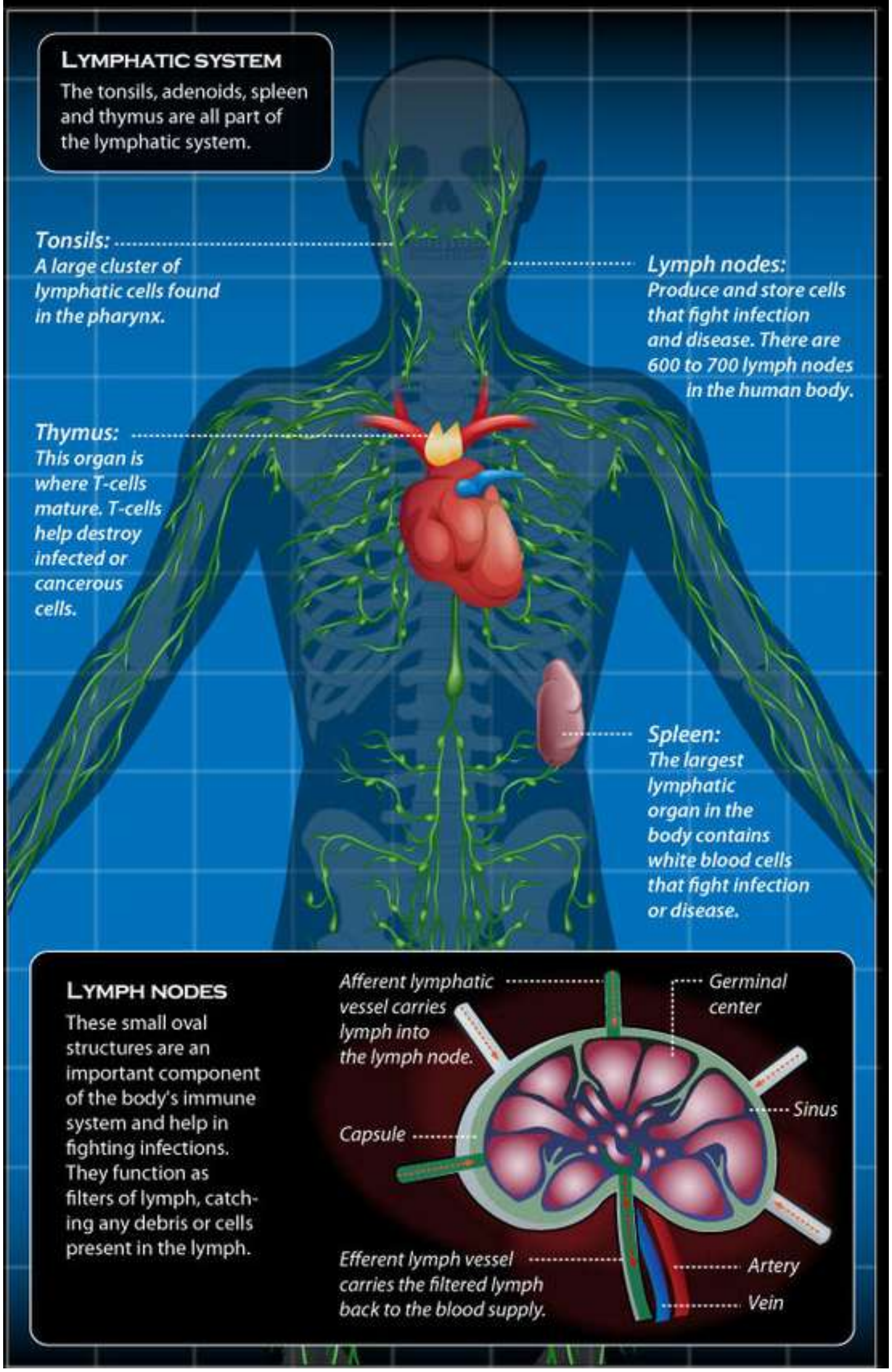
The cardiac cycle is vital to proper cardiovascular system function. Comprised of the heart and the circulatory system, the cardiovascular system transports nutrients to and removes gaseous waste from the cells of the body. The heart and its cardiac cycle provide the "muscle" needed to pump blood throughout the body, while blood vessels act as pathways to transport blood to its destination. The driving force behind the cardiac cycle is cardiac conduction. Cardiac conduction is the electrical system that powers the cardiac cycle and the cardiovascular system. It is what causes the heart muscle to contract, sending nerve impulses that travel throughout the heart wall.



Lymph and Lymphatic circulation.

LYMPHATIC SYSTEM

The lymphatic system is a network of tissues and organs that primarily consists of lymph vessels, lymph nodes and lymph. Its primary function is to transport lymph, a clear, colorless fluid containing white blood cells that helps rid the body of toxins, waste and other unwanted materials.



The lymphatic system is a network of tissues and organs that help rid the body of toxins, waste and other unwanted materials. The primary function of the lymphatic system is to transport lymph, a fluid containing infection-fighting white blood cells, throughout the body.

The lymphatic system primarily consists of lymphatic vessels, which are similar to the circulatory system's veins and capillaries. The vessels are connected to lymph nodes, where the lymph is filtered. The tonsils, adenoids, spleen and thymus are all part of the lymphatic system.

There are hundreds of lymph nodes in the human body. They are located deep inside the body, such as around the lungs and heart, or closer to the surface, such as under the arm or groin.

The spleen, which is located on the left side of the body just above the kidney, is the largest lymphatic organ, according to the U.S. National Library of Medicine (NLM). It controls the amount of red blood cells and blood storage in the body, and helps to fight infection. If the spleen detects potentially dangerous bacteria, viruses, or other microorganisms in the blood, it — along with the lymph nodes — creates white blood cells called lymphocytes, which act as defenders against invaders. The lymphocytes produce antibodies to kill the foreign microorganisms and stop infections from spreading. Humans can live without a spleen, although people who have lost their spleen to disease or injury are more prone to infections.

The thymus is located in the chest just above the heart. This small organ stores immature lymphocytes (specialized white blood cells) and prepares them to become active T cells, which help destroy infected or cancerous cells.

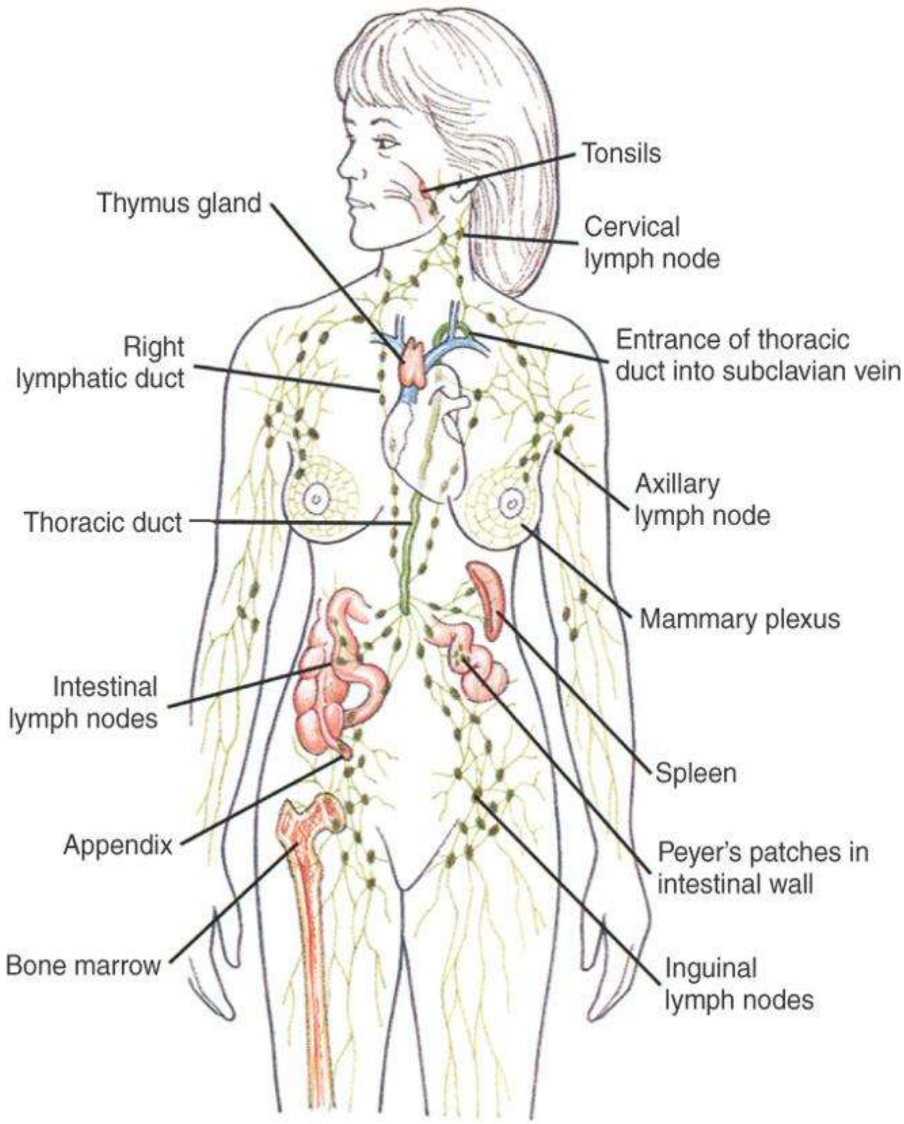
Tonsils are large clusters of lymphatic cells found in the pharynx. According to the American Academy of Otolaryngology, they are the body's "first line of defense as part of the immune system. They sample bacteria and viruses that enter the body through the mouth or nose." They sometimes become infected, and although tonsillectomies occur much less frequently today then they did in the 1950s, it is still among the most common operations performed and typically follows frequent throat infections.

Lymph is a clear and colorless fluid; the word "lymph" comes from the Latin word *lympha*, which means "connected to water,"

The lymphatic system is responsible for the following:

- Cleansing the cellular environment
- Returning proteins and tissue fluids to the blood
- Providing a pathway for the absorption of fats into the bloodstream
- Defending the body against disease

The lymphatic system is composed of **lymph** (or **interstitial fluid**), **lymph vessels**, l**ymph nodes**, **lymph organs** (e.g. tonsils, adenoids, appendix, spleen,, thymus gland, and patches of tissue in the intestines called Peyer patches), and lymphoid tissue. Monocytes and lymphocytes pass from the bloodstream through the blood capillary walls into the spaces between the cells in the body. When they pass into this lymph or interstitial fluid that surrounds cells, they perform their protective functions. Monocytes change into **macrophages**, destroy pathogens, and collect debris from damaged cells. Lymphocytes are much more complicated and are essential to the immune response, so they are discussed in the next section. Once monocytes and lymphocytes pass into the lymphatic capillaries, the fluid is termed *lymph* or *lymphatic fluid*.

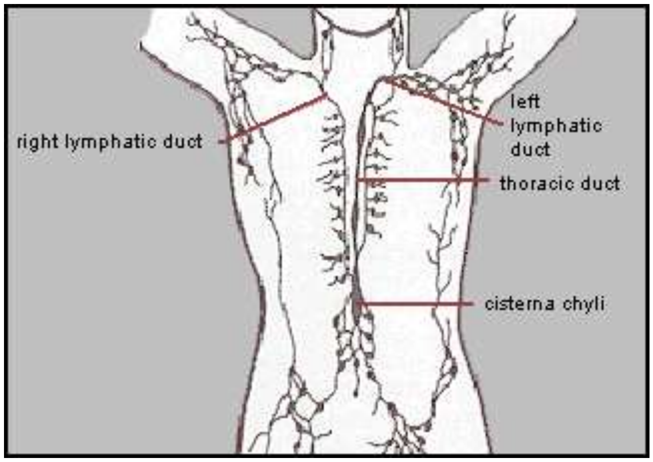


Lymph moves in one directo to prevent pathogens from flowing through the entire body. The system filters out the microorganisms as the lymph passes through its various capillaries, vessels, and nodes. Lymph travels in the following sequence:

1. From the interstitial spaces between the cells, then
2. Toward the heart through lymphatic capillaries.
3. To lymphatic vessels that carry lymph using a valvular system.
4. To the lymphatic nodes, which are also called **lymph glands**, that filter the debris that has been collected through the use of macrophages. These nodes can become enlarged when pathogens are present. Note the major lymph nodes in the figure, including the cervical, axillary, inguinal , and mediastinal nodes.
5. Then to either the **right lymphatic duct** or the **thoracic duct**, both of which empty into the large subclavian veins in the neck.
6. Once in the venous blood, the lymph is then recycled through the body through the circulatory system.

The organs in the lymphatic system are the spleen, the thymus gland, the tonsils, the appendix, and Peyer's patches. the spleen is located in the upper left quadrant and serves to filter, store, and produce blood cells; remove RBCs; and activate B lymphocytes. The thymus gland is located is located in the mediastinum and is instrumental in the development of T lymphocytes (T cells). the tonsils are lymphatic tissue (lingual, pharyngeal, and palatine) that helps protect the entrance to the respiratory and digestive systems. The vermiform appendix and Peyer patches are lymphoid tissue in the intestines.

THE LYMPHATIC SYSTEM IS COOPERATIVE



Major lymphatic ducts. (Courtesy of NIH/NCI)

- The lymphatic system aids the immune system in removing and destroying waste, debris, dead blood cells, pathogens, toxins, and cancer cells.
- The lymphatic system absorbs fats and fat-soluble vitamins from the digestive system and delivers these nutrients to the cells of the body where they are used by the cells.
- The lymphatic system also removes excess fluid, and waste products from the interstitial spaces between the cells.

THE TRANSFORMATION

Arterial blood carries oxygen, nutrients, and hormones for the cells. To reach these cells it leaves the small arteries and flows into the tissues. This fluid is now known as *interstitial fluid* and it delivers its nourshing products to the cells. Then it leaves the cell and removes waste products.

After this task is complete, 90% of this fluid returns to the circulatory system as venous blood.

WHAT IS LYMPH?

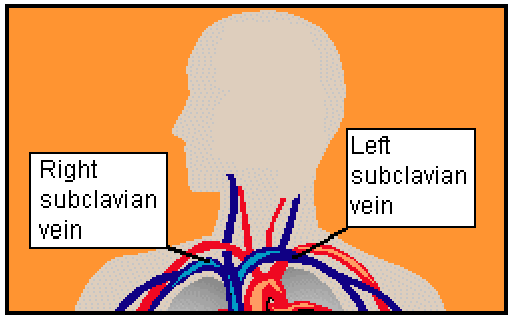
The remaining 10% of the fluid that stays behind in the tissues as a clear to yellowish fluid known as lymph.

- Unlike blood, which flows throughout the body in a continue loop, lymph flows in only one direction within its own system. This flow is only upward toward the neck. Here, it flows into the venous blood stream through the subclavien veins which are located on either sides of the neck near the collarbones.
- After plasma has delivered its nutrients and removed debris, it leaves the cells. 90% of this fluid returns to the venous circulation through the venules and continues as venous blood.
- The remaining 10% of this fluid becomes lymph which is a watery fluid that contains waste products. This waste is protein-rich due to the undigested proteins that were removed from the cells.

LYMPHATIC CIRCULATION

The lymph is moved through the body in its own vessels making a one-way journey from the interstitial spaces to the subclavian veins at the base of the neck.

- Since the lymphatic system does not have a heart to pump it, its upward movement depends on the motions of the muscle and joint pumps.
- As it moves upward toward the neck the lymph passes through lymph nodes which filter it to remove debris and pathogens.
- The cleansed lymph continues to travel in only one direction, which is upward toward the neck.
- At the base of the neck, the cleansed lymph flows into the *subclavian veins* on either side of the neck.



Lymph returning to the subclavian veins. © Lymph Notes

THE ORIGIN OF LYMPH

Lymph originates as plasma (the fluid portion of blood). The ***arterial blood***, which flows out of the heart, slows as it moves through a capillary bed. This slowing allows some plasma to leave the arterioles (small arteries) and flow into the tissues where it becomes tissue fluid.

- Also known as ***extracellular fluid***, this is fluid that flows between the cells but is not into the cells. This fluid delivers nutrients, oxygen, and hormones to the cells.
- As this fluid leaves the cells, it takes with it cellular waste products and protein cells.
- Approximately 90% of this tissue fluid flows into the small veins. Here it enters the venous circulation as plasma and continues in the circulatory system.
- The remaining 10% of the fluid that is left behind is known as lymph.

LYMPHATIC CAPILLARIES

In order to leave the tissues, the lymph must enter the lymphatic system through specialized lymphatic capillaries. Approximately 70% of these are *superficial capillaries* located near, or just under, the skin. The remaining 30%, which are known as *deep lymphatic capillaries*, surround most of the body's organs.

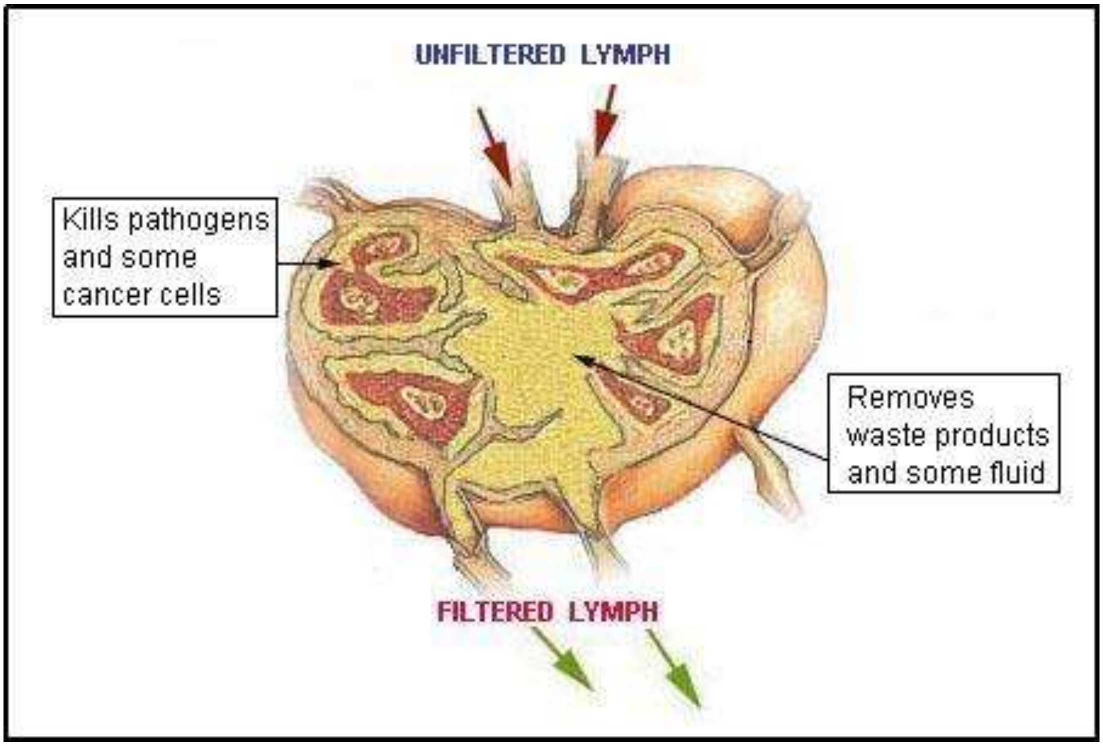
Lymphatic capillaries begin as blind-ended tubes that are only a single cell in thickness. These cells are arranged in a slightly overlapping pattern, much like the shingles on a roof. Each of these individual cells is fastened to nearby tissues by an *anchoring filament*.

LYMPHATIC VESSELS

The lymphatic capillaries gradually join together to form a mesh-like network of tubes that are located deeper in the body.

- As they become larger, and deeper, these structures become lymphatic vessels.
- Deeper within the body the lymphatic vessels become progressively larger and are located near major blood veins.
- Like veins, the lymphatic vessels, which are known as lymphangions, have one-way valves to prevent any backward flow.
- Smooth muscles in the walls of the lymphatic vessels cause the angions to contract sequentially to aid the flow of lymph upward toward the thoracic region. Because of their shape, these vessels are previously referred to as a string of pearls.

LYMPH NODES



Lymph nodes kill pathogens and cancer cells. They also remove debris and excess fluids.

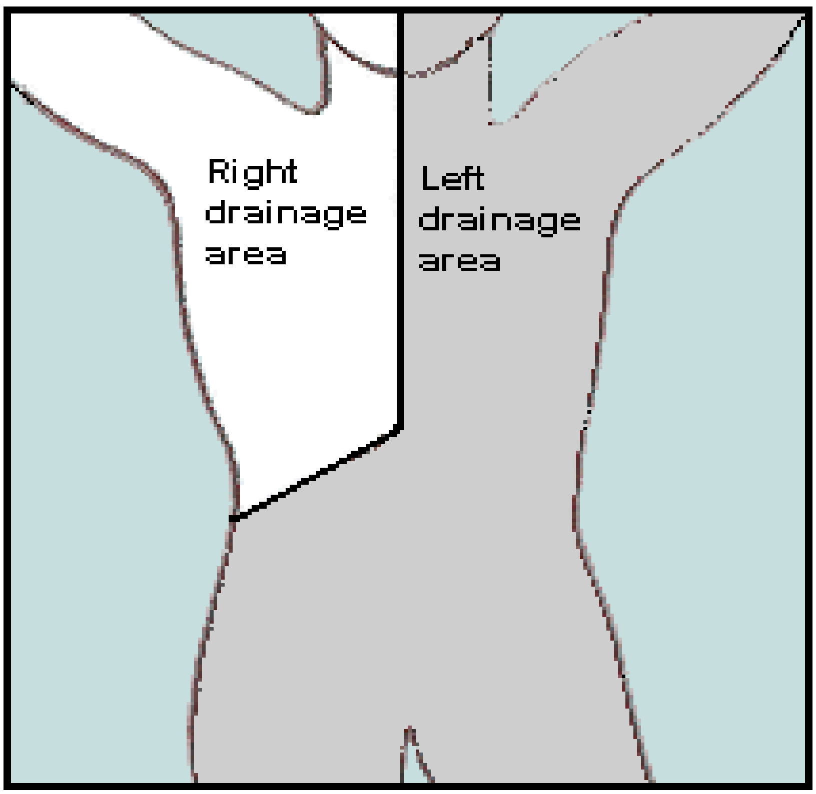
There are between 600-700 lymph nodes present in the average human body. It is the role of these nodes to filter the lymph before it can be returned to the circulatory system. Although these nodes can increase or decrease in size throughout life, any nodes that has been damaged or destroyed, does not regenerate.

- *Afferent lymphatic vessels* carry unfiltered lymph into the node. Here waste products, and some of the fluid, are filtered out.
- In another section of the node, lymphocytes, which are specialized white blood cells, kill any pathogens that may be present. This causes the swelling commonly known as swollen glands.
- Lymph nodes also trap and destroy cancer cells to slow the spread of the cancer until they are overwhelmed by it.

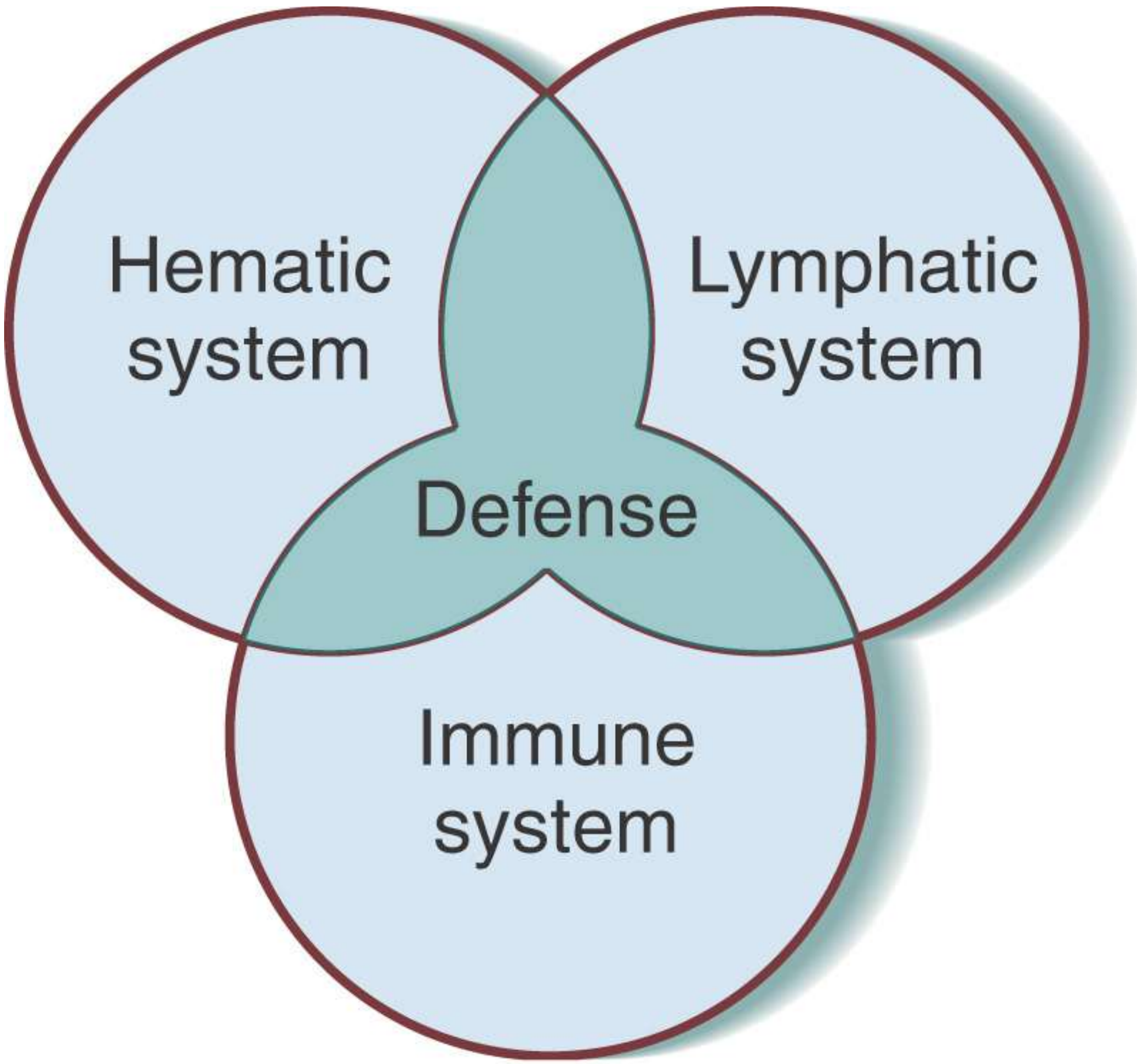
- *Efferent lymphatic vessels* carry the filtered lymph out of the node so that it can continue its return to the circulatory system.

DRAINAGE AREAS

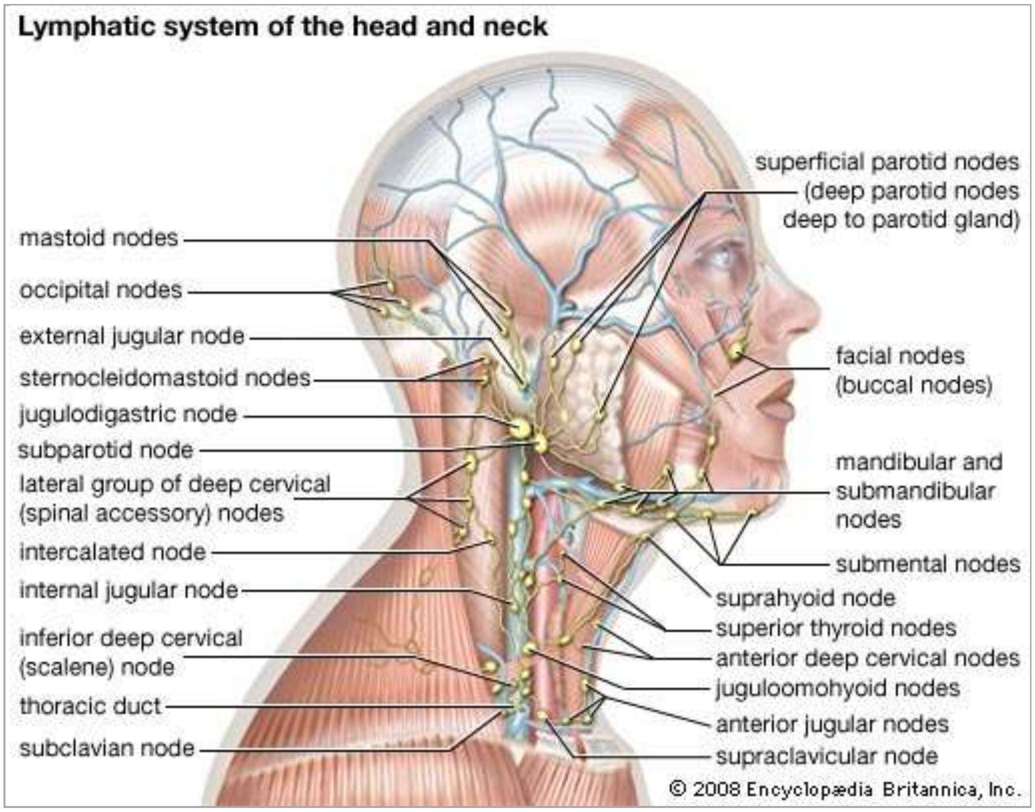
Lymphatic system drainage is organized into two separate, and very unequal drainage areas. The right drainage area clears the right arm and chest. The left drainage area clears all of the other areas of the body including both legs, the lower trunk upper left of the chest, and the left arm.



Lymphatic Drainage Areas


Hematic system
Lymphatic system
Defense
Immune system

Lymphatic circulation



The lymphatic system can be thought of as a drainage system needed because, as blood circulates through the body, blood plasma leaks into tissues through the thin walls of the capillaries. The portion of blood plasma that escapes is called interstitial or extracellular fluid, and it contains oxygen, glucose, amino acids, and other nutrients needed bytissue cells. Although most of this fluid seeps immediately back into the bloodstream, a percentage of it, along with the particulate matter, is left behind. The lymphatic system removes this fluid and these materials from tissues, returning them via the lymphatic vessels to the bloodstream, and thus prevents a fluid imbalance that would result in the organism's death.

The fluid and proteins within the tissues begin their journey back to the bloodstream by passing into tiny lymphatic capillaries that infuse almost every tissue of the body. Only a few regions, including the epidermis of the skin, the mucous membranes, the bone marrow, and the central nervous system, are free of lymphatic capillaries, whereas regions such as the lungs, gut, genitourinary system, and dermis of the skin are densely packed with these vessels. Once within the lymphatic system, the extracellular fluid, which is now called lymph, drains into larger vessels called the lymphatics. These vessels converge to form one of two large vessels called lymphatic trunks, which are connected to veins at the base of the neck. One of these trunks, the right lymphatic duct, drains the upper right portion of the body, returning lymph to the bloodstream via the right subclavian vein. The other trunk, the thoracic duct, drains the rest of the body into the left subclavian vein. Lymph is transported along the system of vessels by muscle contractions, and valves prevent lymph from flowing backward. The lymphatic vessels are punctuated at intervals by small masses of lymph tissue, called lymph nodes, that remove foreign materials such as infectious microorganisms from the lymph filtering through them.

In addition to serving as a drainage network, the lymphatic system helps protect the body against infection by producing white blood cells calledlymphocytes, which help rid the body of disease-causing microorganisms. The organs and tissues of the lymphatic system are the major sites of production, differentiation, and proliferation of two types of lymphocytes—the T lymphocytes and B lymphocytes, also called T cells and B cells. Although lymphocytes are distributed throughout the body, it is within the lymphatic system that they are most likely to encounter foreign microorganisms.

Lymphoid organs

The lymphatic system is commonly divided into the primary lymphoid organs, which are the sites of B and T cell maturation, and the secondary lymphoid organs, in which further differentiation of lymphocytes occurs. Primary lymphoid organs include the thymus, bone marrow, fetal liver, and, in birds, a structure called the bursa of Fabricius. In humans the thymus and bone marrow are the key players in immune function. All lymphocytes derive from stem cells in the bone marrow. Stem cells destined to become B lymphocytes remain in the bone marrow as they mature, while prospective T cells migrate to the thymus to undergo further growth. Mature B and T lymphocytes exit the primary lymphoid organs and are transported via the bloodstream to the secondary lymphoid organs, where they become activated by contact with foreign materials, such as particulate matter and infectious agents, called antigens in this context.

Thymus

The thymus is located just behind the sternum in the upper part of the chest. It is a bilobed organ that consists of an outer, lymphocyte-rich cortex and an inner medulla. The differentiation of T cells occurs in the cortex of the thymus. In humans the thymus appears early in fetal development and continues to grow until puberty, after which it begins to shrink. The decline of the thymus is believed to be the reason T-cell production decreases with age.

In the cortex of the thymus, developing T cells, called thymocytes, come to distinguish between the body's own components, referred to as "self," and those substances foreign to the body, called "nonself." This occurs when the thymocytes undergo a process called positive selection, in which they are exposed to self molecules that belong to the major histocompatibility complex (MHC). Those cells capable of recognizing the body's MHC molecules are preserved, while those that cannot bind these molecules are destroyed. The thymocytes then move to the medulla of the thymus, where further differentiation occurs. There thymocytes that have the ability to attack the body's own tissues are destroyed in a process called negative selection. Positive and negative selection destroy a great number of thymocytes; only about 5 to 10 percent survive to exit the thymus. Those that survive leave the thymus through specialized passages called efferent (outgoing) lymphatics, which drain to the blood and secondary lymphoid organs. The thymus has no afferent (incoming) lymphatics, which supports the idea that the thymus is a T-cell factory rather than a rest stop for circulating lymphocytes.

Bone marrow

In birds B cells mature in the bursa of Fabricius. (The process of B-cell maturation was elucidated in birds—hence *B* for *bursa*.) In mammals the primary organ for B-lymphocyte development is the bone marrow, although the prenatal site of B-cell differentiation is the fetal liver. Unlike the thymus, the bone marrow does not atrophy at puberty, and therefore there is no concomitant decrease in the production of B lymphocytes with age.

Secondary lymphoid organs

Secondary lymphoid organs include the lymph nodes, spleen, and small masses of lymph tissue such as Peyer's patches, the appendix, tonsils, and selected regions of the body's mucosal surfaces (areas of the body lined with mucous membranes). The secondary lymphoid organs serve two basic functions: they are a site of further lymphocyte maturation, and they efficiently trap antigens for exposure to T and B cells.

LYMPH NODES

The lymph nodes, or lymph glands, are small, encapsulated bean-shaped structures composed of lymphatic tissue. Thousands of lymph nodes are found throughout the body along the lymphatic routes, and they are especially prevalent in areas around the armpits (axillary nodes), groin (inguinal nodes), neck (cervical nodes), and knees (popliteal nodes). The nodes contain lymphocytes, which enter from the bloodstream via specialized vessels called the high endothelial venules. T cells congregate in the inner cortex (paracortex), and B cells are organized in germinal centres in the outer cortex. Lymph, along with antigens, drains into the node through afferent (incoming) lymphatic vessels and percolates through the lymph node, where it comes in contact with and activates lymphocytes. Activated lymphocytes, carried in the lymph, exit the node through the efferent (outgoing) vessels and eventually enter the bloodstream, which distributes them throughout the body.

SPLEEN

The spleen is found in the abdominal cavity behind the stomach. Although structurally similar to a lymph node, the spleen filters blood rather than lymph. One of its main functions is to bring blood into contact with lymphocytes. The functional tissue of the spleen is made up of two types of cells: the red pulp, which contains cells called macrophages that remove bacteria, old blood cells, and debris from the circulation; and surrounding regions of white pulp, which contain great numbers of lymphocytes. The splenic artery enters the red pulp through a web of small blood vessels, and blood-borne microorganisms are trapped in this loose collection of cells until they are gradually washed out through the splenic vein. The white pulp contains both B and T lymphocytes. T cells congregate around the tiny arterioles that enter the spleen, while B cells are located in regions called germinal centres, where the lymphocytes are exposed to antigens and induced to differentiate into antibody-secreting plasma cells.

MUCOSA-ASSOCIATED TISSUES

Another group of important secondary lymphoid structures is the mucosa-associated lymphoid tissues. These tissues are associated with mucosal surfaces of almost any organ, but especially those of the digestive, genitourinary, and respiratory tracts, which are constantly exposed to a wide variety of potentially harmful microorganisms and therefore require their own system of antigen capture and presentation to lymphocytes. For example, Peyer's patches, which are mucosa-associated lymphoid tissues of the small intestine, sample passing antigens and expose them to underlying B and T cells. Other, less-organized regions of the gut also play a role as secondary lymphoid tissue.

Diseases of the lymphatic system

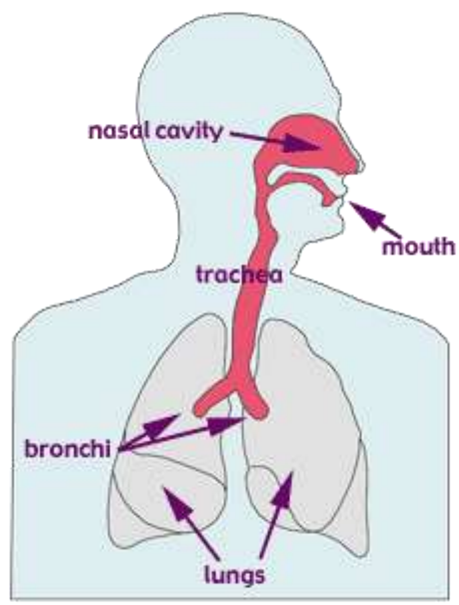
The host of secondary lymphoid organs provides a system of redundancy for antigen sampling by the cells of the immune system. Removal of the spleen, selected lymph nodes, tonsils, or appendix does not generally result in an excessive increase in disease caused by pathogenic microorganisms. However, the importance of the primary lymphoid organs is clear. For example, two autoimmune diseases, DiGeorge syndrome and Nezelof's disease, result in the failure of the thymus to develop and in the subsequent reduction in T-cell numbers, and removal of the bursa from chickens results in a decrease in B-cell counts. The destruction of bone marrow also has devastating effects on the immune system, not only because of its role as the site of B-cell development but also because it is the source of the stem cells that are the precursors for lymphocyte differentiation.

The Respiratory system:

The respiratory system (called also **respiratory** apparatus, ventilator **system**) is a biological **system** consisting of specific organs and structures used for the process of **respiration** in an organism. There are 3 major parts of the respiratory system: the airway, the **lungs**, and the muscles of respiration. The airway, which includes the nose, mouth, **pharynx**, **larynx**, **trachea**, **bronchi**, and **bronchioles**, carries air between the **lungs** and the body's exterior.

What is the respiratory system?

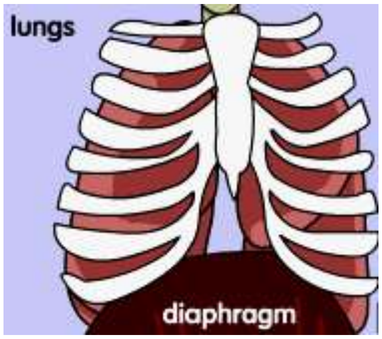
Your respiratory system is made up of the organs in your body that help you to breathe. Remember, that Respiration = Breathing. The goal of breathing is to deliver oxygen to the body and to take away carbon dioxide.



Parts of the respiratory system

Lungs

The lungs are the main organs of the respiratory system. In the lungs oxygen is taken into the body and carbon dioxide is breathed out. The red blood cells are responsible for picking up the oxygen in the lungs and carrying the oxygen to all the body cells that need it. The red blood cells drop off the oxygen to the body cells, then pick up the carbon dioxide which is a waste gas product produced by our cells. The red blood cells transport the carbon dioxide back to the lungs and we breathe it out when we exhale.



Trachea

The trachea (TRAY-kee-uh} is sometimes called the windpipe. The trachea filters the air we breathe and branches into the bronchi.

Bronchi

The bronchi (BRAHN-ky) are two air tubes that branch off of the trachea and carry air directly into the lungs.

Diaphragm

Breathing starts with a dome-shaped muscle at the bottom of the lungs called the diaphragm (DY-uh-fram). When you breathe in, the diaphragm contracts. When it contracts it flattens out and pulls downward. This movement enlarges the space that the lungs are in. This larger space pulls air into the lungs. When you breathe out, the diaphragm expands reducing the amount of space for the lungs and forcing air out. The diaphragm is the main muscle used in breathing.

Respiration is the physiological process by which organisms supply **oxygen** to their cells and the cells use that oxygen to produce high **energy** molecules. Respiration occurs in all types of organisms, including **bacteria**, protists, **fungi**, plants, and animals. In higher animals, respiration is often separated into three separate components: (a) external respiration, the exchange of oxygen and **carbon dioxide** between the environment and the **organism**; (b) internal respiration, the exchange of oxygen and **carbon** dioxide between the internal body fluids, such as **blood**, and individual cells; and (c) cellular respiration, the biochemical oxidation of glucose and consequent synthesis of ATP (**adenosine triphosphate**)

. Respiration - External Respiration

External respiration, commonly known as breathing, is the exchange of oxygen and carbon dioxide between an animal and its environment. Most animals use specialized organs or organ systems, such as lungs, trachea, or gills, for external respiration. In all cases, exchange of gases between the environment and an animal occurs by diffusion through a wet surface on the animal which is permeable to oxy…

Respiration - Internal Respiration

Internal respiration is the exchange of oxygen and carbon dioxide between blood and cells in different tissues of an animal's body. Internal respiration occurs in animals with a circulation system (categories 2, 4, and 5 above). Animals with gills or lungs take up oxygen and transport oxygen-rich blood throughout the body; they transport carbon dioxide-rich blood from the body back into the…

Respiration - Cellular Respiration

Cellular respiration consists of many separate enzymatic reactions. The entire process can be summarized in the chemical equation: Cellular respiration is divided into three sequential series of reactions: glycolysis, the citric acid cycle, and the electron transport chain. In higher organisms (eukaryotes), glycolysis occurs in the cytosol of the cell, the aqueous region outside the nucleus; …

Respiration - Glycolysis

Glycolysis can be defined simply as the lysis, or splitting, of sugar. More particularly, it is the controlled breakdown of glucose, a 6-carbon carbohydrate, into pyruvate, a 3-carbon carbohydrate. Organisms frequently store complex carbohydrates, such as glycogen or starch, and break these down into glucose units which can then enter into glycolysis. Two features of glycolysis suggest that it has…

Respiration - Cirtric Acid Cycle

After pyruvate (a 3-carbon molecule) is synthesized by glycolysis, it moves into the mitochondria and is oxidized to form carbon dioxide (a 1-carbon molecule) and acetyl CoA (a two carbon molecule). Cells can also make acetyl CoA from fats and amino acids and this is how cells often derive energy, in the form of ATP, from molecules other than glucose or complex carbohydrates. After acetyl CoA form…

Respiration - Electron Transfer Chain

The electron transfer chain is the final series of biochemical reactions in cellular respiration. It consists of a series of organic electron carriers associated with the inner membrane of the mitochondria. Cytochromes are among the most important of these electron carriers. Like hemoglobin, cytochromes are colored proteins which contain iron in a nitrogen-containing heme group. The final electron…

Respiration - Anaerobic Respiration

The above reactions of cellular respiration are often referred to as aerobic respiration because the final series of reactions, the electron transfer chain, require oxygen as an electron acceptor. When oxygen is absent or in short supply, cells may rely upon glycolysis alone for their supply of ATP. Glycolysis presumably originated in primitive cells early in Earth's history when very littl…

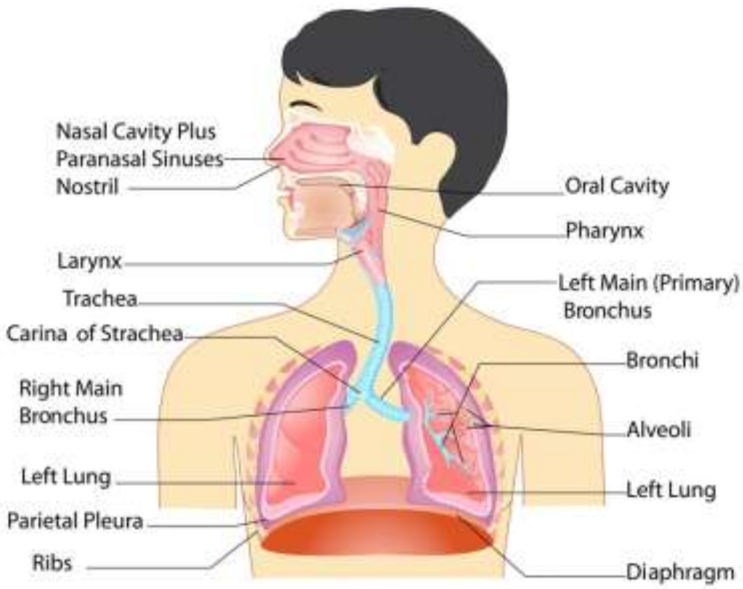
Respiration - Efficiency of Cellular Respiration

One can easily determine the energy efficiency of cellular respiration by calculating the standard free energy change, a thermodynamic quantity, between the reactants and products. On this basis, biochemists often quote the overall efficiency of cellular respiration as about 40%, with the additional 60% of the energy given off as heat. However, many cells regulate the different enzymes of respirat…

The respiratory system plays a vital role in the body, by providing your cells with much needed oxygen, as well as excreting carbon dioxide, which can be deadly if allowed to accumulate. The three major parts of the respiratory system are the airways, the lungs, and the muscles of respiration. This article will explain anatomy of the respiratory system, detailing the organs involved as well as the things that can go wrong.

Anatomy of Respiratory System: Organs and Functions

The three major parts of the respiratory system all work together to carry out their task. The airways (nose, mouth, pharynx, larynx etc.) allow air to enter the body and into the lungs. The lungs work to pass oxygen into the body, whilst removing carbon dioxide from the body. The muscles of respiration, such as the diaphragm, work in unison to pump air into and out of the lungs whilst breathing.



Respiratory Organs	Description	Function
Nose and Nasal Cavity	The nose is the primary opening for the respiratory system, made of bone, muscle, and cartilage. The nasal cavity is a cavity within your nose filled	The nose is used to inhale air into the body. The nasal cavity warms the air as it enters, acting as filtration and purifying the air by removing

	with mucus membranes and hairs.	any dust, pollen, and other contaminants, before it passed to the inner body.
Mouth	Also called the oral cavity, the mouth is the secondary exterior opening for the respiratory system. Most commonly, the majority of respiration is achieved via the nose and nasal cavity, but the mouth can be used if needed.	Inhaling air through the mouth allows more inhalation, as the oral cavity is far larger than the nasal cavity. The air also has less distance to travel, meaning more air can enter your body and be used faster. The oral cavity has no hairs or filtering techniques, meaning the air

		you inhale does not undergo the filtration process.
Pharynx	Also called the throat, the pharynx is a funnel of muscle that extends from the respiratory openings to the esophagus and larynx.	Air that is inhaled enters the pharynx, where it descends into the larynx via a diversion from the epiglottis. As the pharynx is used for swallowing food as well as breathing, the epiglottis ensures that air can pass into the trachea, and that food enters the esophagus.
Larynx	Also known as the voice box, the	Aside from allowing us the

	larynx is situated below the pharynx, in the anterior portion of the neck.	ability of speech, the larynx also acts as a defense mechanism. If any food passes into the esophagus when swallowing, the larynx produces a strong cough reflex.
Trachea	Also known as the wind pipe, the trachea is a tube made of cartilage rings that are lined with pseudostratified ciliated columnar epithelium.	The main respiratory function of the trachea is to provide a clear and unhindered airway for air to enter and exit the lungs. Inside the trachea, small hairs reside upon the inner walls.

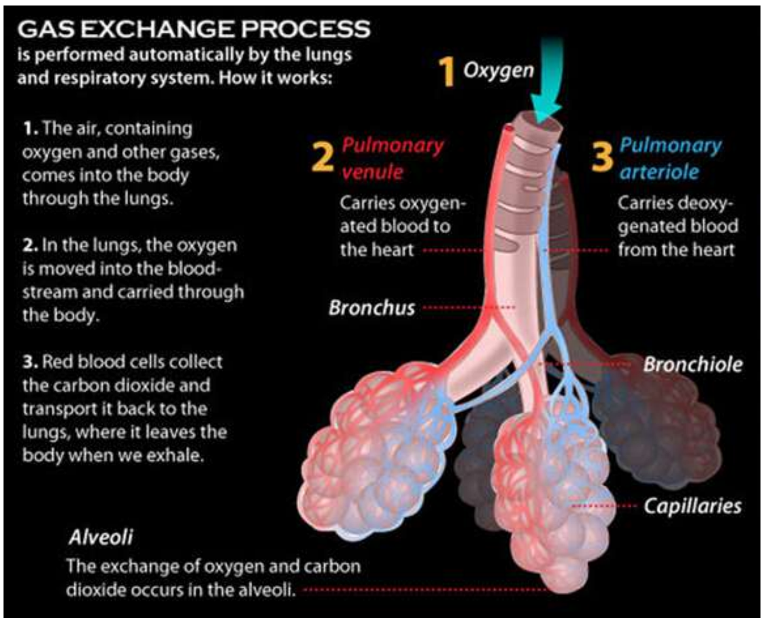
		These hairs catch dust and other contaminants from inhaled air, which are later expelled via coughing.
Bronchi	The bronchi are two tubes stemming off of the end of the trachea. Each tube is connected to a lung.	The bronchi connect the wind pipe to the lungs, allowing air from external respiratory openings to pass efficiently into the lungs. Once in the lungs, the bronchi begin to branch out into secondary, smaller bronchi, coined tertiary bronchi.

Bronchioles	Tertiary bronchi divide to even smaller, narrower tubes known as bronchioles.	Bronchioles lead to alveolar sacs, which are sacs containing alveoli.
Alveoli	Alveoli are hollow, individual cavities that are found within alveolar sacs.	Alveoli have extremely thin walls, which allows the exchange of oxygen and carbon dioxide to take place within the lungs. There are estimated to be three million alveoli in the average lung.
Diaphragm	The diaphragm is an important muscle of respiration which is situated beneath the lungs.	The diaphragm contracts to expand the space inside the thoracic cavity, whilst moving a

		few inches inferiorly into the abdominal cavity. Whilst this is happening, the intercostal muscles also contract, which moves the rip cage up and out. The contractions force air into the lungs, by creating a negative pressure through expansion.

Physiology of Gas Exchange

Anatomy of respiratory system and organ functions cannot be complete if you don't understand the transition between CO2 and O2. Once air has been inhaled, it passed through the airways until it reaches the alveoli within the lungs.Alveolus are surrounded by capillaries, through which the gasses enter and exit. Carbon dioxide enters the alveolus, where oxygen is extracted and passed back into the body. The constant blood flow prevents saturation of the blood, allowing for optimal transfer. The following picture better illustrates the process:

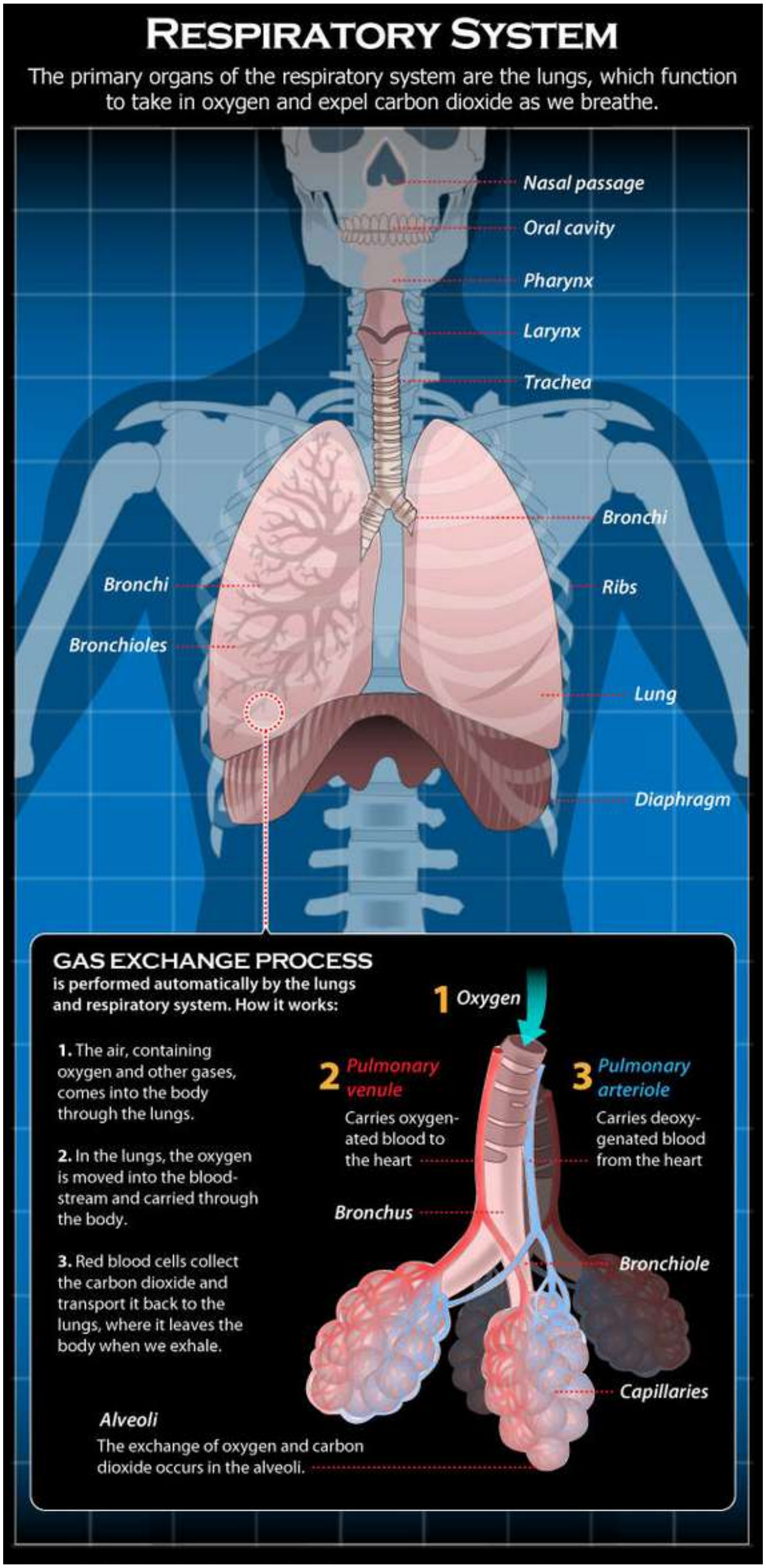


Diseases and Illnesses of the Respiratory System

With knowing the anatomy of respiratory system, you should also know that many conditions and illnesses can affect the respiratory system, some of the common problems include: -

- **Asthma** – Asthma leads to a narrowing of the airways, which can cause breathlessness and wheezing.
- **Bronchitis** – A condition that causes inflammation of the mucus lining within the one lung or both.
- **Emphysema** – A disease that affects alveoli.
- **Influenza** – An illness caused by a virus that can have a detrimental affect on one's respiratory system.

- **Laryngitis** – When one's vocal chords (larynx) become inflamed.
- **Pneumonia** – When one or both lungs become inflamed.
- **Lung cancer** – Although commonly associated with smokers, lung cancer can also affect those who do not smoke.


RESPIRATORY SYSTEM
The primary organs of the respiratory system are the lungs, which function to take in oxygen and expel carbon dioxide as we breathe.
Nasal passage
Oral cavity
Pharynx
Larynx
Trachea
Bronchi
Ribs
Bronchi
Bronchioles
Lung
Diaphragm
GAS EXCHANGE PROCESS
is performed automatically by the lungs and respiratory system. How it works:
1. The air, containing oxygen and other gases, comes into the body through the lungs.
2. In the lungs, the oxygen is moved into the bloodstream and carried through the body.
3. Red blood cells collect the carbon dioxide and transport it back to the lungs, where it leaves the body when we exhale.
1 Oxygen
2 Pulmonary venule
Carries oxygenated blood to the heart
3 Pulmonary arteriole
Carries deoxygenated blood from the heart
Bronchus
Bronchiole
Capillaries
Alveoli
The exchange of oxygen and carbon dioxide occurs in the alveoli.

Every tissue within the body requires oxygen to function. The respiratory system, which includes air passages, pulmonary vessels, the lungs, and breathing muscles, provides oxygenated blood to the body tissues and removes waste gases.

The respiratory system, which includes air passages, pulmonary vessels, the lungs, and breathing muscles, aids the body in the exchange of gases between the air and blood, and between the blood and the body's billions of cells. Most of the organs of the respiratory system help to distribute air, but only the tiny, grape-like alveoli and the alveolar ducts are responsible for actual gas exchange.

In addition to air distribution and gas exchange, the respiratory system filters, warms, and humidifies the air you breathe. Organs in the respiratory system also play a role in speech and the sense of smell.

The respiratory system also helps the body maintain homeostasis, or balance among the many elements of the body's internal environment.

The respiratory system is divided into two main components:

Upper respiratory tract: Composed of the nose, the pharynx, and the larynx, the organs of the upper respiratory tract are located outside the chest cavity.

- **Nasal cavity**: Inside the nose, the sticky mucous membrane lining the nasal cavity traps dust particles, and tiny hairs called cilia help move them to the nose to be sneezed or blown out.
- **Sinuses**: These air-filled spaces alongside the nose help make the skull lighter.
- **Pharynx**: Both food and air pass through the pharynx before reaching their appropriate destinations. The pharynx also plays a role in speech.

- **Larynx**: The larynx is essential to human speech.

Lower respiratory tract: Composed of the trachea, the lungs, and all segments of the bronchial tree (including the alveoli), the organs of the lower respiratory tract are located inside the chest cavity.

- **Trachea**: Located just below the larynx, the trachea is the main airway to the lungs.

- **Lungs**: Together the lungs form one of the body's largest organs. They're responsible for providing oxygen to capillaries and exhaling carbon dioxide.

- **Bronchi:** The bronchi branch from the trachea into each lung and create the network of intricate passages that supply the lungs with air.

- **Diaphragm**: The diaphragm is the main respiratory muscle that contracts and relaxes to allow air into the lungs.

The Respiratory System

The respiratory system is made up of organs and tissues that help you breathe. The main parts of this system are the airways, the lungs and linked blood vessels, and the muscles that enable breathing.

The Respiratory System

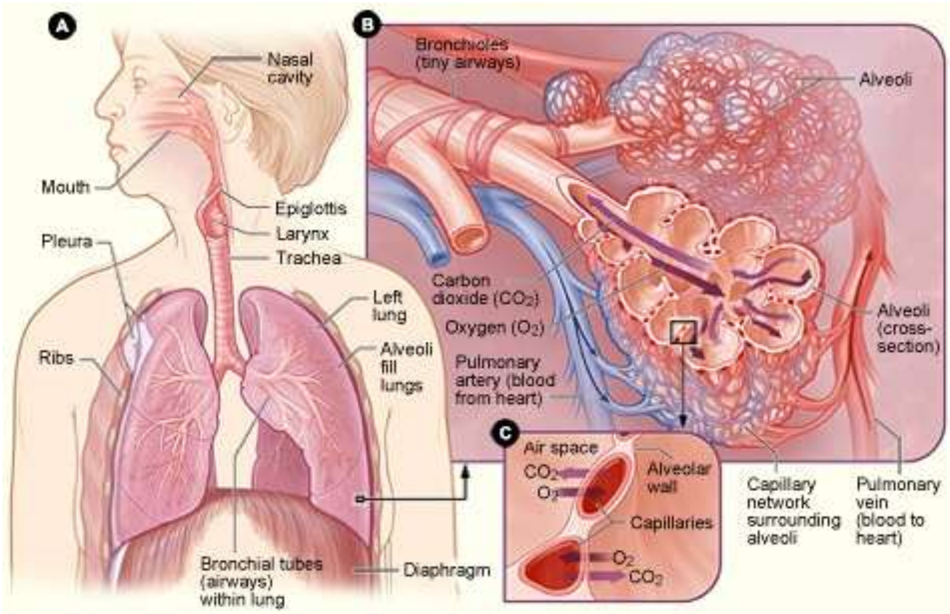


Figure A shows the location of the respiratory structures in the body. Figure B is an enlarged view of the airways, alveoli (air sacs), and capillaries (tiny blood vessels). Figure C is a closeup view of gas exchange between the capillaries and alveoli. CO2 is carbon dioxide, and O2 is oxygen.

Airways

The airways are pipes that carry oxygen-rich air to your lungs. They also carry carbon dioxide, a waste gas, out of your lungs. The airways include your:

- Nose and linked air passages (called nasal cavities)
- Mouth
- Larynx (LAR-ingks), or voice box
- Trachea (TRA-ke-ah), or windpipe
- Tubes called bronchial tubes or bronchi, and their branches

Air first enters your body through your nose or mouth, which wets and warms the air. (Cold, dry air can irritate your lungs.) The air then travels through your voice box and down your windpipe. The windpipe splits into two bronchial tubes that enter your lungs.

A thin flap of tissue called the epiglottis (ep-ih-GLOT-is) covers your windpipe when you swallow. This prevents food and drink from entering the air passages that lead to your lungs.

Except for the mouth and some parts of the nose, all of the airways have special hairs called cilia (SIL-e-ah) that are coated with sticky mucus. The cilia trap germs and other foreign particles that enter your airways when you breathe in air.

These fine hairs then sweep the particles up to the nose or mouth. From there, they're swallowed, coughed, or sneezed out of the body. Nose hairs and mouth saliva also trap particles and germs.

Lungs and Blood Vessels

Your lungs and linked blood vessels deliver oxygen to your body and remove carbon dioxide from your body. Your lungs lie on either side of your breastbone and fill the inside of your chest cavity. Your left lung is slightly smaller than your right lung to allow room for your heart.

Within the lungs, your bronchi branch into thousands of smaller, thinner tubes called bronchioles. These tubes end in bunches of tiny round air sacs called alveoli (al-VEE-uhl-eye).

Each of these air sacs is covered in a mesh of tiny blood vessels called capillaries. The capillaries connect to a network of arteries and veins that move blood through your body.

The pulmonary (PULL-mun-ary) artery and its branches deliver blood rich in carbon dioxide (and lacking in oxygen) to the capillaries that surround the air sacs. Inside the air sacs, carbon dioxide moves from the blood into the air. At the same time, oxygen moves from the air into the blood in the capillaries.

The oxygen-rich blood then travels to the heart through the pulmonary vein and its branches. The heart pumps the oxygen-rich blood out to the body. The lungs are divided into five main sections called lobes. Some people need to have a diseased lung lobe removed. However, they can still breathe well using the rest of their lung lobes.

Muscles Used for Breathing

Muscles near the lungs help expand and contract (tighten) the lungs to allow breathing. These muscles include the:

- Diaphragm (DI-ah-fram)
- Intercostals muscles
- Abdominal muscles
- Muscles in the neck and collarbone area

The diaphragm is a dome-shaped muscle located below your lungs. It separates the chest cavity from the abdominal cavity. The diaphragm is the main muscle used for breathing.

The intercostals muscles are located between your ribs. They also play a major role in helping you breathe.

Beneath your diaphragm are abdominal muscles. They help you breathe out when you're breathing fast (for example, during physical activity).

Muscles in your neck and collarbone area help you breathe in when other muscles involved in breathing don't work well, or when lung disease impairs your breathing.

Breathing In (Inhalation)

When you breathe in, or inhale, your diaphragm contracts (tightens) and moves downward. This increases the space in your chest cavity, into which your lungs expand. The intercostals muscles between your ribs also help enlarge the chest cavity. They contract to pull your rib cage both upward and outward when you inhale.

As your lungs expand, air is sucked in through your nose or mouth. The air travels down your windpipe and into your lungs. After passing through your bronchial tubes, the air finally reaches and enters the alveoli (air sacs).

Through the very thin walls of the alveoli, oxygen from the air passes to the surrounding capillaries (blood vessels). A red blood cell protein called hemoglobin helps move oxygen from the air sacs to the blood.

At the same time, carbon dioxide moves from the capillaries into the air sacs. The gas has traveled in the bloodstream from the right side of the heart through the pulmonary artery.

Oxygen-rich blood from the lungs is carried through a network of capillaries to the pulmonary vein. This vein delivers the oxygen-rich blood to the left side of the heart. The left side of the heart pumps the blood to the rest of the body. There, the oxygen in the blood moves from blood vessels into surrounding tissues.

Breathing Out (Exhalation)

When you breathe out, or exhale, your diaphragm relaxes and moves upward into the chest cavity. The intercostal muscles between the ribs also relax to reduce the space in the chest cavity.

As the space in the chest cavity gets smaller, air rich in carbon dioxide is forced out of your lungs and windpipe, and then out of your nose or mouth.

Breathing out requires no effort from your body unless you have a lung disease or are doing physical activity. When you're physically active, your abdominal muscles contract and push your diaphragm against your lungs even more than usual. This rapidly pushes air out of your lungs.

The act of breathing

The act of breathing has two stages – inhalation and exhalation

- Inhalation – the intake of air into the lungs through expansion of chest volume.
- Exhalation – the expulsion of air from the lungs through contraction of chest volume.

Inhalation and exhalation involves **muscles**:

1. **Rib muscles** = the muscles between the ribs in the chest.

2.**Diaphragm muscle**

Muscle movement – the **diaphragm and rib muscles** are constantly contracting and relaxing (approximately 16 times per minute), thus causing the chest cavity to increase and decrease.

During inhalation – the muscles contract:

Contraction of the diaphragm muscle – causes the diaphragm to flatten, thus enlarging the chest cavity.
Contraction of the rib muscles – causes the ribs to rise, thus increasing the chest volume.

The chest cavity expands, thus reducing air pressure and causing air to be passively drawn into the lungs. Air passes from the high pressure outside the lungs to the low pressure inside the lungs.

During exhalation – the muscles relax:

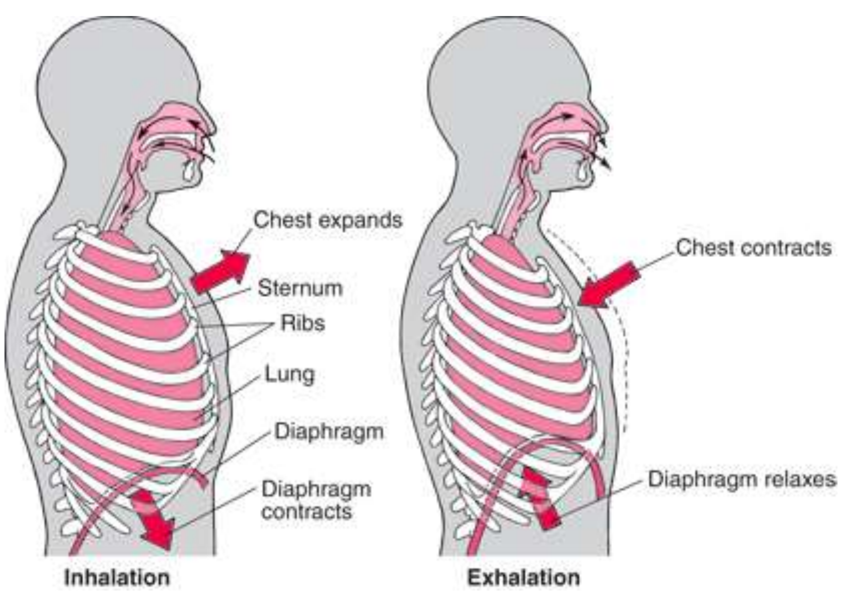
The muscles are no longer contracting, they are relaxed.

The diaphragm curves and rises, the ribs descend – and chest volume decreases.

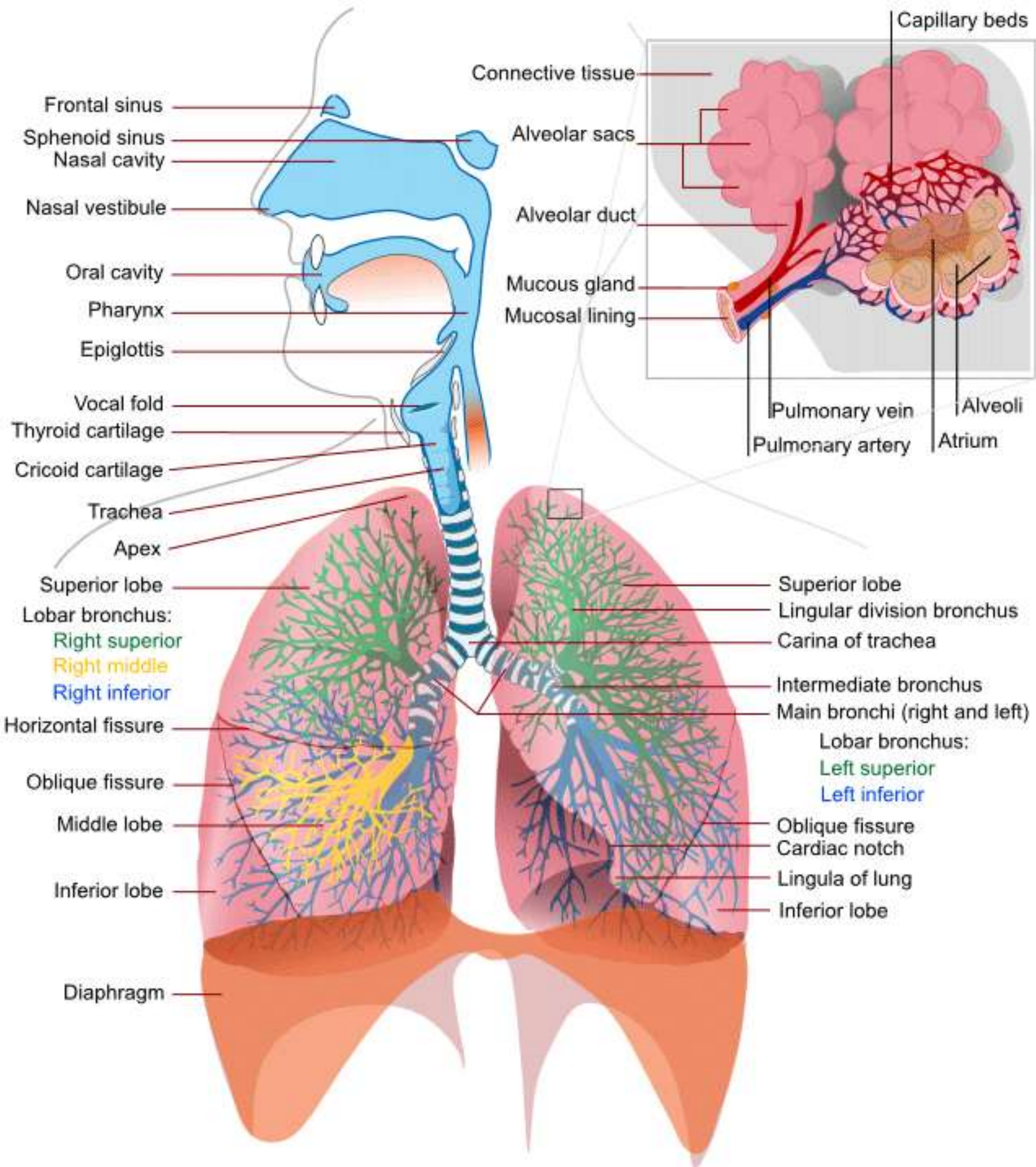
The chest cavity contracts thus increasing air pressure and causing the air in the lungs to be expelled through the upper respiratory tract. Exhalation, too, is passive. Air passes from the high pressure in the lungs to the low pressure in the upper respiratory tract.

Inhalation and exhalation are involuntary and therefore their control requires an effort.

The act of breathing – Illustration & Animation



The respiratory system- Illustration



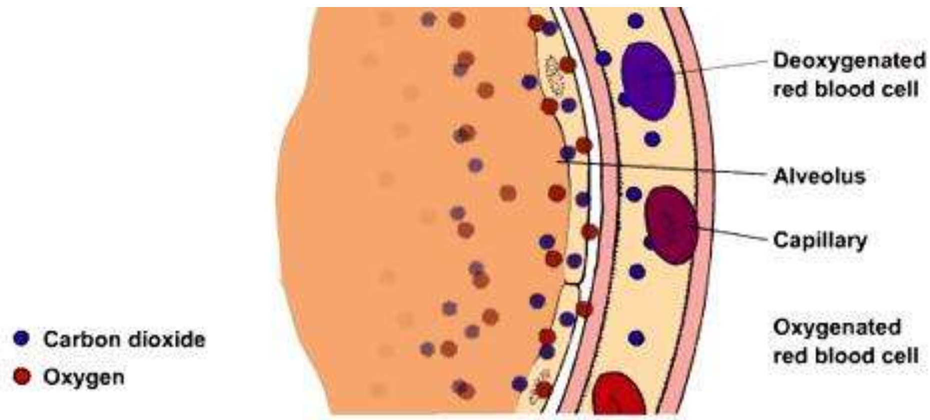
Lungs and their structure and exchange of gases in the lungs:

Gas exchange is the delivery of **oxygen** from the lungs to the bloodstream, and the elimination of carbon dioxide from the bloodstream to the lungs. It occurs in the lungs between the alveoli and a network of tiny blood vessels called capillaries, which are located in the walls of the alveoli.

Respiratory gases—**oxygen** and **carbon dioxide**—move between the**air** and the blood across the respiratory exchange surfaces in the lungs. The structure of the human lung provides an immense internal surface that facilitates gas exchange between the alveoli and the blood in the pulmonary capillaries.

The primary function of the respiratory system is to exchange oxygen and carbon dioxide. Inhaled oxygen enters the lungs and reaches the alveoli. The layers of cells lining the alveoli and the surrounding capillaries are each only one cell thick and are in very close contact with each other. This barrier between air and blood averages about 1 micron ($^{1}/_{10,000}$ of a centimeter, or 0.000039 inch) in thickness. Oxygen passes quickly through this air-blood barrier into the blood in the capillaries. Similarly, carbon dioxide passes from the blood into the alveoli and is then exhaled.

Oxygenated blood travels from the lungs through the pulmonary veins and into the left side of the heart, which pumps the blood to the rest of the body (see Function of the Heart). Oxygen-deficient, carbon dioxide-rich blood returns to the right side of the heart through two large veins, the superior vena cava and the inferior vena cava. Then the blood is pumped through the pulmonary artery to the lungs, where it picks up oxygen and releases carbon dioxide.

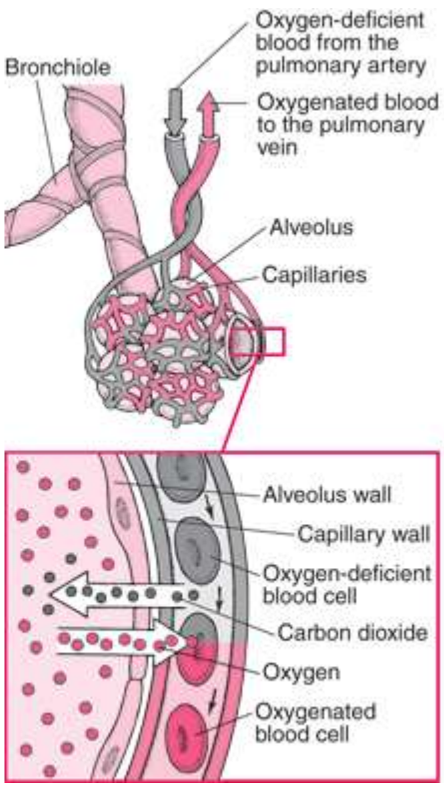


Gas Exchange between Alveoli and Capillaries

To support the exchange of oxygen and carbon dioxide, about 5 to 8 liters (about 1.3 to 2.1 gallons) of air per minute are brought in and out of the lungs, and about three tenths of a liter of oxygen is transferred from the alveoli to the blood each minute, even when the person is at rest. At the same time, a similar volume of carbon dioxide moves from the blood to the alveoli and is exhaled. During exercise, it is possible to breathe in and out more than 100 liters (about 26 gallons) of air per minute and extract 3 liters (a little less than 1 gallon) of oxygen from this air per minute. The rate at which oxygen is used by the body is one measure of the rate of energy expended by the body. Breathing in and out is accomplished by respiratory muscles.

Gas Exchange between Alveolar Spaces and Capillaries

The function of the respiratory system is to exchange two gases: oxygen and carbon dioxic The exchange takes place in the millions of alveoli in the lungs and the capillaries th envelop them. As shown below, inhaled oxygen moves from the alveoli to the blood in t capillaries, and carbon dioxide moves from the blood in the capillaries to the air in t alveoli.



Three processes are essential for the transfer of oxygen from the outside air to the blood flowing through the lungs: ventilation, diffusion, and perfusion.

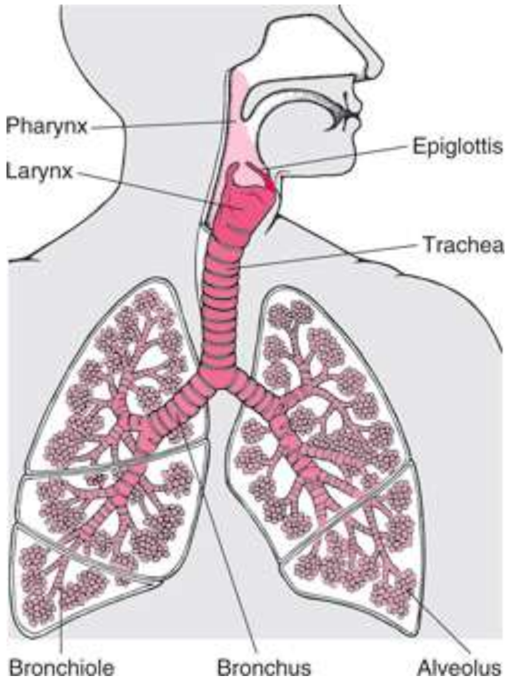
- Ventilation is the process by which air moves in and out of the lungs.
- Diffusion is the spontaneous movement of gases, without the use of any energy or effort by the body, between the gas in the alveoli and the blood in the capillaries in the lungs.
- Perfusion is the process by which the cardiovascular system pumps blood throughout the lungs.

The body's circulation is an essential link between the atmosphere, which contains oxygen, and the cells of the body, which consume oxygen. For example, the delivery of oxygen to the muscle cells throughout the body depends not only on the lungs but also on the ability of the blood to carry oxygen and on the ability of the circulation to transport blood to muscle.

The respiratory system starts at the nose and mouth and continues through the airways and the lungs. Air enters the respiratory system through the nose and mouth and passes down the throat (pharynx) and through the voice box, or larynx. The entrance to the larynx is covered by a small flap of tissue (epiglottis) that automatically closes during swallowing, thus preventing food or drink from entering the airways.

The largest airway is the windpipe (trachea), which branches into two smaller airways: the left and right bronchi, which lead to the two lungs. Each lung is divided into sections (lobes): three in the right lung and two in the left lung. The left lung is a little smaller than the right lung because it shares space in the left side of the chest with the heart.

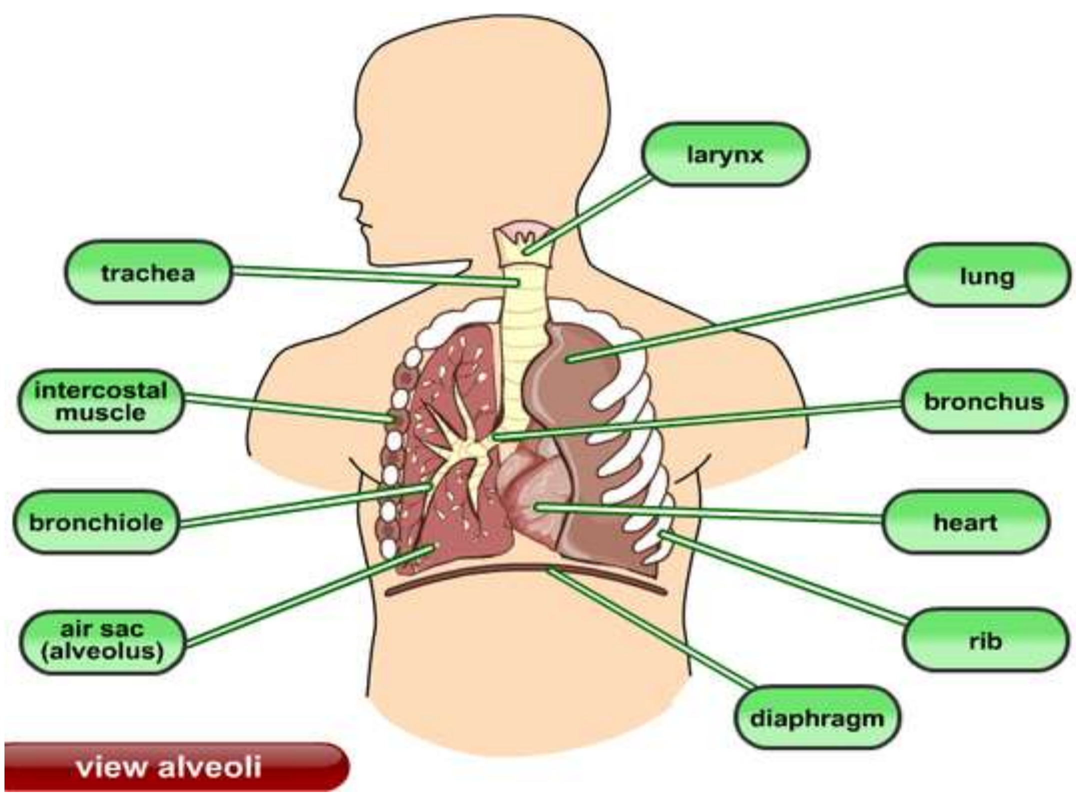
Inside the Lungs and Airways



The bronchi themselves branch many times into smaller airways, ending in the narrowest airways (bronchioles), which are as small as one half of a millimeter across. The airways resemble an upside-down tree, which is why this part of the respiratory system is often called the bronchial tree. Large airways are held open by semiflexible, fibrous connective tissue called cartilage. Smaller airways are supported by the lung tissue that surrounds and is attached to them. The walls of the smaller airways have a thin, circular layer of smooth muscle. The airway muscle can dilate or constrict, thus changing airway size.

At the end of each bronchiole are thousands of small air sacs (alveoli). Together, the millions of alveoli of the lungs form a surface of more than 100 square meters. Within the alveolar walls is a dense network of tiny blood vessels called capillaries. The extremely thin barrier between air and capillaries allows oxygen to move from the alveoli into the blood and allows carbon dioxide to move from the blood in the capillaries into the air in the alveoli.

The pleura are a slippery membrane that covers the lungs as well as the inside of the chest wall. It allows the lungs to move smoothly during breathing and as the person moves. Normally, the two layers of the pleura have only a small amount of lubricating fluid between them. The two layers glide smoothly over each other as the lungs change size and shape.



The respiratory airways include the respiratory apertures (mouth and nose), the trachea and a branching system of long, flexible tubes (bronchi) that branch of to shorter and narrower tubes (broncheoli) until they end in sacs called the pulmonary alveoli.

The lungs encompass the entire system of tubes branching out from the main bronchi to the alveoli.

Measuring the functioning of the lungs is a medical tool for diagnosing problems in the respiratory system.

Air volume (in liters) – lung capacity

- **Maximum lung volume** is known as TLC (total lung capacity). It can be obtained by maximum strenuous inhalation.

  The maximum lung volume of a healthy adult is up to 5-6 liters. In children the maximum lung volume is up to 2-3 liters, depending on age. In infants it is up to 600-1000 milliliters.

  Note! Differences in lung volume can only be caused by gender, age, and height.

- **Essential air volume** is the maximum volume utilized by the lungs for inhalation, also known as VC (vital capacity).

- **Residual volume** (RV) is the volume of air remaining in the lungs after strenuous exhalation when the lungs feel completely empty. Residual volume prevents the broncheoli and the alveoli from sticking together. Residual volume is approximately 1.5 liters (adults).

- The differential between total lung capacity and residual volume is the **maximal volume utilized by the lungs in order to breath. It is**

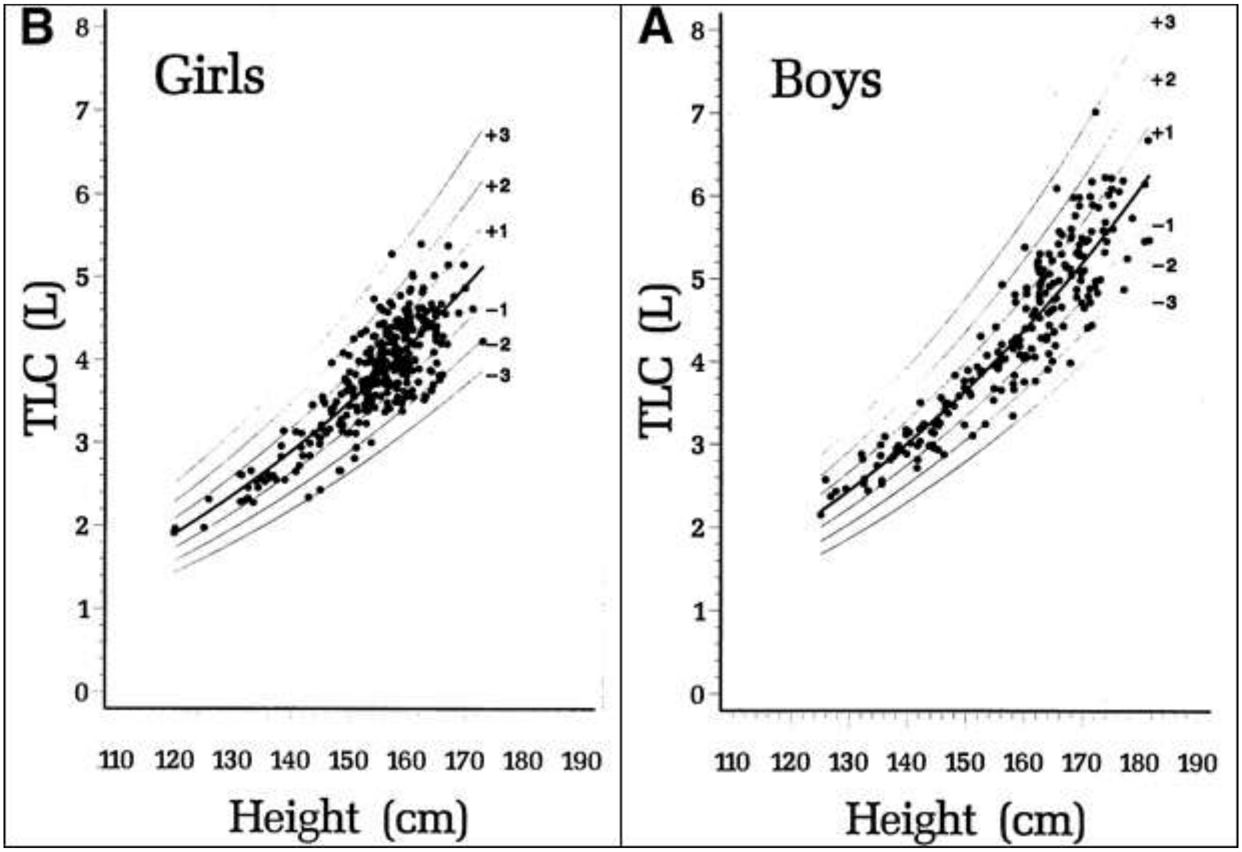
known as vital capacity(VC). In an adult, the VC is between 3.5 and 4.5 liters.

- **Tidal Volume** or VT is the volume of air displaced between normal inspiration and expiration. In a healthy adult the tidal volume is approximately 500 milliliters.

Rate of airflow through the respiratory airways (into and out of the lungs).This measures the effectiveness of airflow.

Efficiency of diffusion of oxygen from the pulmonary alveoli into the blood (not dealt with in this unit).

TLC (total lung capacity) of children



Examining lung function

The most common, accessible and efficient method of measuring lung function is by means of **a spirometer**. Its purpose is to diagnose obstructive diseases of the respiratory system. It produces a diagram (graphic depiction) of the volume of air expired in a given time (liter/minute)

The spirometer shows the rate at which air is expelled from the lungs. It measures the total lung capacity up to the residual volume (this test does not show the rate at which oxygen is absorbed).

If the airways are blocked the rate of the airflow of the lungs decreases. This will show on the diagram and thus indicate that there is a problem in the airways.

The most common obstruction stems from excessive phlegm, or from swelling of the inner wall of the air ways.

The most common problem of blockage of the air ways is asthma. people suffering from asthma it take longer to empty the lungs than healthy people. For example, during the first second of exhalation, only half of the vital air capacity in their lungs is expelled as opposed to 90% in healthy people. The rest is exhaled much later.

A spirometer examination takes only a few seconds. It is completely safe but there is a need for the patient to cooperate in order to obtain accurate results.

Stages of the examination:

1. The patient is asked to inhale as deeply as possible.
2. The patient is asked to exhale strenuously into the spirometer.
3. The patient is asked to continue to expel air for a few seconds, despite the strong urge to breathe in.
4. The test is repeated twice or three times.

Respiratory rate

Children in the upper classes of elementary school breathe about 20 times per minute.

Every breath causes an inhalation of approximately 7 milliliters of air volume per kilogram of body weight.

A child who weighs 30 kilos inhales approximately 210 milliliters of air volume (210X30). In other words, in the duration of a minute some 4200 milliliters of air volume enters and be expelled from the lungs.

Athletes breathe slightly deeper and slower. With every breath they inhale approximately 10 milliliters of air per kilogram. Thus an athletic child who weighs 30 kilos will only breathe 15 times in the duration space of a minute. Each inhalation will require some 300 milliliters of air volume. In the space of a minute 4500 milliliters of air volume will enter and be expelled from the his lungs. We can deduce from this that athletes ventilate their airways in a much more efficient way.

When we are under strain we breathe faster and more deeply. Since the lungs contain a reserve of air, we do not become tired because lack of air (oxygen) is causing respiratory restriction, but because of strain and tiredness in our respiratory and heart muscles.

When we are under emotional stress (before an exam, in distress, or feeling very frightened) we breathe faster, but our breathing is shallower. For example, under stress we inhale 30 times per minute but at a rate of only 4 milliliters per kilo. In other words, overall only 3600 milliliters per minute are passing through our airways, so we feel “short of breath.”

During severe asthma attacks, the breathing of asthma patients is shallower and at a higher rate. Their breathing is thus not very efficient.

nasal cavity: Contains nasal septum, turbinates, and cilia.

nasal septum: Divides nasal cavities into right and left sides.

Turbinates: Bones that protrude into the nasal cavity- they increase surface area for filtering dust and dirt particles by the mucous membrane.

Cilia: Nose hairs, trap larger dirt particles.

Sinuses: Cavities in the skull, ducts connect them to the nasal cavity, lined with mucous membrane to warm and moisten the air. Give resonance to voice.

types of sinuses: Frontal, maxillary, ethmoid, and sphenoid.

Pharynx: Throat. Common passageway for air and food. 5" long.

Epiglottis: When food is swallowed, this closes over the opening to the larnyx, preventing food from entering the lungs.

Larynx: Voice box. Triangular chamber below pharynx. "Adam's Apple".

Glottis: Vocal cords within the larynx.

Trachea: Windpipe. 4.5" long. Walls are alternate bands of membrane and c-shaped rings of hyaline cartilage to keep it open. Lined with ciliated mucous membrane. Coughing and expectoration gets rid of dust-laden mucous.

Bronchi: Similar to trachea with ciliated mucous membrane and hyaline cartilage. Lower end of trachea divides into right and left this.

bronchial tubes: Cartilaginous plates (instead of c-shaped rings of trachea).

Bronchioles: Thinner walls of smooth muscle, lined with ciliated epithelium. Subdivision of bronci. At the end, alveolar duct and cluster of alveoli.

Alveoli: Composed of single layer of epithelial tissue. Inner surfaces covered with surfactant to keep from collapsing. Each surrounded by capillaries. Oxygen and carbon dioxide exchange takes place between these and capillaries.

Lungs: Fill thoracic cavity. Tissue is porous and spongy- it floats.

Apex:Upper part of lung.

Base: Lower part of lung.

right lung: Larger and shorter (displaced by liver) and has three lobes.

left lung: Smaller (displaced by heart) and has two lobes.

Pleura: Thin, moist, slippery membrane that covers lungs. Double-walled sac. Space is pleural cavity- filled with pleural fluid to prevent friciton.

functions of the respiratory system: Respiration (external, internal, and cellular). Production of sound (vocal cords). Pulmonary venilation. Inspiration (intercostal muscles lift ribs outward, sternum rises and the diaphragm contracts and moves downward- this increases the volume of the lungs and the air rushes in).

pulmonary ventilation:Breathing.

respiratory movement: 1 inspiration and 1 expiration= 1 respiration. Normal adult= 14-20 respirations per minute. Increases with exercise, body temperature, and certain diseases. Age (newborn= 40-60 per minute). Sleep= respirations go down. Emotion can bring respirations up or down.

Coughing: Deep breath followed by forceful expulsion of air to clean lower respiratory tract.

Hiccups: Spasm of diaphragm and spasmodic closure of the glottis- irritation to diaphragm or phrenic nerve.

Sneezing: Air forced through nose to clear respiratory tract.

Yawning: Deep prolonged breath that fills the lungs, increases oxygen within the blood.

neural factors of breathing control: Respiratory center located in medulla oblongata (in the brain). Increase in CO_2 and decrease in O_2 in the blood will trigger respiratory center.

phrenic nerve: Stimulates the diaphragm.

chemical factors of breathing control: Depends on the levels of CO_2 in the blood. Chemoreceptors in aorta and carotid arteries sensitive to the amount of blood oxygen.

Diseases of the respiratory system

Diseases and conditions of the respiratory system fall into two categories: Viruses such as influenza, bacterial pneumonia and the newenterovirus respiratory virus that has been diagnosed in children; and chronic diseases, such as asthma and chronic obstructive pulmonary disease (COPD). According to Dr. Neal Chaisson, who practices pulmonary medicine at the Cleveland Clinic, there is not much that can be done for viral infections but to let them run their course. "Antibiotics are not effective in treating viruses and the best thing to do is just rest," he said.

COPD is the intersection of three related conditions — chronic bronchitis, chronic asthma and emphysema, Chaisson told Live Science. It is a progressive disease that makes it increasingly difficult for sufferers to breath.

Asthma is a chronic inflammation of the lung airways that causes coughing, wheezing, chest tightness or shortness of breath, according to Tonya Winders, president of the Allergy & Asthma Network**.** These signs and symptoms may be worse when a person is exposed to their triggers, which can include air pollution, tobacco smoke, factory fumes, cleaning solvents, infections, pollens, foods, cold air, exercise, chemicals and medications.

Lung cancer is often associated with smoking, but the disease can affect non-smokers as well. Every year, about 16,000 to 24,000 Americans die of lung cancer, even though they have never smoked, according to the American. Like all cancers, lung cancer is caused by the uncontrolled growth of abnormal cells.

Mechanism of respiration (internal and external respiration)

Breathing: everyone does it, but how does it work? Most people tend to equate breathing with respiration, assuming they are one and the same, but really the process of respiration is a much longer, more complicated system, of which breathing is just one of its many steps. There are also two different types of respiration: cellular and physiological, the latter of which concerns the process of breathing and the respiratory system.

In this guide, we'll cover physiological respiration, and touch a bit on cellular respiration and its two types: aerobic and anaerobic. For some more helpful background information, **consider this introduction to biology course**.

What is Respiration?

There are two types of respiration: cellular and physiological. Before we get into either, **you might want to consider this course on medical terminology** or **this course on the principles of medical language**, both of which should make understanding the processes described here much easier.

- **Cellular Respiration**

The process of converting molecules into energy through oxidization. This is the opposite of photosynthesis, the biochemical process used by plants and some types of bacteria to convert light energy into chemical energy. **Learn more about photosynthesis in this guide**.

In terms of cellular respiration, there are two types: aerobic and anaerobic. In short, the process of aerobic respiration requires oxygen, while the process of anaerobic respiration does not require oxygen. **Learn a bit more about both aerobic and anaerobic respiration in this guide**.

- **Physiological Respiration**

The process involving absorption of oxygen in the air into the cells of an organism, with the output of carbon dioxide back into the environment. It is a cycle between the organisms that breath oxygen and the organisms that breath carbon dioxide.

There are two types of physiological respiration in animals: internal respiration, and external respiration. Internal respiration is the process of cells in the body exchanging gases, while external respiration is the process of respiration that actually takes place within respiratory organs like the lungs. This is the actual exchange of oxygen and carbon dioxide between an organism and its environment, which involves the process of breathing directly.

It’s important to work out and learn proper breathing techniques to maintain a strong cardiovascular and respiratory system.

Process of Respiration: Physiological

For humans and other oxygen-breathing vertebrates, the process of respiration takes place within the lungs, driven by a series of mechanics called inhalation and exhalation. These are the biological mechanisms that make up breathing. We breathe in to take in oxygen, and breathe out to expel carbon dioxide! There’s more involved with the process of respiration than just the lungs, though. The entire process uses the nasal cavity, the mouth, the larynx, the trachea, and the bronchial tubes of the lungs as well.

- **External Respiration**

To breathe in and breathe out, we use our intercostals muscles, the muscle group that lies between our ribs. When we breathe in through the nose or mouth, these intercostals muscles contract, our sternum moves up and out along with our ribs, and our diaphragm flattens. The diaphragm is a sheet of muscle that lies across the bottom of the rib cage, and it is vital for proper respiration. When the diaphragm contracts, this allows the volume in our thoracic cavity to expand, thus reducing pressure and enabling us to draw air into our lungs. With the help of our diaphragm and thoracic cavity, our body creates a literal suction.

Similarly, when we exhale, our intercostals muscles and our diaphragm relax. This causes the volume of the thoracic cavity to decrease and the pressure inside to increase, which expels the air in what is called an exhalation.

- **Internal Respiration**

What is actually happening inside the body between the inhale and the exhale? That's where internal respiration comes in. Internal respiration occurs after and during the process of external respiration, and it's when the gases in the air we've drawn into our lungs can be sorted out, the oxygen absorbed in our blood and the carbon dioxide removed.

This happens because our heart is pumping oxygen-low blood through the pulmonary arteries and into the lungs. At the ends of the pulmonary arteries are small blood vessels called capillaries, which wrap like a net around the alveoli. The alveoli is where our bronchial tubes transport the air we inhale. They are the round, clustered, and sac-like tips of the respiratory tree where gas exchange occurs.

Inside the alveoli, the oxygen rich air we've inhaled is pumped into the red blood cells located in the surrounding capillaries, enriching the blood with much needed oxygen. In exchange, the red blood cells expel the carbon dioxide they're carrying into the alveoli.

Carbon dioxide is a waste product created through the process of metabolism, and too much of it in our blood can cause harm to our body. It can raise the levels of acidity in your blood, which is damaging to your heart, and even cause suffocation! When you hold your breath by inhaling and then not immediately exhaling, the reason you begin to feel light-headed is not actually due to the sudden lack of oxygen intake, but the excess of carbon dioxide built up in your body. Of course, both are just as important, **so make sure to practice proper breathing techniques**!

Once the air in your alveoli are enriched with carbon dioxide from the newly oxygen riched red blood cells, this air travels back up the bronchial tubes and out the nose or mouth, in a process called exhalation. At the same time, the pulmonary veins transport the oxygen rich blood back to the heart to be distributed throughout the body.

There is a big difference between external and internal respiration. External respiration is basically the transfer of gas between respiratory organs such as lungs and the outer environment. It takes place prior to internal respiration. Internal respiration is the transfer of gas between the blood and cells.

External respiration also known as breathing refers to a process of inhaling oxygen from the air into the lungs and expelling carbon dioxide from the lungs to the air. Exchange of gases both in and out of the blood occurs simultaneously. External respiration is a physical process during which oxygen is taken up by capillaries of lung alveoli and carbon dioxide is released from blood.

Internal respiration or tissue respiration/cellular respiration refers to a metabolic process in which oxygen is released to tissues or living cells and carbon dioxide is absorbed by the blood. Once inside the cell the oxygen is used for producing energy in the form of ATP or adenosine triphosphate.

Lung capacity: The inspiratory capacity plus the functional residual capacity; the volume of air contained in the lungs at the end of a maximal inspiration; also equals vital capacity plus residual volume.

The average total lung capacity of an adult human male is about six liters of air, but only a small amount of this capacity is used during normal breathing. Tidal breathing is normal, resting breathing; the tidal volume is the volume of air that is inhaled or exhaled in a single such breath.

The lung capacities are measurements of two or more volumes. The vital capacity (VC) measures the maximum amount of air that can be inhaled or exhaled during a respiratory cycle. It is the sum of the expiratory reserve volume, tidal volume, and inspiratory reserve volume.

Lung volumes and **lung capacities** refer to the volume of air associated with different phases of the respiratory cycle. Lung volumes are directly measured; Lung capacities are inferred from lung volumes. The average total lung capacity of an adult human male is about 6 liters of air, but only a small amount of this capacity is used during normal breathing.

Tidal breathing is normal, resting breathing; the tidal volume is the volume of air that is inhaled or exhaled in only a single such breath.

The average human respiratory rate is 30-60 breaths per minute at birth, decreasing to 12-20 breaths per minute in adults.

A person who is born and lives at sea level will develop a slightly smaller lung capacity than a person who spends their life at a high altitude. This is because the partial pressure of oxygen is lower at higher altitude which, as a result means that oxygen less readily diffuses into the bloodstream. In response to higher altitude, the body's diffusing capacity increases in order to process more air.

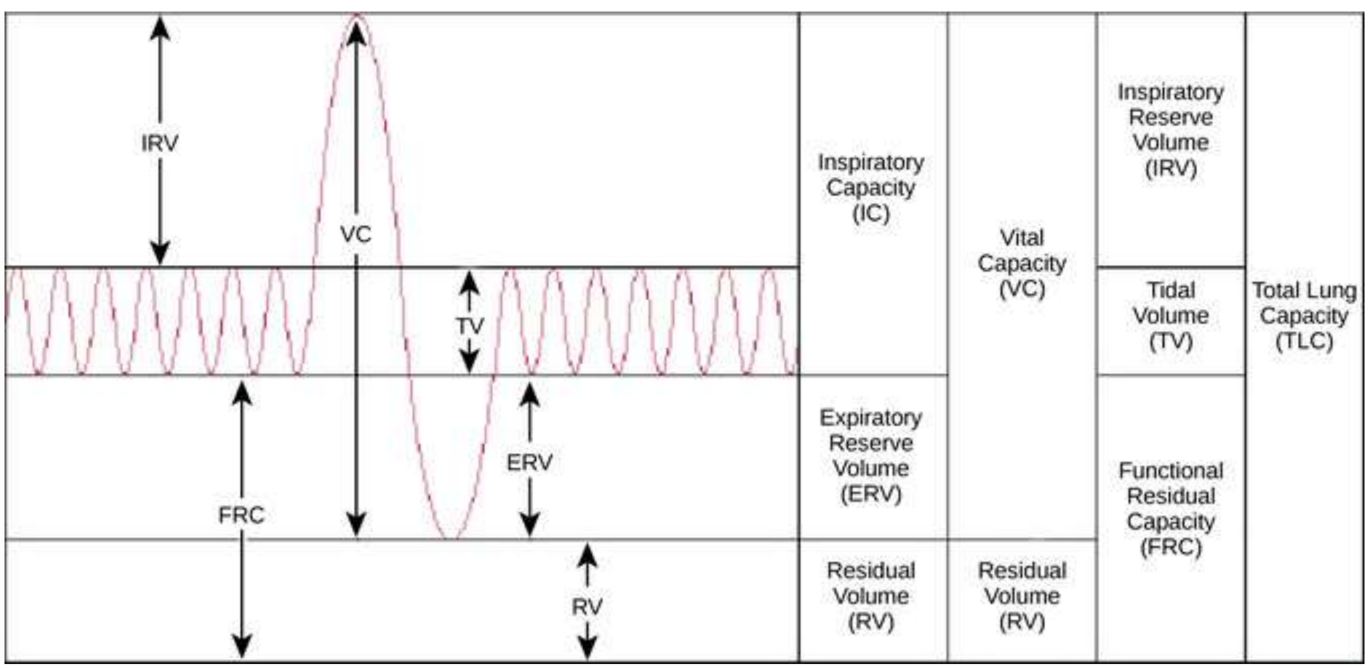
When someone living at or near sea level travels to locations at high altitudes (e.g., the Andes; Denver, Colorado; Tibet; the Himalayas) that person can develop a condition called altitude sickness because their lungs remove adequate amounts of carbon dioxide but they do not take in enough oxygen. (In normal individuals, carbon dioxide is the primary determinant of respiratory drive.)

Specific changes in lung volumes also occur during pregnancy. Functional residual capacity drops 18–20%, typically falling from 1.7 to 1.35 liters, due to the compression of the diaphragm by the uterus. The compression also causes a decreased total lung capacity (TLC) by 5% and decreased expiratory reserve volume by 20%.Tidal volume increases by 30–40%, from 0.5 to 0.7 liters, and minute ventilation by 30–40% giving an increase in pulmonary ventilation. This is necessary to meet the increased oxygen requirement of the body, which reaches 50 mL/min, 20 mL of which goes to reproductive tissues. Overall, the net change in maximum breathing capacity is zero.

Lung Volumes and Capacities

Different animals exhibit different lung capacities based on their activities. For example, cheetahs have evolved a much higher lung capacity than humans in order to provide oxygen to all the muscles in the body, allowing them to run very fast. Elephants also have a high lung capacity due to their large body and their need to take up oxygen in accordance with their body size.

Human lung size is determined by genetics, gender, and height. At maximal capacity, an average lung can hold almost six liters of air; however, lungs do not usually operate at maximal capacity. Air in the lungs is measured in terms of lung volumes and lung capacities . Volume measures the amount of air for one function (such as inhalation or exhalation) and capacity is any two or more volumes (for example, how much can be inhaled from the end of a maximal exhalation).



Human lung volumes and capacities

The total lung capacity of the adult male is six liters. Tidal volume is the volume of air inhaled in a single, normal breath. Inspiratory capacity is the amount of air taken in during a deep breath, while residual volume is the amount of air left in the lungs after forceful respiration.

Lung Volumes

The volume in the lung can be divided into four units: tidal volume, expiratory reserve volume, inspiratory reserve volume, and residual volume. Tidal volume (TV) measures the amount of air that is inspired and expired during a normal breath. On average, this volume is around one-half liter, which is a little less than the capacity of a 20-ounce drink bottle. The expiratory reserve volume (ERV) is the additional amount of air that can be exhaled after a normal exhalation. It is the reserve amount that can be exhaled beyond what is normal. Conversely, the inspiratory reserve volume (IRV) is the additional amount of air that can be inhaled after a normal inhalation. The residual volume (RV) is the amount of air that is left after expiratory reserve volume is exhaled. The lungs are never completely empty; there is always some air left in the lungs after a maximal exhalation. If this residual volume did not exist and the lungs emptied completely, the lung tissues would stick together. The energy necessary to re-inflate the lung could be too great to overcome. Therefore, there is always some air remaining in the lungs. Residual volume is also important for preventing large fluctuations in respiratory gases (O_2 and CO_2). The residual volume is the only lung volume that cannot be measured directly because it is impossible to completely empty the lung of air. This volume can only be calculated rather than measured. .

Lung volumes are measured by a technique called spirometry. An important measurement taken during spirometry is the forced expiratory volume (FEV), which measures how much air can be forced out of the lung over a specific period, usually one second (FEV1). In addition, the forced vital capacity (FVC), which is the total amount of air that can be forcibly exhaled, is measured. The ratio of these values (FEV1/FVC ratio) is used to diagnose lung diseases including asthma, emphysema, and fibrosis. If the FEV1/FVC ratio is high, the lungs are not compliant (meaning they are stiff and unable to bend properly); the patient probably has lung fibrosis. Patients exhale most of the lung volume very quickly. Conversely, when the FEV1/FVC ratio is low, there is resistance in the lung that is characteristic of asthma. In this instance, it is difficult for the patient to get the air out of his or her lungs. It takes a long time to reach the maximal exhalation volume. In either case, breathing is difficult and complications arise.

Lung Capacities

The lung capacities are measurements of two or more volumes. The vital capacity (VC) measures the maximum amount of air that can be inhaled or exhaled during a respiratory cycle. It is the sum of the expiratory reserve volume, tidal volume, and inspiratory reserve volume. The inspiratory capacity (IC) is the amount of air that can be inhaled after the end of a normal expiration. It is, therefore, the sum of the tidal volume and inspiratory reserve volume. The functional residual capacity (FRC) includes the expiratory reserve volume and the residual volume. The FRC measures the amount of additional air that can be exhaled after a normal exhalation. The total lung capacity (TLC) is a measurement of the total amount of air that the lung can hold. It is the sum of the residual volume, expiratory reserve volume, tidal volume, and inspiratory reserve volume.

The following terms describe the various lung (respiratory) volumes:

- The tidal volume (TV),about 500 mL, is the amount of air inspired during normal, relaxed breathing.
- The inspiratory reserve volume (IRV), about 3,100 mL, is the additional air that can be forcibly inhaled after the inspiration of a normal tidal volume.
- The expiratory reserve volume (ERV), about 1,200 mL, is the additional air that can be forcibly exhaled after the expiration of a normal tidal volume.
- Residual volume (RV), about 1,200 mL, is the volume of air still remaining in the lungs after the expiratory reserve volume is exhaled.

Summing specific lung volumes produces the following lung capacities:

- The total lung capacity (TLC), about 6,000 mL, is the maximum amount of air that can fill the lungs (TLC = TV + IRV + ERV + RV).
- The vital capacity (VC), about 4,800 mL, is the total amount of air that can be expired after fully inhaling (VC = TV + IRV + ERV = approximately 80 percent TLC). The value varies according to age and body size.
- The inspiratory capacity (IC), about 3,600 mL, is the maximum amount of air that can be inspired (IC = TV + IRV).
- The functional residual capacity (FRC), about 2,400 mL, is the amount of air remaining in the lungs after a normal expiration (FRC = RV + ERV).

Some of the air in the lungs does not participate in gas exchange. Such air is located in the anatomical dead space within bronchi and bronchioles—that is, outside the alveoli.

Tidal volume: Tidal volume is the lung volume representing the normal volume of air displaced between normal inhalation and exhalation when extra effort is not applied. In a healthy, young human adult, tidal volume is approximately 500 mL per inspiration or 7 mL/kg of body mass.

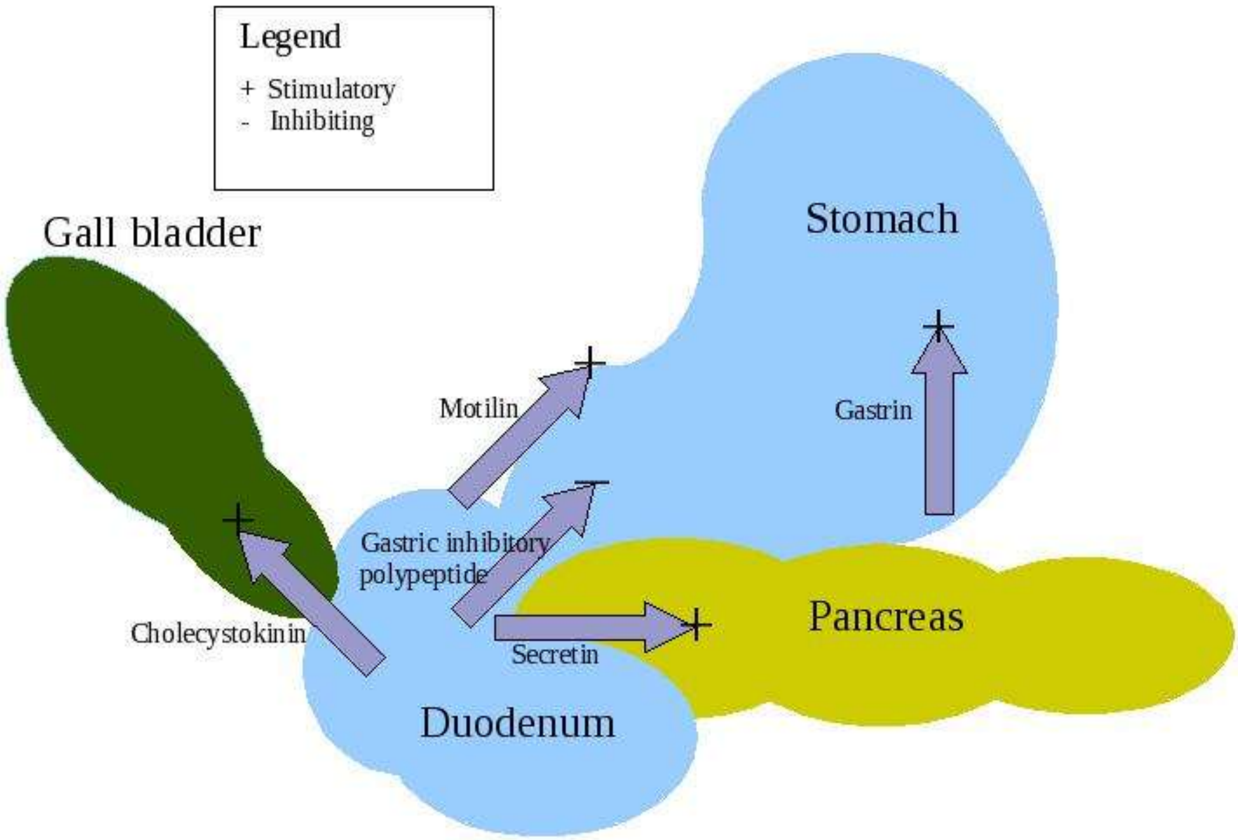
Tidal volume plays a significant role during mechanical ventilation to ensure adequate ventilation without causing trauma to the lungs. Tidal volume is measured in milliliters and ventilation volumes are estimated based on a patient's ideal body mass. Measurement of tidal volume can be affected (usually overestimated) by leaks in the breathing circuit or the introduction of additional gas, for example during the introduction of nebulizer drugs.

Ventilator-induced lung injury such as ALI/ARDS can be caused by ventilation with very large tidal volumes in normal lungs, as well as ventilation with moderate or small volumes in previously injured lungs, and research shows that the incidence of ALI increases with higher tidal volume settings in non neurologically-impaired patients.

DIGESTIVE SYSTEM

The digestive system is a group of organs working together to convert food into energy and basic nutrients to feed the entire body. Food passes through a long tube inside the body known as the alimentary canal or **the gastrointestinal** tract (GI tract).

The mouth is the beginning of the **digestive** tract. In fact, **digestion**starts here as soon as you take the first bite of a meal. Chewing breaks the food into pieces that are more easily **digested**, while saliva mixes with food to begin the **process** of breaking it down into a form your body can absorb and use. The hollow organs that make up the **GI tract** are the **mouth**, esophagus,**stomach**, small intestine, large intestine—which includes the **rectum**—and anus. Food enters the **mouth** and passes to the anus through the hollow organs of the **GI tract**. The **liver**, **pancreas**, and **gallbladder** are the solid organs of the digestive.



Digestion is **important** for breaking down food into nutrients, which the body uses for energy, growth, and cell repair. Food and drink must be changed into smaller molecules of nutrients before the blood absorbs them and carries them to cells throughout the body. The digestive tract, also known as the gastrointestinal (GI) tract, starts at the mouth, continues to the esophagus, stomach, small intestine, large intestine (commonly referred to as the colon) and rectum, and ends at the anus. The entire system — from mouth to anus — is about **30 feet** (**9 meters**) long.

The **human digestive system** consists of the gastrointestinal tract plus the **accessory organs of digestion** (the tongue, salivary, pancreas, liver, and gallbladder). In this system, the process of digestion has many stages, the first of which starts in the mouth (oral cavity). Digestion involves the breakdown of food into smaller and smaller components which can be absorbed and assimilated into the body. The secretion of saliva helps to produce a bolus which can be swallowed to pass down the esophagus and into the stomach.

Saliva also contains a catalytic enzyme called amylase which starts to act on food in the mouth. Another digestive enzyme called lingual is secreted by some of the lingual papillae on the tongue and also from serous glands in the main salivary glands. Digestion is helped by the mastication of food by the teeth and also by the muscular actions of peristalsis and segmentation contractions. Gastric juice in the stomach is essential for the continuation of digestion as is the production of mucus in the stomach.

Peristalsis is the rhythmic contraction of muscles that begins in the esophagus and continues along the wall of the stomach and the rest of the gastrointestinal tract. This initially results in the production of chyme which when fully broken down in the small intestine is absorbed as chyle into the lymphatic system. Most of the digestion of food takes place in the small intestine. Water and some minerals are reabsorbed back into the blood, in the colon of the large intestine. The waste products of digestion are defecated from the anus via the rectum.

There are several organs and other components involved in the digestion of food. The organs known as the accessory digestive glands are the liver, gall bladder and pancreas. Other components include the mouth, teeth and epiglottis.

The largest structure of the digestive system is the gastrointestinal tract (GI tract). This starts at the mouth and ends at the anus, covering a distance of about nine (9) metres. The largest part of the GI tract is the colon or large intestine. Water is absorbed here and remaining waste matter is stored prior to defecation. Most of the digestion of food takes place in the small intestine. A major digestive organ is the stomach. Within its mucosa are millions of embedded gastric glands. Their secretions are vital to the functioning of the organ. There are many specialized cells of the GI tract. These include the various cells of the gastric glands, taste cells, pancreatic duct cells,enterocytes and microfold cells.

Mouth

The mouth is the first part of the gastrointestinal tract and is equipped with several structures that begin the first processes of digestion. These include salivary glands, teeth and the tongue. The mouth consists of two regions, the vestibule and the oral cavity proper. The vestibule is the area between the teeth, lips and cheeks, and the rest is the oral cavity proper. Most of the oral cavity is lined with oral mucosa, a mucous membrane that produces a lubricating mucus, of which only a small amount is needed. Mucous membranes vary in structure in the different regions of the body but they all produce a lubricating mucus, which is either secreted by surface cells or more usually by underlying glands. The mucous membrane in the mouth continues as the thin mucosa which lines the bases of the teeth. The main component of mucus is a glycoprotein called mucin and the type secreted varies according to the region involved. Mucin is viscous, clear, and clinging. Underlying the mucous membrane in the mouth is a thin layer of smooth muscle tissue and the loose connection to the membrane gives it its great elasticity. It covers the cheeks, inner surfaces of the lips, and floor of the mouth.

The roof of the mouth is termed the palate and it separates the oral cavity from the nasal cavity. The palate is hard at the front of the mouth since the overlying mucosa is covering a plate of bone; it is softer and more pliable at the back being made of muscle and connective tissue, and it can move to swallow food and liquids. The soft palateends at the uvula. The surface of the hard palate allows for the pressure needed in eating food, to leave the nasal passage clear. The lips are the mouth's front boundary and the fauces (the passageway between the tonsils, also called the throat), mark its posterior boundary. At either side of the soft palate are the palatoglossus muscles which also reach into regions of the tongue. These muscles raise the back of the tongue and also close both sides of the fauces to enable food to be swallowed. Mucus helps in the mastication of food in its ability to soften and collect the food in the formation of the bolus.

Salivary glands

There are three pairs of main salivary glands and between 800 and 1,000 minor salivary glands, all of which mainly serve the digestive process, and also play an important role in the maintenance of dental health and general mouth lubrication, without which speech would be impossible. The main glands are all exocrine glands, secreting via ducts. All of these glands terminate in the mouth. The largest of these are the parotid glands – their secretion is mainly serous. The next pair are underneath the jaw, the submandibular glands, these produce both serous fluid and mucus. The serous fluid is produced by serous glands in these salivary glands which also produce lingual lipase. They produce about 70% of the oral cavity saliva.

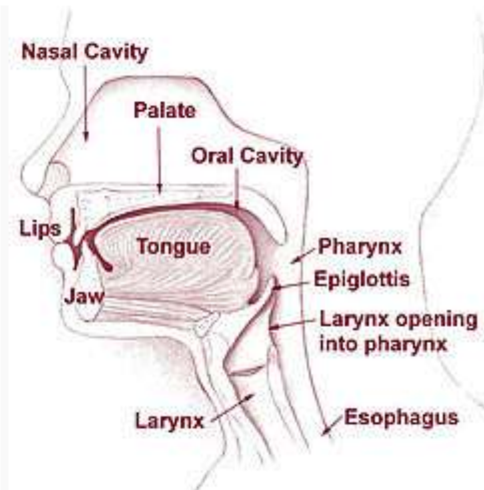
The third pair are the sublingual glands located underneath the tongue and their secretion is mainly mucous with a small percentage of saliva.

Within the oral mucosa (a mucous membrane) lining the mouth and also on the tongue and palates and mouth floor, are the minor salivary glands; their secretions are mainly mucous and are innervated by the facial nerve (the seventh cranial nerve). The glands also secreteamylase a first stage in the breakdown of food acting on the carbohydrate in the food to transform the starch content into maltose. There are other glands on the surface of the tongue that encircle taste buds on the back part of the tongue and these also produce lingual lipase.Lipase is a digestive enzyme that catalyses the hydrolysis of lipids (fats). These glands are termed Von Ebner's glands which have also been shown to have another function in the secretion of histatins which offer an early defense (outside of the immune system) against microbes in food, when it makes contact with these glands on the tongue tissue. Sensory information can stimulate the secretion of saliva providing the necessary fluid for the tongue to work with and also to ease swallowing of the food.

Saliva

Saliva functions initially in the digestive system to moisten and soften food into the formation of a bolus. The bolus is further helped by the lubrication provided by the saliva in its passage from the mouth into the oesophagus. Also of importance is the presence in saliva of the digestive enzymes amylase and lipase. Amylase starts to work on thestarch in carbohydrates, breaking it down into the simple sugars of maltose and dextrose that can be further broken down in the small intestine. Saliva in the mouth can account for 30% of this initial starch digestion. Lipase starts to work on breaking down fats. Lipase is further produced in the pancreas where it is released to continue this digestion of fats. The presence of salivary lipase is of prime importance in young babies whose pancreatic lipase has yet to be developed

As well as its role in supplying digestive enzymes, saliva has a cleansing action for the teeth and mouth. It also has an immunological role in supplying antibodies to the system, such as immunoglobulin A. This is seen to be key in preventing infections of the salivary glands, importantly that of parotitis.



Saliva also contains a glycoprotein called haptocorrin which is a binding protein to vitamin B_{12}. It binds with the vitamin in order to carry it safely through the acidic content of the stomach. When it reaches the duodenum, pancreatic enzymes break down the glycoprotein and free the vitamin which then binds with intrinsic factor

Tongue

Food enters the mouth where the first stage in the digestive process takes place, with the action of the tongue and the secretion of saliva. The tongue is a fleshy and muscular sensory organ, and the very first sensory information is received via the taste buds on its surface. If the taste is agreeable the tongue will go into action, manipulating the food in the mouth which stimulates the secretion of saliva from the salivary glands. The liquid quality of the saliva will help in the softening of the food and its enzyme content will start to break down the food whilst it is still in the mouth. The first part of the food to be broken down is the starch of carbohydrates. The tongue is attached to the floor of the mouth by a ligamentous band called the frenum and this gives it great mobility for the manipulation of food (and speech); the range of manipulation is optimally controlled by the action of several muscles and limited in its external range by the stretch of the frenum. The tongue's two sets of muscles, are four intrinsic muscles that originate in the tongue and are involved with its shaping, and four extrinsic muscles originating in bone that are involved with its movement.

Taste

Taste is a form of chemoreception that takes place in the specialised receptors of taste cells, contained in structures called taste budsin the mouth. Taste buds are mainly on the upper surface (dorsum) of the tongue. Taste perception is vital to help prevent harmful or rotten foods from being consumed. This is a function of the gustatory system where the taste buds are at the forefront. There are taste buds elsewhere in the mouth not just on the surface of the tongue. The taste buds are innervated by a branch of the facial nerve thechorda tympani, and the glossopharyngeal nerve. Taste messages are sent via these cranial nerves to the brain. The brain can distinguish between the chemical qualities of the food. The five basic tastes are referred to as those of saltiness, sourness, bitterness and sweetness, and the most recent addition of a certain savouriness termed umami. The detection of saltiness and sourness enables the control of salt and acid balance. The detection of bitterness warns of poisons – many of a plant's defences are of poisonous compounds that are bitter. Sweetness guides to those foods that will supply energy; the initial breakdown of the energy-giving carbohydrates by salivary amylase creates the taste of sweetness since simple sugars are the first result. The taste of umami is thought to signal protein-rich food. Sour tastes are acidic which is often found in bad food. The brain has to decide very quickly whether to eat the food or not. It was the findings in 1991, describing the first olfactory receptors that helped to prompt the research into taste. The olfactory receptors are located on cell surfaces in the nose which bind to chemicals enabling the detection of smells. It is assumed that signals from taste receptors work together with the signals from those in the nose, to form an idea of complex food flavours.

Teeth

Teeth are complex structures made of materials specific to them. They are made of a bone-like material called dentin, which is covered by the hardest tissue in the body—enamel. Teeth have different shapes to deal with different aspects of mastication employed in tearing and chewing pieces of food into smaller and smaller pieces. This results in a much larger surface area for the action of digestive enzymes. The teeth are named after their particular roles in the process of mastication—incisors are used for cutting or biting off pieces of food; canines, are used for tearing, premolars and molars are used for chewing and grinding. Mastication of the food with the help of saliva and mucus results in the formation of a soft bolus which can then be swallowed to make its way down the upper gastrointestinal tract to the stomach. The digestive enzymes in saliva also help in keeping the teeth clean by breaking down any lodged food particles.

Epiglottis

The epiglottis is a flap that is made of elastic cartilage and attached to the entrance of the larynx. It is covered with a mucous membrane and there are taste buds on its lingual surface which faces into the mouth. Its laryngeal surface faces into the larynx. The epiglottis functions to guard the entrance of the glottis, the opening between the vocal folds. It is normally pointed upward during breathing with its underside functioning as part of the pharynx, but during swallowing, the epiglottis folds down to a more horizontal position, with its upper side functioning as part of the pharynx. In this manner it prevents food from going into the trachea and instead directs it to the oesophagus, which is posterior. During swallowing, the backward motion of the tongue forces the epiglottis over the glottis' opening to prevent any food that is being swallowed from entering the larynx which leads to the lungs; the larynx is also pulled upwards to assist this process. Stimulation of the larynx by ingested matter produces a strong cough reflex in order to protect the lungs.

Pharynx

The pharynx is a part of the conducting zone of the respiratory system and also a part of the digestive system. It is the part of the throat immediately behind the nasal cavity at the back of the mouth and above the oesophagus and larynx.The pharynx is made up of three parts. The lower two parts– the oropharynx and the laryngopharynx are involved in the digestive system. The laryngo pharynx connects to the esophagus and it serves as a passageway for both air and food. Air enters the larynx anteriorly but anything swallowed has priority and the passage of air is temporarily blocked. The pharynx is innervated by the pharyngeal plexus of the vagus nerve Muscles in the pharynx push the food into the esophagus. The pharynx joins the esophagus at the esophageal inlet which is located behind the cricoids cartilage.

Esophagus

The **esophagus** is a muscular tube connecting the pharynx to the stomach that is part of the **upper gastrointestinal tract**. It carries swallowed masses of chewed food along its length. At the inferior end of the esophagus is a muscular ring called the lower esophageal sphincter or cardiac sphincter. The function of this sphincter is to close of the end of the esophagus and trap food in the stomach.

Stomach

The **stomach** is a muscular sac that is located on the left side of the abdominal cavity, just inferior to the **diaphragm**. In an average person, the stomach is about the size of their two fists placed next to each other. This major organ acts as a storage tank for food so that the body has time to digest large meals properly. The stomach also contains hydrochloric acid and digestive enzymes that continue the digestion of food that began in the mouth.

Small Intestine

The **small intestine** is a long, thin tube about 1 inch in diameter and about 10 feet long that is part of the **lower gastrointestinal tract**. It is located just inferior to the stomach and takes up most of the space in the abdominal cavity. The entire small intestine is coiled like a hose and the inside surface is full of many ridges and folds. These folds are used to maximize the digestion of food and absorption of nutrients. By the time food leaves the small intestine, around 90% of all nutrients have been extracted from the food that entered it.

Liver and Gallbladder

The **liver** is a roughly triangular accessory organ of the digestive system located to the right of the stomach, just inferior to the diaphragm and superior to the small intestine. The liver weighs about 3 pounds and is the second largest organ in the body. The liver has many different functions in the body, but the main function of the liver in digestion is the production of bile and its secretion into the small intestine. The **gallbladder** is a small, pear-shaped organ located just posterior to the liver. The gallbladder is used to store and recycle excess bile from the small intestine so that it can be reused for the digestion of subsequent meals.

Pancreas

The **pancreas** is a large gland located just inferior and posterior to the stomach. It is about 6 inches long and shaped like short, lumpy snake with its "head" connected to the duodenum and its "tail" pointing to the left wall of the abdominal cavity. The pancreas secretes digestive enzymes into the small intestine to complete the chemical digestion of foods.

Large Intestine

The **large intestine** is a long, thick tube about 2 ½ inches in diameter and about 5 feet long. It is located just inferior to the stomach and wraps around the superior and lateral border of the small intestine. The large intestine absorbs water and contains many symbiotic bacteria that aid in the breaking down of wastes to extract some small amounts of nutrients. Feces in the large intestine exit the body through the anal canal.

The digestive system is responsible for taking whole foods and turning them into energy and nutrients to allow the body to function, grow, and repair itself. The six primary processes of the digestive system include:

1. Ingestion of food
2. Secretion of fluids and digestive enzymes
3. Mixing and movement of food and wastes through the body
4. Digestion of food into smaller pieces
5. Absorption of nutrients
6. Excretion of wastes

Ingestion

The first function of the digestive system is ingestion, or the intake of food. The mouth is responsible for this function, as it is the orifice through which all food enters the body. The mouth and stomach are also responsible for the storage of food as it is waiting to be digested. This storage capacity allows the body to eat only a few times each day and to ingest more food than it can process at one time.

Secretion

In the course of a day, the digestive system secretes around 7 liters of fluids. These fluids include saliva, mucus, hydrochloric acid, enzymes, and bile. Saliva moistens dry food and contains salivary amylase, a digestive enzyme that begins the digestion of carbohydrates. Mucus serves as a protective barrier and lubricant inside of the GI tract. Hydrochloric acid helps to digest food chemically and protects the body by killing bacteria present in our food. Enzymes are like tiny biochemical machines that disassemble large macromolecules like **proteins, carbohydrates, and lipids** into their smaller components. Finally, bile is used to emulsify large masses of lipids into tiny globules for easy digestion.

Mixing and Movement

The digestive system uses 3 main processes to move and mix food:

- *Swallowing*. Swallowing is the process of using smooth and skeletal muscles in the mouth, tongue, and pharynx to push food out of the mouth, through the pharynx, and into the esophagus.
- *Peristalsis*. Peristalsis is a muscular wave that travels the length of the GI tract, moving partially digested food a short distance down the tract. It takes many waves of peristalsis for food to travel from the esophagus, through the stomach and **intestines**, and reach the end of the GI tract.
- *Segmentation*. Segmentation occurs only in the small intestine as short segments of intestine contract like hands squeezing a toothpaste tube. Segmentation helps to increase the absorption of nutrients by mixing food and increasing its contact with the walls of the intestine.

Digestion

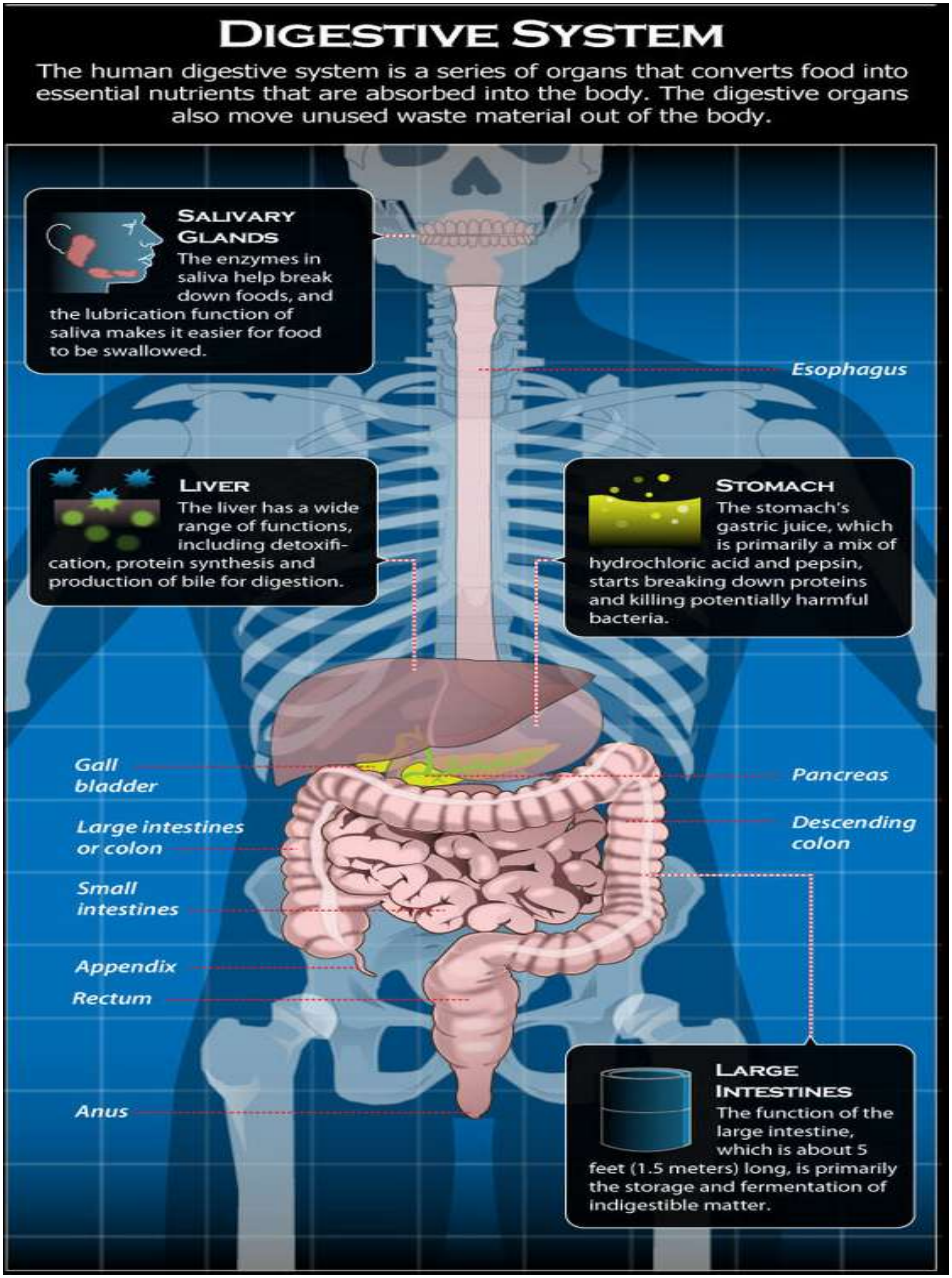
Digestion is the process of turning large pieces of food into its component chemicals. Mechanical digestion is the physical breakdown of large pieces of food into smaller pieces. This mode of digestion begins with the chewing of food by the teeth and is continued through the muscular mixing of food by the stomach and intestines. Bile produced by the liver is also used to mechanically break fats into smaller globules. While food is being mechanically digested it is also being chemically digested as larger and more complex molecules are being broken down into smaller molecules that are easier to absorb. Chemical digestion begins in the mouth with salivary amylase in saliva splitting complex carbohydrates into simple carbohydrates. The enzymes and acid in the stomach continue chemical digestion, but the bulk of chemical digestion takes place in the small intestine thanks to the action of the pancreas. The pancreas secretes an incredibly strong digestive cocktail known as pancreatic juice, which is capable of digesting lipids, carbohydrates, proteins and nucleic acids. By the time food has left the **duodenum**, it has been reduced to its chemical building blocks—fatty acids, amino acids, monosaccharides, and nucleotides.

Absorption

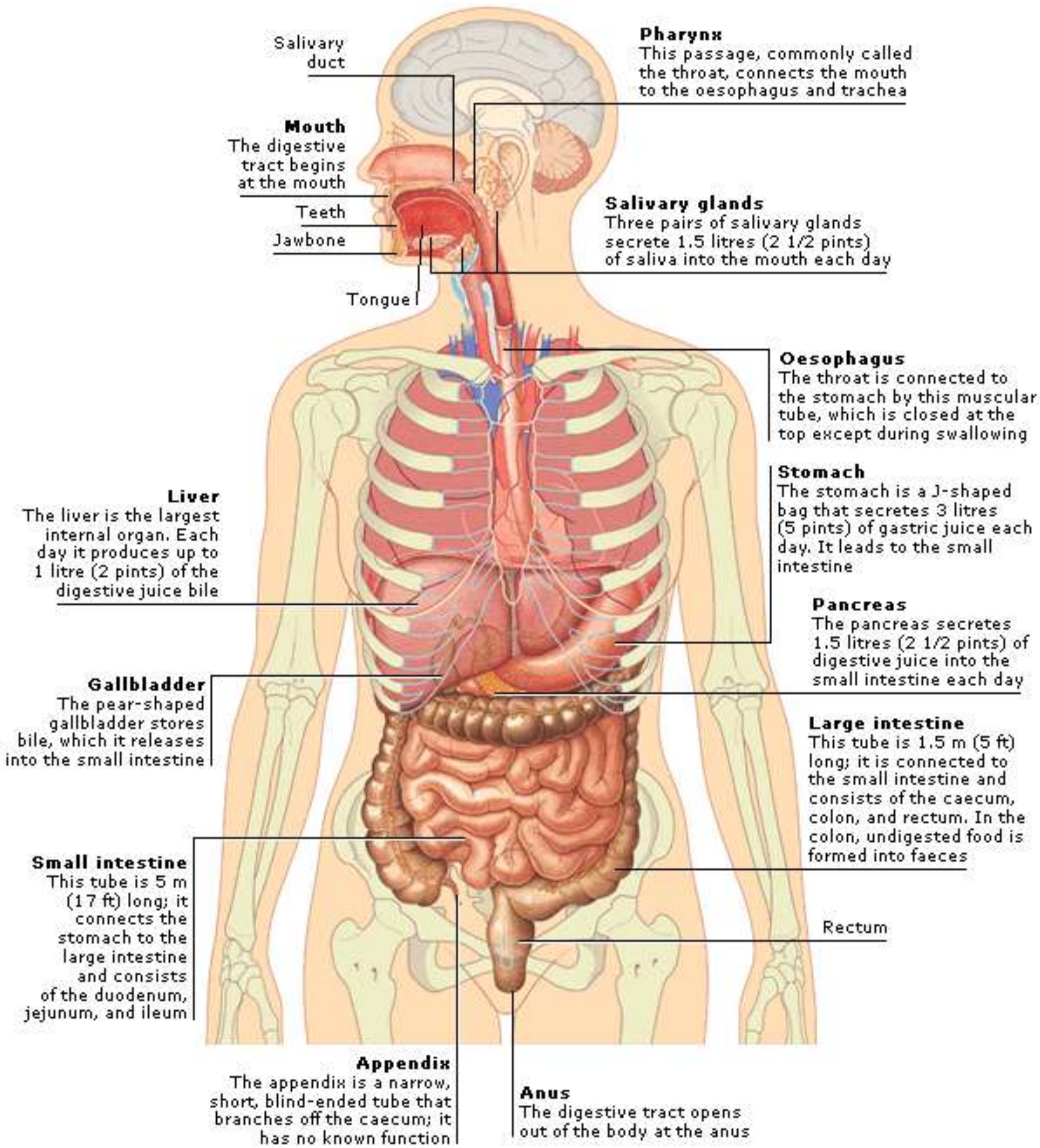
Once food has been reduced to its building blocks, it is ready for the body to absorb. Absorption begins in the stomach with simple molecules like water and alcohol being absorbed directly into the bloodstream. Most absorption takes place in the walls of the small intestine, which are densely folded to maximize the surface area in contact with digested food. Small blood and lymphatic vessels in the intestinal wall pick up the molecules and carry them to the rest of the body. The large intestine is also involved in the absorption of **water** and vitamins B and K before feces leave the body.

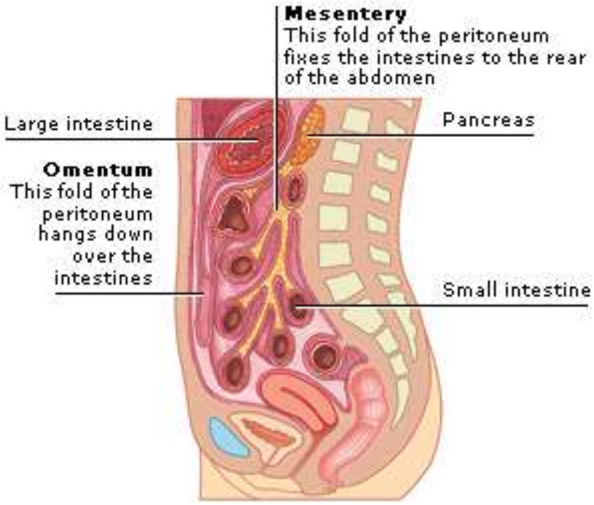
Excretion

The final function of the digestive system is the excretion of waste in a process known as defecation. Defecation removes indigestible substances from the body so that they do not accumulate inside the gut. The timing of defecation is controlled voluntarily by the conscious part of the brain, but must be accomplished on a regular basis to prevent a backup of indigestible materials.


DIGESTIVE SYSTEM
The human digestive system is a series of organs that converts food into essential nutrients that are absorbed into the body. The digestive organs also move unused waste material out of the body.
SALIVARY GLANDS
The enzymes in saliva help break down foods, and the lubrication function of saliva makes it easier for food to be swallowed.
Esophagus
LIVER
The liver has a wide range of functions, including detoxification, protein synthesis and production of bile for digestion.
STOMACH
The stomach's gastric juice, which is primarily a mix of hydrochloric acid and pepsin, starts breaking down proteins and killing potentially harmful bacteria.
Gall bladder
Pancreas
Large intestines or colon
Descending colon
Small intestines
Appendix
Rectum
Anus
LARGE INTESTINES
The function of the large intestine, which is about 5 feet (1.5 meters) long, is primarily the storage and fermentation of indigestible matter.

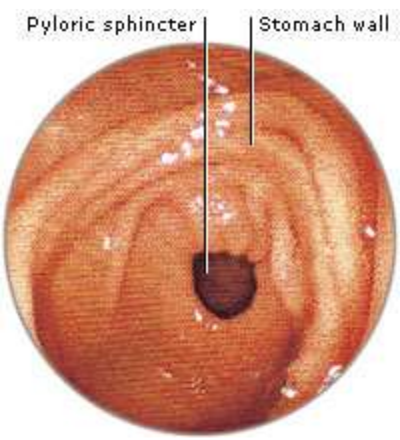
The digestive system consists of the digestive tract and its associated organs. The digestive tract is a tube about 7 m (24 ft) long through which food passes while it is broken down. The tract consists of the mouth and pharynx (throat), esophagus, stomach, the small and large intestines, and the anus. The associated digestive organs include three pairs of salivary glands, the liver, the pancreas, and the gallbladder.


Salivary duct
Pharynx
This passage, commonly called the throat, connects the mouth to the oesophagus and trachea
Mouth
The digestive tract begins at the mouth
Teeth
Jawbone
Salivary glands
Three pairs of salivary glands secrete 1.5 litres (2 1/2 pints) of saliva into the mouth each day
Tongue
Oesophagus
The throat is connected to the stomach by this muscular tube, which is closed at the top except during swallowing
Stomach
The stomach is a J-shaped bag that secretes 3 litres (5 pints) of gastric juice each day. It leads to the small intestine
Liver
The liver is the largest internal organ. Each day it produces up to 1 litre (2 pints) of the digestive juice bile
Pancreas
The pancreas secretes 1.5 litres (2 1/2 pints) of digestive juice into the small intestine each day
Gallbladder
The pear-shaped gallbladder stores bile, which it releases into the small intestine
Large intestine
This tube is 1.5 m (5 ft) long; it is connected to the small intestine and consists of the caecum, colon, and rectum. In the colon, undigested food is formed into faeces
Small intestine
This tube is 5 m (17 ft) long; it connects the stomach to the large intestine and consists of the duodenum, jejunum, and ileum
Rectum
Appendix
The appendix is a narrow, short, blind-ended tube that branches off the caecum; it has no known function
Anus
The digestive tract opens out of the body at the anus



The peritoneum

This folded membrane covers and secures the digestive organs and also covers the inside of the abdominal wall.



One-way valve

The pyloric sphincter, which joins the stomach to the small intestine, is one of several one-way valves in the digestive tract.

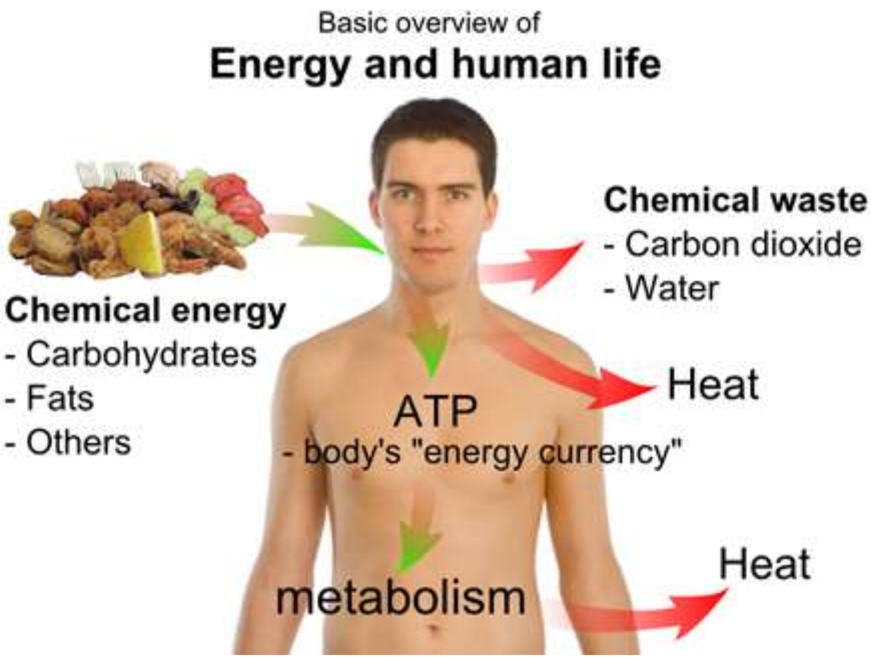
Digestive organs, Metabolism

Metabolism

The chemical processes that occur within a living organism in order to maintain life.

"The metabolism of fatty acids in the kidney"

How Human Body Metabolism Works



To understand the digestive system and body metabolism, knowing the organs involved and what roles they play is the first step, they we should learn how metabolism works. The process of metabolism can be split up in to two types, anabolism, and catabolism:

- **Anabolism** – Also known as constructive metabolism supports the storage of energy for use at a later date, as well as cell growth and repair. During the process of anabolism, small molecules are transformed into larger molecules of fat, protein, and/or carbohydrates.

- **Catabolism** – Also known as destructive metabolism, catabolism is the process of breaking down large fat, protein, and/or carbohydrate molecules to use for energy.

A gland called the pancreas secretes hormones to help your body to determine whether its main metabolic activity will be catabolic or anabolic.

The speed in which your body metabolized the food that you consume varies depending on the individual. An individual's rate of metabolism is dependent upon the volume of thyroxine that is produced within the thyroid; thyroxine being a hormone that regulates metabolism.

Calories and Basal Metabolic Rate

The chemical process of metabolism is very complex, which has lead many people to look at it in the simplest way possible; it affects how easily you gain or loose weight. As we eat, we store calories (a calorie is a unit of measurement used to determine the quantity of energy given to the body by a particular food), the calories we store are later metabolized and utilized as energy. But, it is possible to overload on calories and end up with an excess amount, which is stored as body fat.

The amount of calories a person can burn in a day is dependent upon their basal metabolic rate (BMR), this is the measurement of the rate at which a person "burns" calories as energy. The higher a person's BMR, the faster they can burn calories meaning less are stored as body fat. This means that they will be able to eat more and store less.

Although it is thought that a person's BMR is inherited, there are steps you can take to increase yours. Exercise is the best method, as this will not only help you lose calories and stay fit, it is often the case that low body fat levels equals low BMR, and vice versa.

Your Digestive System and How it Works

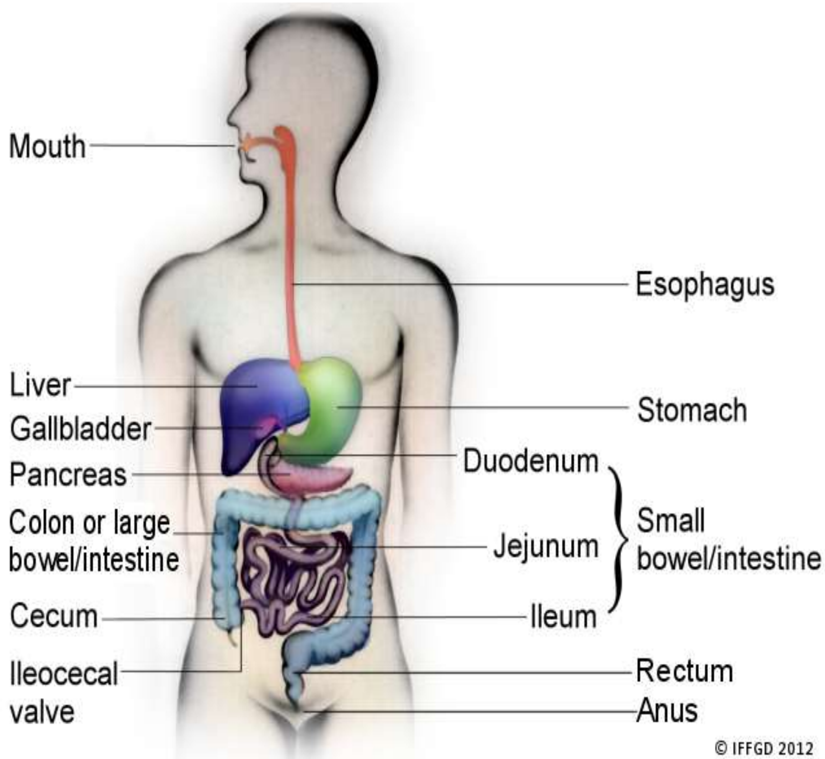
Digestion is the breakdown of large insoluble food molecules into small water-soluble food molecules so that they can be absorbed into the watery blood plasma. In certain organisms, these smaller substances are absorbed through the small intestine into the blood stream

The digestive system is a series of hollow organs joined in a long, twisting tube from the mouth to the anus (see Figure 1). Inside this tube is a lining called the mucosa? In the mouth, stomach, and small intestine, the mucosa contains tiny glands that produce juices to help digest food.

Two solid organs, the liver and the pancreas, produce digestive juices that reach the intestine through small tubes. In addition, parts of other organ systems (for instance, nerves and blood) play a major role in the digestive system.

Why is digestion important

Digestion involves the mixing of food, its movement through the digestive tract, and the chemical breakdown of the large molecules of food into smaller molecules. Digestion begins in the mouth, when we chew and swallow, and is completed in the small intestine. The chemical process varies somewhat for different kinds of food.



Movement of Food Through the System

The large, hollow organs of the digestive system contain muscle that enables their walls to move. The movement of organ walls can propel food and liquid and also can mix the contents within each organ.

Typical movement of the esophagus, stomach, and intestine is called peristalsis. The action of peristalsis looks like an ocean wave moving through the muscle.

The muscle of the organ produces a narrowing and then propels the narrowed portion slowly down the length of the organ. These waves of narrowing push the food and fluid in front of them through each hollow organ.

The first major muscle movement occurs when food or liquid is swallowed. Although we are able to start swallowing by choice, once the swallow begins, it becomes involuntary and proceeds under the control of the nerves.

The esophagus is the organ into which the swallowed food is pushed. It connects the throat above with the stomach below. At the junction of the esophagus and stomach, there is a ringlike valve closing the passage between the two organs. However, as the food approaches the closed ring, the surrounding muscles relax and allow the food to pass.

The food then enters the stomach, which has three mechanical tasks to do. First, the stomach must store the swallowed food and liquid. This requires the muscle of the upper part of the stomach to relax and accept large volumes of swallowed material.

The second job is to mix up the food, liquid, and digestive juice produced by the stomach. The lower part of the stomach mixes these materials by its muscle action. (The mixture is referred to as chyme.)

The third task of the stomach is to empty its contents slowly into the small intestine.

Several factors affect emptying of the stomach, including the nature of the food (mainly its fat and protein content) and the degree of muscle action of the emptying stomach and the next organ to receive the contents (the small intestine).

As the food is digested in the small intestine and dissolved into the juices from the pancreas, liver, and intestine, the contents of the intestine are mixed and pushed forward to allow further digestion.

Finally, all of the digested nutrients are absorbed through the intestinal walls. The waste products of this process include undigested parts of the food, known as fiber, and older cells that have been shed from the mucosa. These materials are propelled into the colon, where they remain, usually for a day or two, until the feces are expelled by a bowel movement.

Small Intestine/Bowel

The mixture of food, liquid, and digestive juice (chyme) that passes out of the stomach, in a regulated controlled manner, enters into the small intestine/bowel. The average total length of the normal small bowel in adults is about 7 meters/22 feet. The small intestine has 3 segments:

- the duodenum,
- the jejunum, and
- the ileum.

Each part or section performs an important role in nutrient absorption.

Duodenum – The chyme first enters into the duodenum where it is exposed to secretions that aid digestion. The secretions include bile salts, enzymes, and bicarbonate. The bile salts from the liver help digest fats and fat soluble vitamins (Vitamin A, D, E, and K). Pancreatic enzymes help digest carbohydrates and fats. Bicarbonate from the pancreas neutralizes the acid from the stomach.

Jejunum – The chyme is then further transited down into the second or middle part of the small intestine, the jejunum. Mainly in the first half of the jejunum, the majority (about 90%) of nutrient absorption occurs involving proteins, carbohydrates, vitamins, and minerals.

Ileum – The ileum is the last section of the small intestine and leads to the large intestine or colon. The ileum mainly absorbs water, bile salts, and vitamin B12.

The *ileocecal valve* is a one-way valve located between the ileum and the cecum, which is the first portion of the colon. This valve helps control the passage of contents into the colon and increases the contact time of nutrients and electrolytes (essential minerals) with the small intestine. It also prevents back-flow (reflux) from the colon up into the ileum, and helps minimize the movement of bacteria from the large intestine up into the small bowel.

Large Intestine or Colon

The primary function of the large intestine or colon is to absorb fluids and electrolytes, particularly sodium and potassium, and to convert remaining luminal contents into more solid stool. The colon absorbs on average 1–1.5 liters (about 1–1.5 quarts) of fluid every day and has a capacity to adapt its fluid absorption to as much as 5 liters/quarts per day if needed.

Another function of the colon is to break down (ferment) dietary fiber to produce short chain fatty acids – substances that can be absorbed and provide added nutrition.

The first portion of the colon, the cecum, is shaped like a pouch, and is the area of storage for the contents arriving from the ileum. The second portion is the ascending colon, where fluids are absorbed and where some stool formation begins.

Production of Digestive Juices

The glands that act first are in the mouth – the salivary glands. Saliva produced by these glands contains an enzyme that begins to digest the starch from food into smaller molecules.

The next set of digestive glands is in the stomach lining. They produce stomach acid and an enzyme that digests protein. One of the unsolved puzzles of the digestive system is why the acid juice of the stomach does not dissolve the tissue of the stomach itself. In most people, the stomach mucosa is able to resist the juice, although food and other tissues of the body cannot.

After the stomach empties the food and juice mixture into the small intestine, the juices of two other digestive organs mix with the food to continue the process of digestion.

One of these organs is the pancreas. It produces a juice that contains a wide array of enzymes to break down the carbohydrate, fat, and protein in food. Other enzymes that are active in the process come from glands in the wall of the intestine or even a part of that wall.

The liver produces yet another digestive juice – bile. The bile is stored between meals in the gallbladder. At mealtime, it is squeezed out of the gallbladder into the bile ducts to reach the intestine and mix with the fat in our food. The bile acids dissolve the fat into the watery contents of the intestine, much like detergents that dissolve grease from a frying pan. After the fat is dissolved, it is digested by enzymes from the pancreas and the lining of the intestine.

Absorption and Transport of Nutrients

Digested molecules of food, as well as water and minerals from the diet, are absorbed from the cavity of the upper small intestine. Most absorbed materials cross the mucosa into the blood and are carried off in the bloodstream to other parts of the body for storage or further chemical change. As already noted, this part of the process varies with different types of nutrients.

Carbohydrates. It is recommended that about 55 to 60 percent of total daily calories be from carbohydrates. Some of our most common foods contain mostly carbohydrates. Examples are bread, potatoes, legumes, rice, spaghetti, fruits, and vegetables. Many of these foods contain both starch and fiber.

The digestible carbohydrates are broken into simpler molecules by enzymes in the saliva, in juice produced by the pancreas, and in the lining of the small intestine.

Starch is digested in two steps: First, an enzyme in the saliva and pancreatic juice breaks the starch into molecules called maltose; then an enzyme in the lining of the small intestine (maltase) splits the maltose into glucose molecules that can be absorbed into the blood.

Glucose is carried through the bloodstream to the liver, where it is stored or used to provide energy for the work of the body.

Table sugar is another carbohydrate that must be digested to be useful. An enzyme in the lining of the small intestine digests table sugar into glucose and fructose, each of which can be absorbed from the intestinal cavity into the blood. Milk contains yet another type of sugar, lactose, which is changed into absorbable molecules by an enzyme called lactase, also found in the intestinal lining.

Protein. Foods such as meat, eggs, and beans consist of giant molecules of protein that must be digested by enzymes before they can be used to build and repair body tissues. An enzyme in the juice of the stomach starts the digestion of swallowed protein.

Further digestion of the protein is completed in the small intestine. Here, several enzymes from the pancreatic juice and the lining of the intestine carry out the breakdown of huge protein molecules into small molecules called amino acids. These small molecules can be absorbed from the hollow of the small intestine into the blood and then be carried to all parts of the body to build the walls and other parts of cells.

Fats. Fat molecules are a rich source of energy for the body. The first step in digestion of a fat such as butter is to dissolve it into the watery content of the intestinal cavity.

The bile acids produced by the liver act as natural detergents to dissolve fat in water and allow the enzymes to break the large fat molecules into smaller molecules, some of which are fatty acids and cholesterol. The bile acids combine with the fatty acids and cholesterol and help these molecules to move into the cells of the mucosa.

In these cells the small molecules are formed back into large molecules, most of which pass into vessels (called lymphatics) near the intestine. These small vessels carry the reformed fat to the veins of the chest, and the blood carries the fat to storage depots in different parts of the body.

Vitamins. Another vital part of our food that is absorbed from the small intestine is the class of chemicals we call vitamins. The two different types of vitamins are classified by the fluid in which they can be dissolved: water-soluble vitamins (all the B vitamins and vitamin C) and fat-soluble vitamins (vitamins A, D, E, and K).

Water and salt. Most of the material absorbed from the cavity of the small intestine is water in which salt is dissolved. The salt and water come from the food and liquid we swallow and the juices secreted by the many digestive glands.

How is the digestive process controlled

Hormone Regulators

A fascinating feature of the digestive system is that it contains its own regulators. The major hormones that control the functions of the digestive system are produced and released by cells in the mucosa of the stomach and small intestine. These hormones are released into the blood of the digestive tract, travel back to the heart and through the arteries, and return to the digestive system, where they stimulate digestive juices and cause organ movement.

The hormones that control digestion are gastrin, secretin, and cholecystokinin (CCK):

- **Gastrin** causes the stomach to produce an acid for dissolving and digesting some foods. It is also necessary for the normal growth of the lining of the stomach, small intestine, and colon.
- **Secretin** causes the pancreas to send out a digestive juice that is rich in bicarbonate. It stimulates the stomach to produce pepsin, an enzyme that digests protein, and it also stimulates the liver to produce bile.
- **CCK** causes the pancreas to grow and to produce the enzymes of pancreatic juice, and it causes the gallbladder to empty.

Additional hormones in the digestive system regulate appetite:

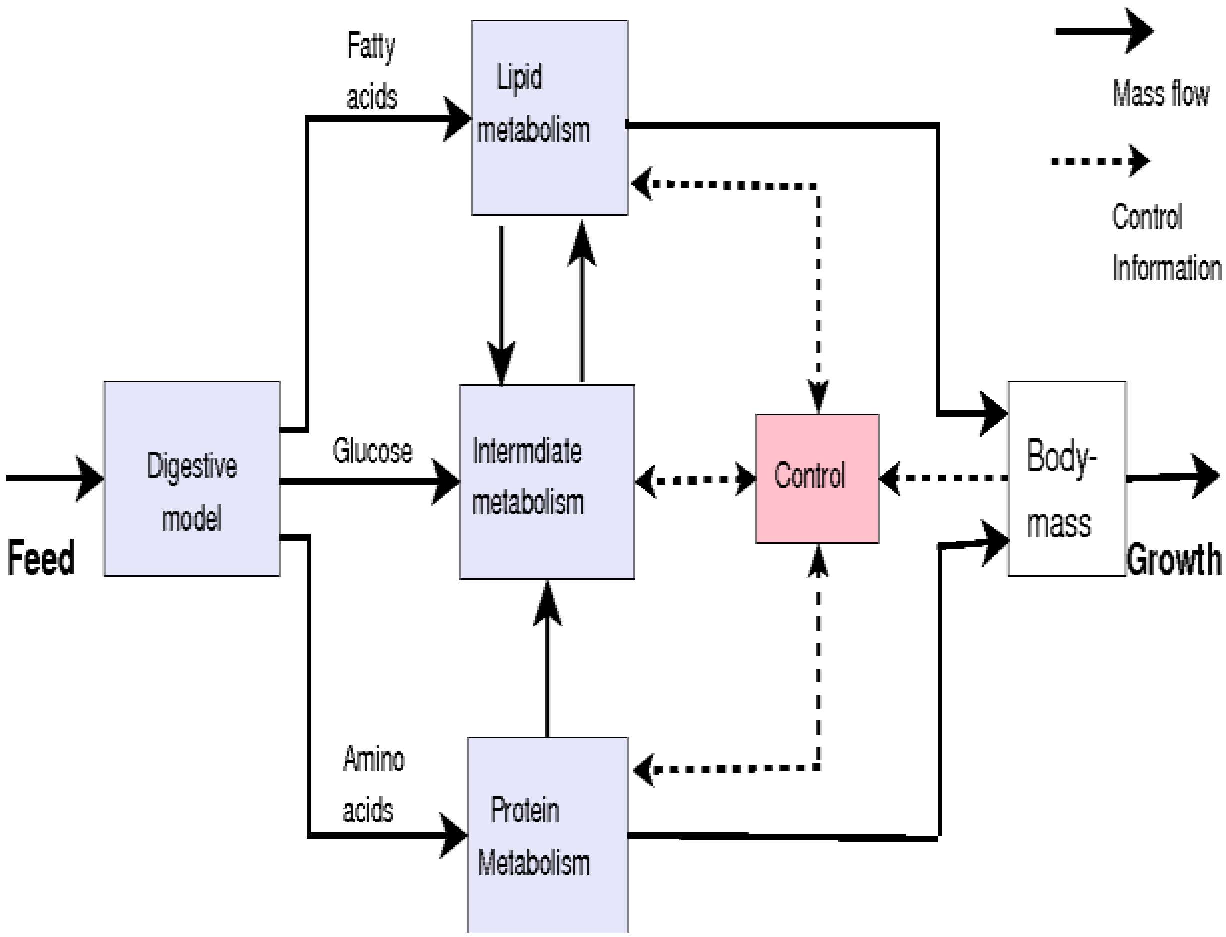
- **Ghrelin** is produced in the stomach and upper intestine in the absence of food in the digestive system and stimulates appetite.
- **Peptide YY** is produced in the GI tract in response to a meal in the system and inhibits appetite.

Both of these hormones work on the brain to help regulate the intake of food for energy.

Nerve Regulators

Two types of nerves help to control the action of the digestive system. Extrinsic (outside) nerves come to the digestive organs from the unconscious part of the brain or from the spinal cord. They release a chemical called acetylcholine and another called adrenaline. Acetylcholine causes the muscle of the digestive organs to squeeze with more force and increase the "push" of food and juice through the digestive tract. Acetylcholine also causes the stomach and pancreas to produce more digestive juice. Adrenaline relaxes the muscle of the stomach and intestine and decreases the flow of blood to these organs.

Even more important, though, are the intrinsic (inside) nerves, which make up a very dense network embedded in the walls of the esophagus, stomach, small intestine, and colon. The intrinsic nerves are triggered to act when the walls of the hollow organs are stretched by food. They release many different substances that speed up or delay the movement of food and the production of juices by the digestive organs.



The Excretory System:

The excretory system is the system of an organism's body that performs the function of excretion, the bodily process of discharging wastes. The Excretory system is responsible for the elimination of wastes produced by homeostasis.

The excretory system is essential to one's health. Its responsibility is to remove waste from the body. The excretory system is made up of numerous organs that work in unison to ensure that waste is effectively removed from your body. Below are the details of the excretory system organs, along with the roles they play in detoxification.

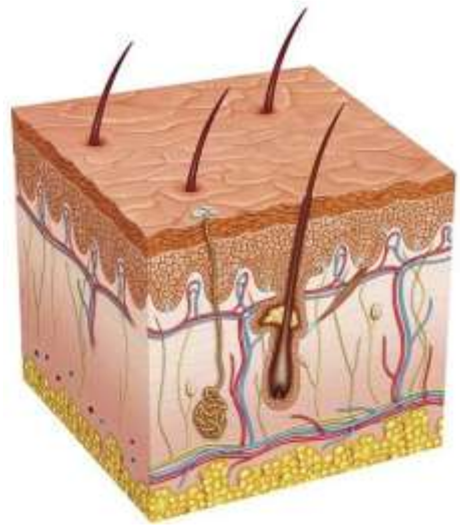
Primary Excretory System Organs

1. Kidneys

.

Kidneys are bean-shaped organs of a reddish brown color that are found in the sides of the vertebral column. Once the body has extracted what it needs from food and drink, it sends the wastes to the kidneys. **The kidneys filter the wastes,** including urea, salt and excess water, **which are flushed out of the body as urine**.

Wastes in the blood come from tissue breakdown, and from food. After the body takes and uses what it needs, it sends the wastes to the kidneys. The kidneys are bean-shaped organs, about the size of a fist. Having atleast one kidney is mandatory for living, unless treated immidietally. Because of the enormous amounts of blood passing through the kidney, kidneys sxtract 180 liters of fluid daily. If we extracted all of the fluid as urine, we would lose nutrients and dehydrate, Kidneys are responsible for filtering the filtrate and returning most of the solutes and water to the blood.



2. Skin

The skin performs its excretory function via the **sweat glands**. These glands produce sweat that contains salt, excess oils, water, and other unnecessary substances which are then excreted out of the body through small pores. Sweating also helps to cool the body during evaporation. Your skin has a very important part in the excretory system. It holds moisture into every part of your body. In the excretory system, the skins job is to regulate one's body temperature. The salt in the skin helps in evaporation of the water off of the body, to cool off one who is hot. Sweat is excreted through sweat glands. Sweating helps the body maintain a cool, consistent temperature, which also helps one maintain homeostasis.

3. Lungs

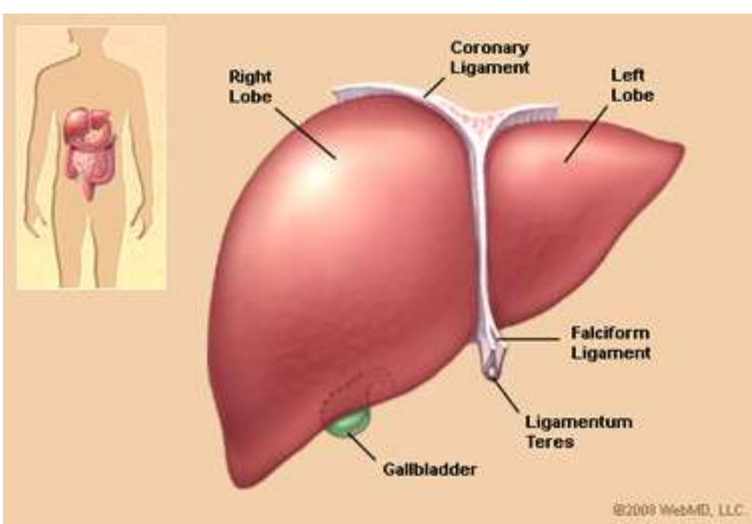
The lungs are very important excretory organs as they **expel carbon dioxide from the body via exhalation**. The lungs use cells known as alveoli to remove the carbon dioxide from our blood. Otherwise, the carbon dioxide would accumulate and have a detrimental effect to our body.

Accessory Excretory System Organs

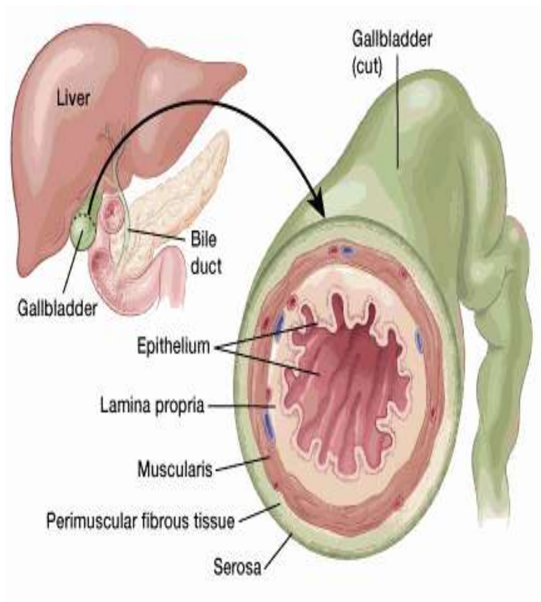
1. Liver

Although considered a secondary, or accessary excretory system organ, the liver plays a vital part in keeping the body clean. **Harmful**

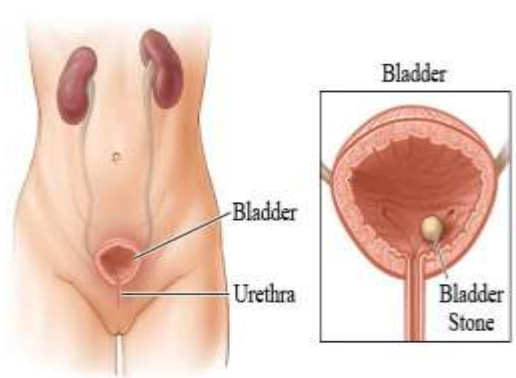
poisons and chemicals that are either produced in the body or consumed are broken down and detoxified by the liver. For example, a bi-product of the metabolic process within the body is ammonia and the liver processes this into urea, a less harmful substance which continues to be filtered and excreted by the kidneys as urine. When we eat fatty foods, the liver orders the gall bladder to release bile into the intestines. The bile then puts the waste products into the intestines. Then the intestines absorb the fats into the blood stream. The liver is then given the blood, and removes all waste products from it as it passes through. The liver removes the iron, which involves red blood cell production. Amino acids are then broken down and passed into the kidney. The kidney uses these to carryout their function in the excretory system. The liver then stores the vitamins, and repeats its cycle.



2. Gallbladder

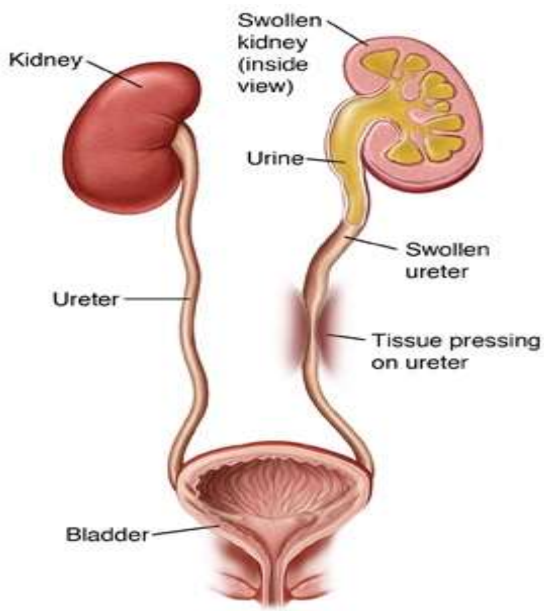


Although the gallbladder does not have a highly significant role to play in the excretory system, it does have a function that assists the overall process. **Bile, a liquid produced by the liver to break down waste, is first stored in the gallbladder**. When needed, it is discharged into the small intestine whose role is to break down fats, ethanol and other acidic wastes.



3. Urinary Bladder

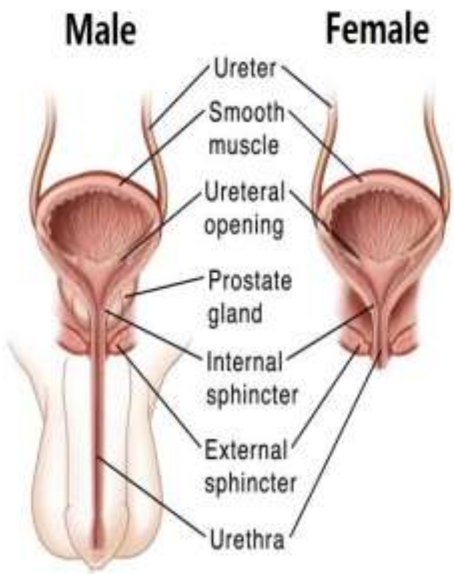
The waste fluid that is created in the liver and collected in the kidney is transferred into the urinary bladder where it is temporarily stored until the individual urinates. **The urinary bladder provides a short term solution for storing urine in the body** until it is ultimately discharged. After the kidneys filter the fluid, the remaining wastes go to your bladder. The organ stores the urine, and keeps storing it until you can feel it. When you can feel it, it means that the bladder has become full, and you must urinate to release the wastes from your body.



4. Ureters

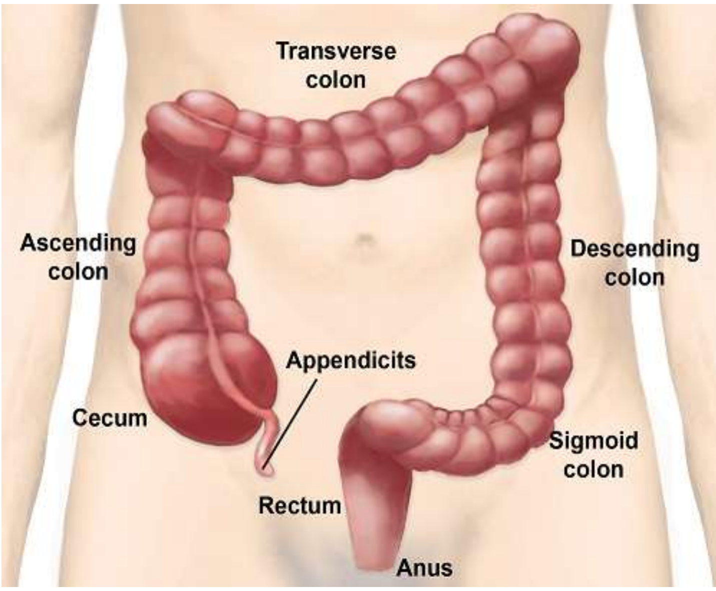
The ureters tubes of smooth muscle fiber transfer liquid waste from the kidneys into the urinary bladder. The urine is moved with peristaltic movements which force the urine away from the kidneys. The ureters also have ureterovesical valves which ensure the waste fluid does not travel back into the kidney.

5. Urethra



The urethra runs through the penis in males, and serves as **a carrier of semen as well as urine for their ultimate discharge out of the body**. The urethra tube is shorter in females and is just above the vaginal opening.

7. Large Intestine



Food particles are absorbed into the blood stream via the small intestine. The undigested substances are transferred to the large intestine which essentially serves as **a storage organ for the excretory products**. The descending, ascending and transverse colons also facilitate the absorption of leftover vitamins, water and salt. The distal straight section (known as the rectum) is used for the storage of waste products (feces) before they are excreted from the body via the anal canal with the help of internal and external sphincters.

Common Diseases Affecting Excretory System Organs

1. Kidney Stones

Kidney stones are believed to form from crystals that have separated from urine, forming hard masses in the urinary tract, though the exact cause is unknown. Symptoms for kidney stones include extreme pain, cramping in the lower abdominals and back, nausea, and vomiting.

Most kidney stones can be passed by increasing your intake of water to flush them out, although surgery may be needed in some cases.

2. Urethritis

Urethritis is a viral or bacterial infection that causes inflammation of the urethra. Symptoms for urethritis vary between the sexes.

- **Symptoms for men** include pain or swelling of the penis, blood in urine or semen, frequent urination and pain during ejaculation.
- **Symptoms for females** include pain during urination, abdominal pain, fever, chills, frequent urination, vaginal discharge and pelvis pain. Urethritis is usually treated with anti-viral medication, or antibiotics. Painkillers are often used to help sufferers combat the symptoms.

3. Pyelonephritis

Pyelonephritis is a type of urinary tract infection that travels from the urethra or bladder and to the kidneys. This infection occurs when bacteria enter the body through the urinary tract. Symptoms include frequent urination, burning during urination, blood in the urine, pain in the groin and abdominal pain. Pyelonephritis is usually treated with oral anti-biotics, although the anti-biotics are sometimes administered intravenously in cases of severe infections.

4. Cystitis

Cystitis is the medical term for inflammation of the bladder and it is one of the most common disease that affects excretory system organs.

As the bladder stores urine before it is excreted from the body, bacteria can build up in the bladder and cause cystitis.

5. Urinary Tract Infection

Urinary tract infection (UTI) is the infection of the urethra or the bladder. The symptoms include abdominal pain, painful or difficult urination and fever. The best way to avoid UTI is by drinking loads of water.

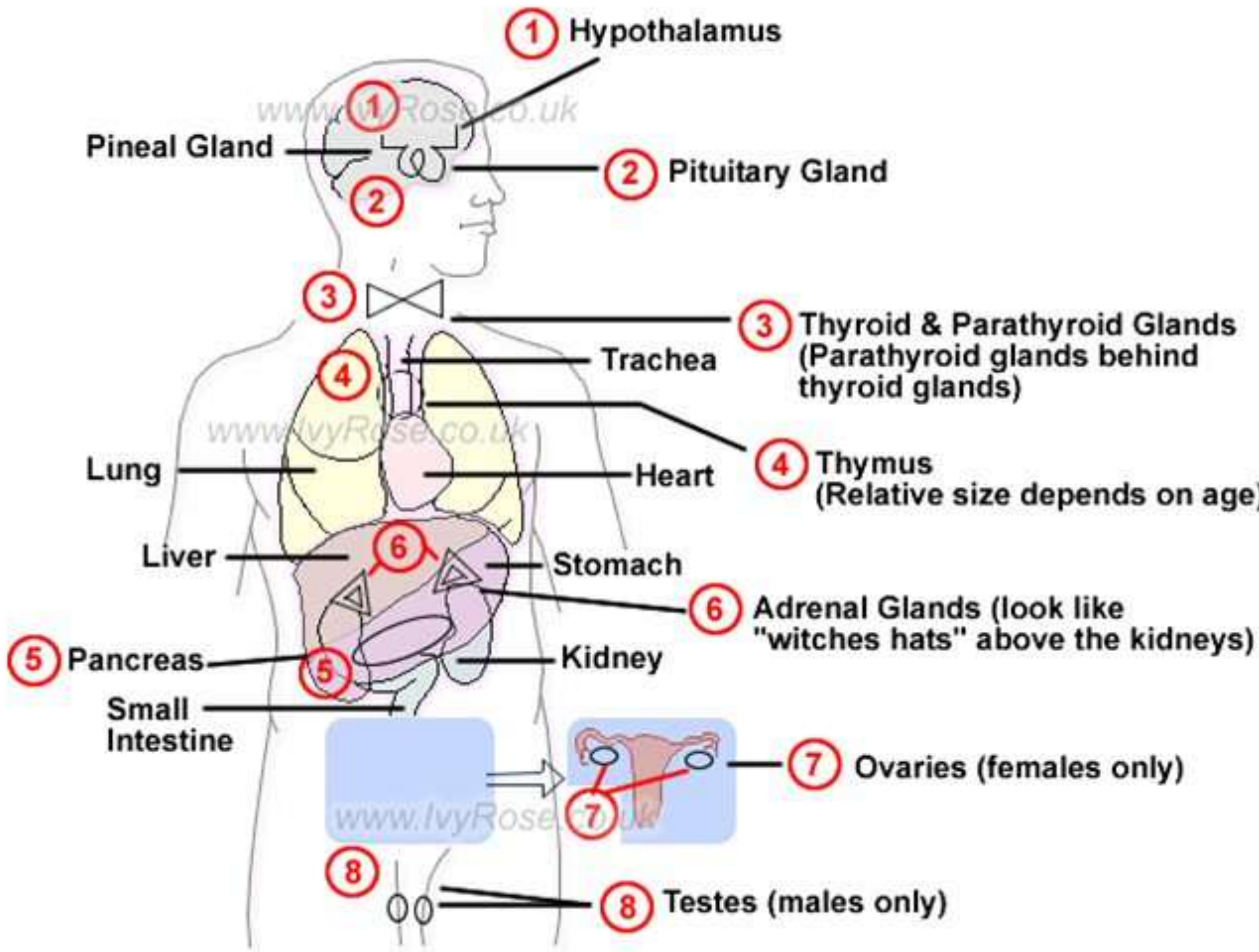
The Endocrine glands:

Endocrine glands are glands of the endocrine system that secrete their products, hormones, directly into the blood rather than through a duct. The major glands of the endocrine system include the

pineal gland,**pituitary gland**, **pancreas**, ovaries, **testes**, **thyroid gland**, **parathyroid**gland, **hypothalamus** and **adrenal** glands.

When hormone levels reach a certain normal amount, the **endocrine system** helps the body to keep that level of hormone in the blood. For example, if the thyroid gland has secreted the right amount of thyroid hormones into the blood, the pituitary gland senses the normal levels of thyroid hormone in the bloodstream. **Endocrine glands** are **glands** of the **endocrine system** that **secrete** their products, hormones, directly into the blood rather than through a duct. The main **endocrine glands** include the pituitary **gland**, pancreas, ovaries, testes, thyroid **gland**, and adrenal **glands**.

The main **function** of endocrine glands is to secrete **hormones** directly into the bloodstream. **Hormones** are chemical substances that affect the activity of another part of the body (target site). In essence, **hormones** serve as messengers, controlling and coordinating activities throughout the body.



Glands are located throughout various parts of the human body. These glands take on the critical task of releasing hormones, and as a whole, they are most commonly referred to as the endocrine system.

Major endocrine glands and other organs

Major endocrine glands

Gland	Function
Hypothamlus (1)	The hypothalamus is situated in the brain, at the base of the optic chiasm and is attached to the pituitary via a stalk-like structure. It acts as a collecting centre for information concerned with the internal well being of the body and uses much of this information to regulate the secretion of the hormones produced by the pituitary.
Pituitary (1)	The pituitary gland is an important gland and it is often referred to as the 'master gland', because it controls several of the other hormone glands. It is usually about the size of a pea and is situated in a bony hollow beneath the base of the brain and just behind the bridge of your nose. The gland consists of two parts (often called lobes) each of which has different functions. The pituitary gland is also sometimes called the Hypophysis.
Thyroid (1) & parathyroid (4)	The thyroid gland is situated in the front part of the neck, near the windpipe. Embedded in the rear surface of this gland are four parathyroid glands. The thyroid gland controls many body functions, including heart rate, temperature and metabolism. Both these glands play a role in the metabolism of calcium in the body.
Adrenals (2)	The adrenal glands (each of which weighs about 4 grams and is about the size of your thumb) are situated just above the kidneys and consist of two parts, the adrenal medulla and the adrenal cortex.

	These glands produce hormones which are essential for life and help us cope with stress.
Pineal (1)	The pineal gland is a tiny body located at the base of the brain. It produces the hormone melatonin.

Other organs in the body containing endocrine tissue

Gland	**Function**
Kidneys (2)	The kidneys are situated near the middle of the back, just below the cage. These glands control the blood fluid and mineral levels within body by processing the blood to remove waste products and any exc fluid.
Ovaries (2)	The ovaries are situated either side of the uterus. In addition to contain the egg cells necessary for reproduction, they produce the hormo Oestrogen and Progesterone which are necessary for menstruation a producing the other female sexual characteristics.
Testes (2)	The testes are situated in a pouch that hangs outside the male body. Th produce the hormones necessary for the production of sperm and the ot male sexual characteristics.
Pancreas (1)	In addition to its digestive functions, cells in the pancreas regulate blood sugar that provides the body with energy.

Hypothalamus

The **hypothalamus** is a part of the **brain** located superior and anterior to the brain stem and inferior to the **thalamus**. It serves many different functions in the **nervous system**, and is also responsible for the direct control of the endocrine system through the pituitary gland. The hypothalamus contains special cells called neurosecretory cells—neurons that secrete hormones:

- Thyrotropin-releasing hormone (TRH)
- Growth hormone-releasing hormone (GHRH)
- Growth hormone-inhibiting hormone (GHIH)
- Gonadotropin-releasing hormone (GnRH)
- Corticotropin-releasing hormone (CRH)
- Oxytocin
- Antidiuretic hormone (ADH)

All of the releasing and inhibiting hormones affect the function of the anterior pituitary gland. TRH stimulates the anterior pituitary gland to release thyroid-stimulating hormone. GHRH and GHIH work to regulate the release of growth hormone—GHRH stimulates growth hormone release, GHIH inhibits its release. GnRH stimulates the release of follicle stimulating hormone and luteinizing hormone while CRH stimulates the release of adrenocorticotropic hormone. The last two hormones—oxytocin and antidiuretic hormone—are produced by the hypothalamus and transported to the posterior pituitary, where they are stored and later released.

Pineal Gland

The **pineal gland** is a small pinecone-shaped mass of glandular tissue found just posterior to the thalamus of the brain. The pineal gland produces the hormone melatonin that helps to regulate the human sleep-wake cycle known as the circadian rhythm. The activity of the pineal gland is inhibited by stimulation from the photoreceptors of the retina. This light sensitivity causes melatonin to be produced only in low light or darkness. Increased melatonin production causes humans to feel drowsy at nighttime when the pineal gland is active.

Thymus

The **thymus** is a soft, triangular-shaped organ found in the chest posterior to the sternum. The thymus produces hormones called thymosins that help to train and develop T-lymphocytes during fetal development and childhood. The T-lymphocytes produced in the thymus go on to protect the body from pathogens throughout a person’s entire life. The thymus becomes inactive during puberty and is slowly replaced by adipose tissue throughout a person’s life.

Gonads

The gonads—ovaries in females and testes in males—are responsible for producing the sex hormones of the body. These sex hormones determine the secondary sex characteristics of adult females and adult males.

- *Testes*: The **testes** are a pair of ellipsoid organs found in the scrotum of males that produce the androgen testosterone in males after the start of puberty. Testosterone has effects on many parts of the body, including the muscles, bones, sex organs, and hair follicles. This hormone causes growth and increases in strength of the bones and muscles, including the accelerated growth of long bones during adolescence. During puberty, testosterone controls the growth and development of the sex organs and body hair of males, including pubic, chest, and facial hair. In men who have inherited genes for baldness testosterone triggers the onset of androgenic alopecia, commonly known as male pattern baldness.

- *Ovaries*: The **ovaries** are a pair of almond-shaped glands located in the pelvic body cavity lateral and superior to the uterus in females. The ovaries produce the female sex hormones progesterone and estrogens. Progesterone is most active in females during ovulation and pregnancy where it maintains appropriate conditions in the human body to support a developing fetus. Estrogens are a group of related hormones that function as the primary female sex hormones. The release of estrogen during puberty triggers the development of female secondary sex characteristics such as uterine development, breast development, and the growth of pubic hair. Estrogen also triggers the increased growth of bones during adolescence that lead to adult height and proportions.

The main glands and organs of the endocrine system include:

Pituitary gland – is inside the brain. It oversees the other glands and keeps hormone levels in check. It can bring about a change in hormone production somewhere else in the system by releasing its own 'stimulating' hormones. The pituitary gland is also connected to the nervous system through part of the brain called the hypothalamus. The hormones released by the pituitary gland are gonadotropins (LH and FSH), growth hormone (GH), thyroid stimulating hormone (TSH), adrenocorticotropic hormone (ACTH), prolactin, antidiuretic hormone and oxytocin.
The **pituitary gland**, also known as the hypophysis, is a small pea-sized lump of tissue connected to the inferior portion of the hypothalamus of the

brain. Many **blood vessels**surround the pituitary gland to carry the hormones it releases throughout the body. Situated in a small depression in the **sphenoid bone** called the sella turcica, the pituitary gland is actually made of 2 completely separate structures: the posterior and anterior pituitary glands.

1. *Posterior Pituitary*: The posterior pituitary gland is actually not glandular tissue at all, but nervous tissue instead. The posterior pituitary is a small extension of the hypothalamus through which the axons of some of the neurosecretory cells of the hypothalamus extend. These neurosecretory cells create 2 hormones in the hypothalamus that are stored and released by the posterior pituitary:

   2.

      1. Oxytocin triggers uterine contractions during childbirth and the release of milk during breastfeeding.
      2. Antidiuretic hormone (ADH) prevents water loss in the body by increasing the re-uptake of water in the kidneys and reducing blood flow to sweat glands.

   3. *Anterior Pituitary*: The anterior pituitary gland is the true glandular part of the pituitary gland. The function of the anterior pituitary gland is controlled by the releasing and inhibiting hormones of the hypothalamus. The anterior pituitary produces 6 important hormones:

      1. Thyroid stimulating hormone (TSH), as its name suggests, is a tropic hormone responsible for the stimulation of the thyroid gland.

2. Adrenocorticotropic hormone (ACTH) stimulates the adrenal cortex, the outer part of the adrenal gland, to produce its hormones.
3. Follicle stimulating hormone (FSH) stimulates the follicle cells of the gonads to produce gametes—ova in females and sperm in males.
4. Luteinizing hormone (LH) stimulates the gonads to produce the sex hormones—estrogens in females and testosterone in males.
5. Human growth hormone (HGH) affects many target cells throughout the body by stimulating their growth, repair, and reproduction.
6. Prolactin (PRL) has many effects on the body, chief of which is that it stimulates the **mammary glands** of the breast to produce milk.

- **Thyroid gland** – sits in the neck at the front of the windpipe. It releases thyroid hormone (T4 and T3) which is required for metabolism and body homeostasis. It is controlled by TSH which is produced by the pituitary gland through a feed-back loop. The **thyroid gland** is a butterfly-shaped gland located at the base of the neck and wrapped around the lateral sides of the trachea. The thyroid gland produces 3 major hormones:
  - Calcitonin
- Triiodothyronine (T3)
- Thyroxine (T4)
- Calcitonin is released when calcium ion levels in the blood rise above a certain set point. Calcitonin functions to reduce the concentration of calcium

ions in the blood by aiding the absorption of calcium into the matrix of bones. The hormones T3 and T4 work together to regulate the body's metabolic rate. Increased levels of T3 and T4 lead to increased cellular activity and energy usage in the body

- **Parathyroid gland** – there are usually four parathyroid glands which lie alongside the thyroid gland. The parathyroid gland is involved in calcium, phosphate and vitamin D regulation. The **parathyroid glands** are 4 small masses of glandular tissue found on the posterior side of the thyroid gland. The parathyroid glands produce the hormone parathyroid hormone (PTH), which is involved in calcium ion homeostasis. PTH is released from the parathyroid glands when calcium ion levels in the blood drop below a set point. PTH stimulates the osteoclasts to break down the calcium containing bone matrix to release free calcium ions into the bloodstream. PTH also triggers the kidneys to return calcium ions filtered out of the blood back to the bloodstream so that it is conserved.

  Adrenal glands – there are two adrenal glands which sit on top of each kidney. They make a number of different hormones. The outside part of the gland (adrenal cortex) makes cortisol, aldosterone and sex hormones. The centre of the adrenal gland (adrenal medulla) makes adrenaline. Adrenaline is an example of a hormone that is under the control of the nervous system. The **adrenal glands** are a pair of roughly triangular glands found immediately superior to the kidneys. The adrenal glands are each made of 2 distinct layers, each with their own unique functions: the outer adrenal cortex and inner adrenal medulla.

- *Adrenal cortex*: The adrenal cortex produces many cortical hormones in 3 classes: glucocorticoids, mineralocorticoids, and androgens.

-

1. Glucocorticoids have many diverse functions, including the breakdown of proteins and lipids to produce glucose. Glucocorticoids also function to reduce inflammation and immune response.
2. Mineralocorticoids, as their name suggests, are a group of hormones that help to regulate the concentration of mineral ions in the body.
3. Androgens, such as testosterone, are produced at low levels in the adrenal cortex to regulate the growth and activity of cells that are receptive to male hormones. In adult males, the amount of androgens produced by the testes is many times greater than the amount produced by the adrenal cortex, leading to the appearance of male secondary sex characteristics.

- *Adrenal medulla*: The adrenal medulla produces the hormones epinephrine and norepinephrine under stimulation by the sympathetic division of the autonomic nervous system. Both of these hormones help to increase the flow of blood to the brain and muscles to improve the "fight-or-flight" response to stress. These hormones also work to increase heart rate, breathing rate, and blood pressure while decreasing the flow of blood to and function of organs that are not involved in responding to emergencies.
-
- **Pancreas** – an organ of digestion which is inside the abdomen. It makes insulin, which controls the amount of sugar in the bloodstream. It also makes other hormones such as glucagon and somatostatin. The **pancreas** is a large gland located in the abdominal cavity just inferior and posterior to the **stomach**. The pancreas is considered to be a heterocrine gland as it

contains both endocrine and exocrine tissue. The endocrine cells of the pancreas make up just about 1% of the total mass of the pancreas and are found in small groups throughout the pancreas called islets of Langerhans. Within these islets are 2 types of cells—alpha and beta cells. The alpha cells produce the hormone glucagon, which is responsible for raising blood glucose levels. Glucagon triggers muscle and liver cells to break down the polysaccharide glycogen to release glucose into the bloodstream. The beta cells produce the hormone insulin, which is responsible for lowering blood glucose levels after a meal. Insulin triggers the absorption of glucose from the blood into cells, where it is added to glycogen molecules for storage.

- **Ovaries** – are inside the female pelvis. They make female sex hormones like oestrogen.

- **Testes** – they hang in the male scrotal sack. They make male sex hormones like testosterone.

Other lesser known endocrine organs include:

- **Adipose tissue (fat tissue)** – is recognised to be metabolically important. It releases hormones such as leptin, which affect appetite, and is also a site of oestrogen production. Insulin also acts on adipose tissue.

- **Kidneys** – produce erythropoietin (EPO) which stimulates red blood cell production, produce renin which is needed for blood pressure regulation and produce the active form of Vitamin D (1–25 dihydroxy vitamin D3)

- **Gut** – an increasing number of hormones in the gut are being researched and being understood to effect metabolism and appetite. Included are glucagon-like peptide 1 (GLP–1), ghrelin which stimulates appetite, and somatostatin.

Problems of the endocrine system

Numerous problems can occur in the endocrine system. These can be considered as excessive or deficient hormone production. Endocrine organs are also prone to tumours (adenomas) which can over produce hormones. Some problems of the endocrine system include:

- **Diabetes** – too much sugar in the blood caused by problems with insulin production. This includes type 1 diabetes (deficiency of insulin) and type 2 diabetes (initially excessive, then deficiency, of insulin).
- **Menstruation abnormalities** – irregular menstruation or lack of menstruation. Some causes of this include polycystic ovarian syndrome (PCOS), pituitary adenoma or primary ovarian failure (POF).
- **Thyroid problems** – when the gland is overactive (hyperthyroidism) or underactive (hypothyroidism). Thyroid nodules are common but thyroid cancers are rare.
- **Parathyroid problems** – an enlargement or one of more of the parathyroid glands can lead to high calcium levels in the blood (hypercalcemia).
- **Pituitary adenomas** – these are tumours of the pituitary gland that can make too much of a certain hormone or cause deficiencies of hormones. These tumours can be small (microadenomas) or large (macroadenomas).
- **Neuro-endocrine tumours** – these are rare to tumours of certain endocrine glands (usually the adrenal gland, pancreas or small bowel). These can include too much adrenaline released by the adrenal gland (pheochromocytoma), or too much hormone 5–HIAA from a carcinoid tumour which causes diarrhoea and flushing.

Functions of the endocrine system

Some of the roles of the endocrine system include:

- Growth
- Repair
- Sexual reproduction
- Digestion
- Homeostasis (constant internal balance).

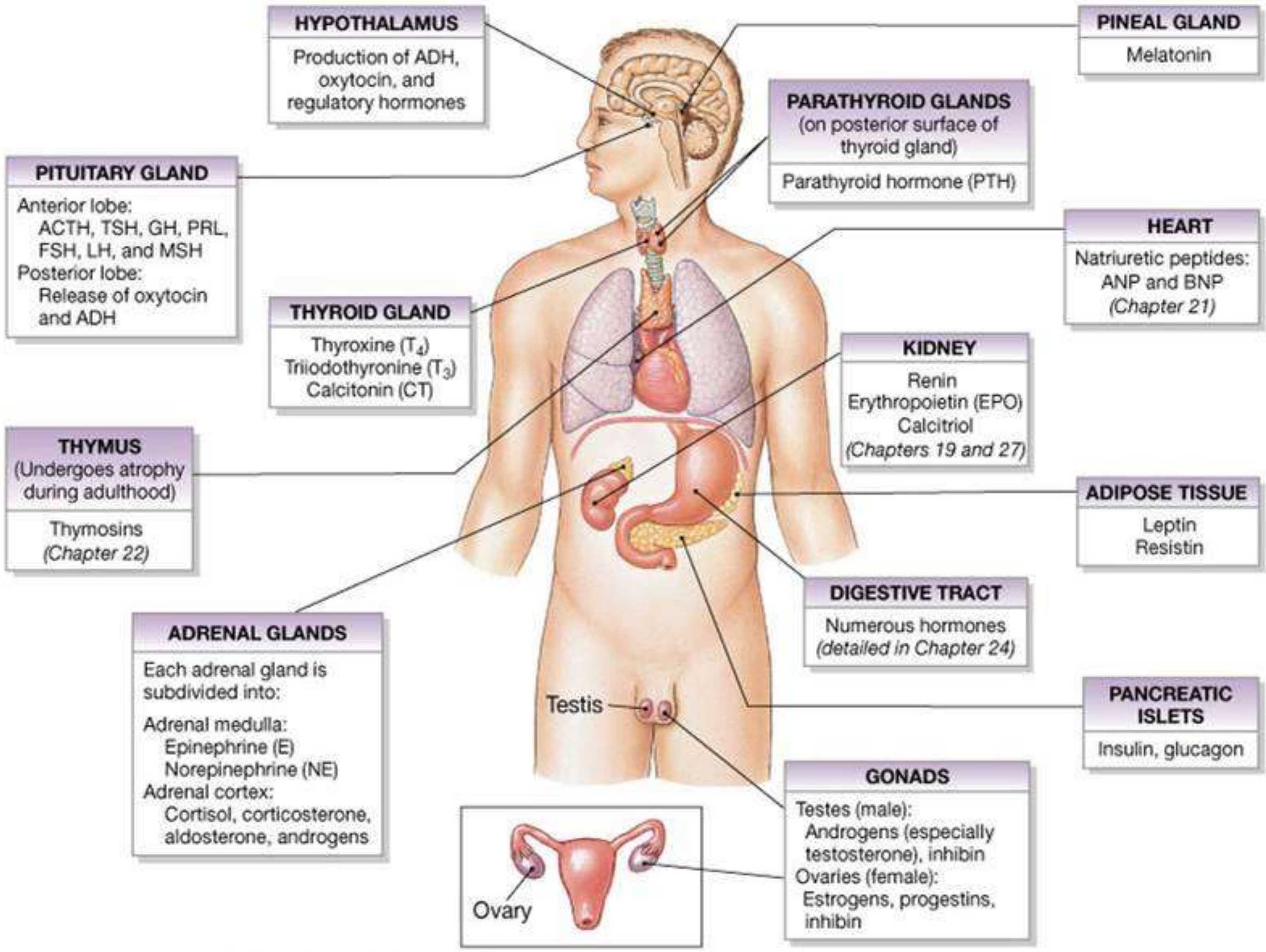
How hormones work

A hormone will only act on a part of the body if it 'fits'. A hormone can be thought of as a key, and its target site (such as an organ) has specially shaped locks on the cell walls. If the hormone fits the cell wall, then it will work.

The hormones can set off a cascade of other signaling pathways in the cell to cause an immediate effect (for instance, insulin signaling leads to a rapid uptake of glucose into muscle cells) or a more delayed effect (glucocorticoids bind to DNA elements in a cell to switch on the production of certain proteins, which takes a while to produce).

The endocrine system is a tightly regulated system that keeps the hormones and their effects at just the right level. One way this is achieved is through ‘feedback loops’. The release of hormones is regulated by other hormones, proteins or neuronal signals.

The released hormone then has its effect on other organs. This effect on the organ feeds back to the original signal to control any further hormone release. The pituitary gland is well known for its feedback loops



Other Hormone Producing Organs

In addition to the glands of the endocrine system, many other non-glandular organs and tissues in the body produce hormones as well.

- *Heart*: The cardiac muscle tissue of the **heart** is capable of producing the hormone atrial natriuretic peptide (ANP) in response to **high blood pressure** levels. ANP works to reduce blood pressure by triggering vasodilation to provide more space for the blood to travel through. ANP also reduces blood volume and pressure by causing water and salt to be excreted out of the blood by the kidneys.

- *Kidneys*: The **kidneys** produce the hormone erythropoietin (EPO) in response to low levels of oxygen in the blood. EPO released by the kidneys travels to the red bone marrow where it stimulates an increased production of red blood cells. The number of red blood cells increases the oxygen carrying capacity of the blood, eventually ending the production of EPO.

- *Digestive System*: The hormones cholecystokinin (CCK), secretin, and gastrin are all produced by the organs of the gastrointestinal tract. CCK, secretin, and gastrin all help to regulate the secretion of pancreatic juice, bile, and gastric juice in response to the presence of food in the stomach. CCK is also instrumental in the sensation of satiety or "fullness" after eating a meal.

- *Adipose*: Adipose tissue produces the hormone leptin that is involved in the management of appetite and energy usage by the body. Leptin is produced at levels relative to the amount of adipose tissue in the body, allowing the brain to monitor the body's energy storage condition. When the body contains a sufficient level of adipose for energy storage, the level of leptin in the blood tells the brain that the body is not starving and may work normally. If the level of adipose or leptin decreases below a certain threshold, the body enters starvation mode and attempts to conserve energy through increased hunger and food intake and decreased energy usage. Adipose tissue also produces very low levels of estrogens in both men and women. In obese people the large volume of adipose tissue may lead to abnormal estrogen levels.

- *Placenta*: In pregnant women, the placenta produces several hormones that help to maintain pregnancy. Progesterone is produced to relax the uterus, protect the fetus from the mother's **immune system**, and prevent premature delivery of the fetus. Human chorionic gonadotropin (HCG) assists progesterone by signaling the ovaries to maintain the production of estrogen and progesterone throughout pregnancy.
- *Local Hormones*: Prostaglandins and leukotrienes are produced by every tissue in the body (except for blood tissue) in response to damaging stimuli. These two hormones mainly affect the cells that are local to the source of damage, leaving the rest of the body free to function normally.

1. Prostaglandins cause swelling, inflammation, increased pain sensitivity, and increased local body temperature to help block damaged regions of the body from infection or further damage. They act as the body's natural bandages to keep pathogens out and swell around damaged joints like a natural cast to limit movement.
2. Leukotrienes help the body heal after prostaglandins have taken effect by reducing inflammation while helping white blood cells to move into the region to clean up pathogens and damaged tissues.

Endocrine System vs. Nervous System Function

The endocrine system works alongside of the nervous system to form the control systems of the body. The nervous system provides a very fast and narrowly targeted system to turn on specific glands and muscles throughout the body. The endocrine system, on the other hand, is much slower acting, but has very widespread, long lasting, and powerful effects. Hormones are distributed by glands through the bloodstream to the entire body, affecting any cell with a receptor for a particular hormone. Most hormones affect cells in several organs or throughout the entire body, leading to many diverse and powerful responses.

Hormone Properties

Once hormones have been produced by glands, they are distributed through the body via the bloodstream. As hormones travel through the body, they pass through cells or along the plasma membranes of cells until they encounter a receptor for that particular hormone. Hormones can only affect target cells that have the appropriate receptors. This property of hormones is known as specificity. Hormone specificity explains how each hormone can have specific effects in widespread parts of the body.

Many hormones produced by the endocrine system are classified as tropic hormones. A tropic hormone is a hormone that is able to trigger the release of another hormone in another gland. Tropic hormones provide a pathway of control for hormone production as well as a way for glands to be controlled in distant regions of the body. Many of the hormones produced by the pituitary gland, such as TSH, ACTH, and FSH are tropic hormones.

Hormonal Regulation

The levels of hormones in the body can be regulated by several factors. The nervous system can control hormone levels through the action of the hypothalamus and its releasing and inhibiting hormones. For example, TRH produced by the hypothalamus stimulates the anterior pituitary to produce TSH. Tropic hormones provide another level of control for the release of hormones. For example, TSH is a tropic hormone that stimulates the thyroid gland to produce T3 and T4. Nutrition can also control the levels of hormones in the body. For example, the thyroid hormones T3 and T4 require 3 or 4 iodine atoms, respectively, to be produced. In people lacking iodine in their diet, they will fail to produce sufficient levels of thyroid hormones to maintain a healthy metabolic rate. Finally, the number of receptors present in cells can be varied by cells in response to hormones. Cells that are exposed to high levels of hormones for extended periods of time can begin to reduce the number of receptors that they produce, leading to reduced hormonal control of the cell.

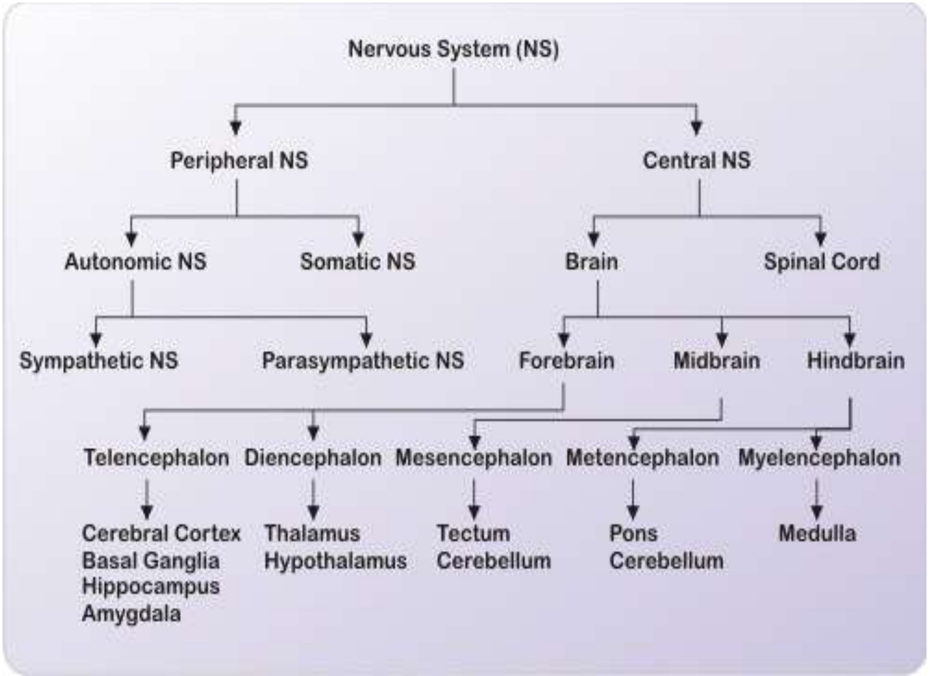
Classes of Hormones

Hormones are classified into 2 categories depending on their chemical make-up and solubility: water-soluble and lipid-soluble hormones. Each of these classes of hormones has specific mechanisms for their function that dictate how they affect their target cells.

- *Water-soluble hormones*: Water-soluble hormones include the peptide and amino-acid hormones such as insulin, epinephrine, HGH, and oxytocin. As their name indicates, these hormones are soluble in water. Water-soluble hormones are unable to pass through the phospholipid bilayer of the plasma membrane and are therefore dependent upon receptor molecules on the surface of cells. When a water-soluble hormone binds to a receptor molecule on the surface of a cell, it triggers a reaction inside of the cell. This reaction may change a factor inside of the cell such as the permeability of the membrane or the activation of another molecule. A common reaction is to cause molecules of cyclic adenosine monophosphate (cAMP) to be synthesized from adenosine triphosphate (ATP) present in the cell. cAMP acts as a second messenger within the cell where it binds to a second receptor to change the function of the cell's physiology.

- *Lipid-soluble hormones*: Lipid-soluble hormones include the steroid hormones such as testosterone, estrogens, glucocorticoids, and mineralocorticoids. Because they are soluble in lipids, these hormones are able to pass directly through the phospholipid bilayer of the plasma membrane and bind directly to receptors inside the cell nucleus. Lipid-soluble hormones are able to directly control the function of a cell from these receptors, often triggering the transcription of particular genes in the DNA to produce "messenger RNAs (mRNAs)" that are used to make proteins that affect the cell's growth and function.

Nervous systems:

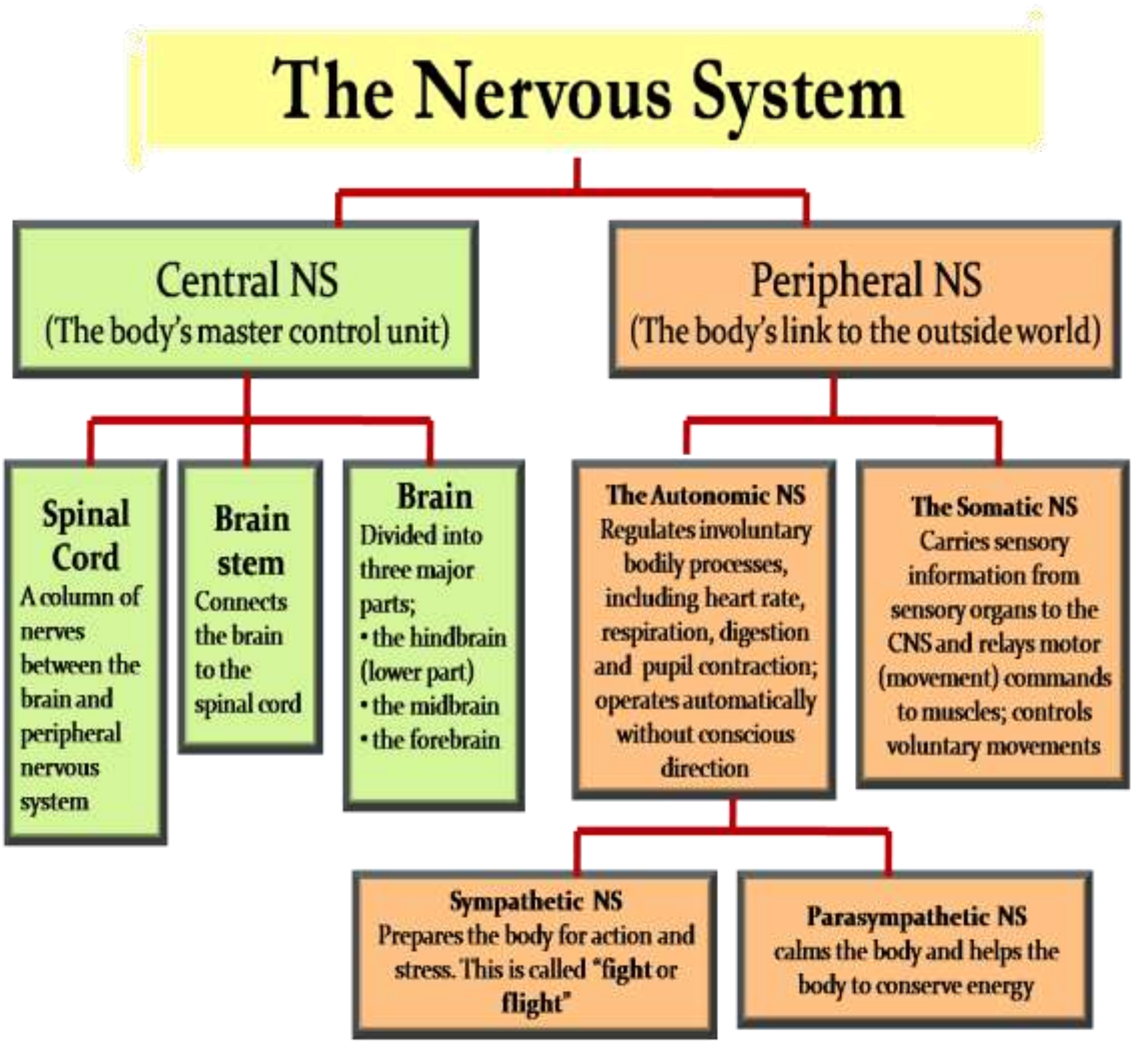


The nervous system is a complex collection of nerves and specialized cells known as neurons that transmit signals between different parts of the body. It is essentially the body's electrical wiring. Nerves are cylindrical bundles of fibers that start at the brain and central cord and branch out to every other part of the body. Every minute of every day, your nervous system is sending and receiving countless messages about what is happening both inside and around your body. Right now, your nervous system is receiving sensory input from your eyes about the words on the screen, from your ears about the sound of the computer, from your skin about the feel of your clothes, etc. At the same time, your brain is receiving information from sensors that monitor your heartrate, blood pressure, levels of oxygen and the contents of your stomach and intestines. Your brain then interprets all of these signals, which allows for an understanding of the words on the screen, the recognition of the noise as computer noise, and the development of motor responses such as moving your eyeballs, changing positions in your chair, and decreasing or increasing your heartrate and digestion. In short, your nervous system coordinates all the activities of your body. This module will provide a general overview of the nervous system as a whole. A word of caution: A system capable of so many sophisticated and complicated functions has to be extremely complex. One module cannot possibly present all the information about the nervous system, and it will probably take a few trips through the nervous system before the pieces fall into place, so don't despair if you're a bit confused. *An Introduction to Nervous Systems* presents the principles of neurobiology from an evolutionary perspective—from single–celled organisms to complex invertebrates such as flies—and is ideal for use as a supplemental textbook. Greenspan describes the mechanisms that allow behavior to become ever more sophisticated—from simple avoidance behavior of *Paramecium* through to the complex cognitive behaviors of the honeybee—and shows how these mechanisms produce the increasing neural complexity found in these organisms. The book ends with a discussion of what is universal about nervous systems and what may be required, neurobiologically, to be human. This novel and highly readable presentation of fundamental principles of neurobiology is designed to be accessible to undergraduate and graduate students not already steeped in the subject.

The Central **nervous system** is made up of the brain and spinal cord and The Peripheral **nervous system** is made up of the Somatic and the Autonomic **nervous systems**. The Central **nervous system**. The central **nervous system** is divided into two major parts: the brain and the spinal cord. The**nervous system** has two major parts: the central **nervous system**(CNS) and the peripheral **nervous system** (PNS). The central **system**is the primary control center for the body and is composed of the brain and spinal cord. he **nervous system** has three **main** functions: gathering sensory input, integrating data, and forming motor output. Neurons sense external stimuli through receptors in the body, providing the first major **function of the nervous system**—gathering sensory input. The nervous system consists of the brain, spinal cord, and a complex network of neurons. This system is responsible for sending, receiving, and interpreting information from all parts of the body. The nervous system monitors and coordinates **internal** organ function and responds to changes in the external environment.

The nervous system is a complex network of nerves and cells that carry messages to and from the brain and spinal cord to various parts of the body.

The nervous system includes both the Central nervous system and Peripheral nervous system. The Central nervous system is made up of the brain and spinal cord and The Peripheral nervous system is made up of the Somatic and the Autonomic nervous systems.



In vertebrates the system has two main divisions, the central and the peripheral nervous systems. The central nervous system consists of the brain and spinal cord. Linked to these are the cranial, spinal, and autonomic nerves, which, with their branches, constitute the peripheral nervous system. The brain might be compared to a computer and its memory banks, the spinal cord to the conducting cable for the computer's input and output, and the nerves to a circuit supplying input information to the cable and transmitting the output to muscles and organs.

The nervous system is built up of nerve cells, called neurons, which are supported and protected by other cells. Of the 200 billion or so neurons making up the human nervous system, approximately half are found in the brain. From the cell body of a typical neuron extend one or more outgrowths (dendrites), threadlike structures that divide and subdivide into ever smaller branches. Another, usually longer structure called the axon also stretches from the cell body. It sometimes branches along its length but always branches at its microscopic tip. When the cell body of a neuron is chemically stimulated, it generates an impulse that passes from the axon of one neuron to the dendrite of another; the junction between axon and dendrite is called a synapse. Such impulses carry information throughout the nervous system. Electrical impulses may pass directly from axon to axon, from axon to dendrite, or from dendrite to dendrite.

So-called white matter in the central nervous system consists primarily of axons coated with light-colored myelin produced by certain neuroglial cells. Nerve cell bodies that are not coated with white matter are known as gray matter. Nonmyelinated axons that are outside the central nervous system are enclosed only in a tubelike neurilemma sheath composed of Schwann cells, which are necessary for nerve regeneration. There are regular intervals along peripheral axons where the myelin sheath is interrupted. These areas, called nodes of Ranvier, are the points between which nerve impulses, in myelinated fibers, jump, rather than pass, continuously along the fiber (as is the case in unmyelinated fibers). Transmission of impulses is faster in myelinated nerves, varying from about 3 to 300 ft (1–91 m) per sec.

Both myelinated and unmyelinated dendrites and axons are termed nerve fibers; a nerve is a bundle of nerve fibers; a cluster of nerve cell bodies (neurons) on a peripheral nerve is called a ganglion. Neurons are located either in the brain, in the spinal cord, or in peripheral ganglia. Grouped and interconnected ganglia form a plexus, or nerve center. Sensory (afferent) nerve fibers deliver impulses from receptor terminals in the skin and organs to the central nervous system via the peripheral nervous system. Motor (efferent) fibers carry impulses from the central nervous system to effector terminals in muscles and glands via the peripheral system.

The peripheral system has 12 pairs of cranial nerves: olfactory, optic, oculomotor, trochlear, trigeminal, abducent, facial, vestibulo-cochlear (formerly known as acoustic), glossopharyngeal, vagus, spinal accessory, and hypoglossal. These have their origin in the brain and primarily control the activities of structures in the head and neck. The spinal nerves arise in the spinal cord, 31 pairs radiating to either side of the body: 8 cervical, 12 thoracic, 5 lumbar, 5 sacral, and 1 coccygeal.

Autonomic Nervous System

The autonomic nerve fibers form a subsidiary system that regulates the iris of the eye and the smooth-muscle action of the heart, blood vessels, glands, lungs, stomach, colon, bladder, and other visceral organs not subject to willful control. Although the autonomic nervous system's impulses originate in the central nervous system, it performs the most basic human functions more or less automatically, without conscious intervention of higher brain centers. Because it is linked to those centers, however, the autonomic system is influenced by the emotions; for example, anger can increase the rate of heartbeat. All of the fibers of the autonomic nervous system are motor channels, and their impulses arise from the nerve tissue itself, so that the organs they innervate perform more or less involuntarily and do not require stimulation to function.

Autonomic nerve fibers exit from the central nervous system as part of other peripheral nerves but branch from them to form two more subsystems: the sympathetic and parasympathetic nervous systems, the actions of which usually oppose each other. For example, sympathetic nerves cause arteries to contract while parasympathetic nerves cause them to dilate. Sympathetic impulses are conducted to the organs by two or more neurons. The cell body of the first lies within the central nervous system and that of the second in an external ganglion. Eighteen pairs of such ganglia interconnect by nerve fibers to form a double chain just outside the spine and running parallel to it. Parasympathetic impulses are also relayed by at least two neurons, but the cell body of the second generally lies near or within the target organ.

Autonomic Nervous System

Another part of the nervous system is the Autonomic Nervous System. It has three parts:

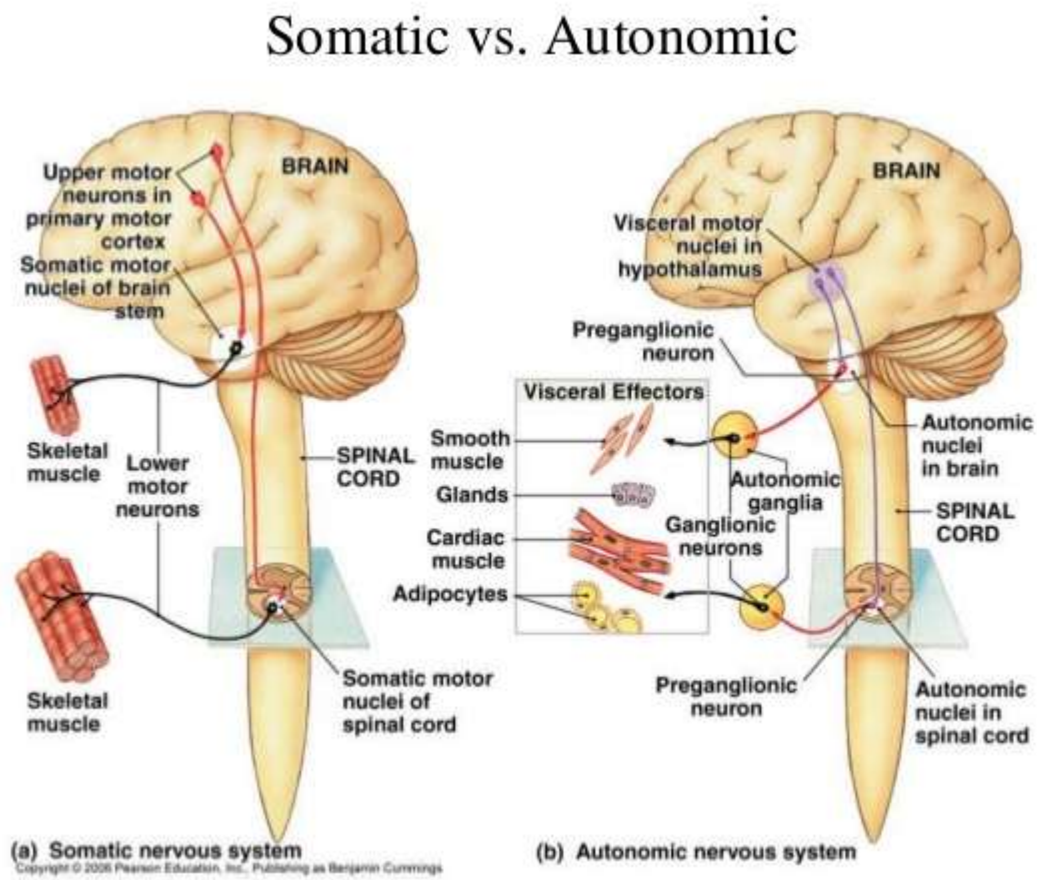
- the sympathetic nervous system

- the parasympathetic nervous system
- the enteric nervous system

This nervous system controls the nerves of the inner organs of the body on which humans have no conscious control. This includes the heartbeat, digestion, breathing (except conscious breathing) etc.

The nerves of the autonomic nervous system enervate the smooth involuntary muscles of the (internal organs) and glands and cause them to function and secrete their enzymes etc.

The Enteric nervous system is the third part of the autonomic nervous system. The enteric nervous system is a complex network of nerve fibers that innervate the organs within the abdomen like the gastrointestinal tract, pancreas, gall bladder etc. It contains nearly 100 million nerves.



Somatic nervous system

The somatic nervous system consists of peripheral nerve fibers that pick up sensory information or sensations from the peripheral or distant organs (those away from the brain like limbs) and carry them to the central nervous system.

These also consist of motor nerve fibers that come out of the brain and take the messages for movement and necessary action to the skeletal muscles. For example, on touching a hot object the sensory nerves carry information about the heat to the brain, which in turn, via the motor nerves, tells the muscles of the hand to withdraw it immediately.

The whole process takes less than a second to happen. The cell body of the neuron that carries the information often lies within the brain or spinal cord and projects directly to a skeletal muscle.

The nervous system consists of the brain, spinal cord, sensory organs, and all of the nerves that connect these organs with the rest of the body. Together, these organs are responsible for the control of the body and communication among its parts. The brain and spinal cord form the control center known as the central nervous system (CNS), where information is evaluated and decisions made. The sensory nerves and sense organs of the peripheral nervous system (PNS) monitor conditions inside and outside of the body and send this information to the CNS. Efferent nerves in the PNS carry signals from the control center to the muscles, glands, and organs to regulate their functions.

Nervous Tissue

The majority of the nervous system is tissue made up of two classes of cells: neurons and neuroglia.

Neurons. Neurons, also known as nerve cells, communicate within the body by transmitting electrochemical signals. Neurons look quite different from other cells in the body due to the many long cellular processes that extend from their central cell body. The cell body is the roughly round part of a neuron that contains the nucleus, mitochondria, and most of the cellular organelles. Small tree-like structures called dendrites extend from the cell body to pick up stimuli from the environment, other neurons, or sensory receptor cells. Long transmitting processes called axons extend from the cell body to send signals onward to other neurons or effect or cells in the body.

The smallest worker in the nervous system is the neuron. For each of the chain of impulses there is one preganglionic neuron, or one before the cell body or ganglion, that is like a central controlling body for numerous neurons going out peripherally.

The preganglionic neuron is located in either the brain or the spinal cord. In the autonomic nervous system this preganglionic neuron projects to an autonomic ganglion. The postganglionic neuron then projects to the target organ.

In the somatic nervous system there is only one neuron between the central nervous system and the target organ while the autonomic nervous system uses two neurons.

There are 3 basic classes of neurons: afferent neurons, efferent neurons, and inter neurons.

1. ***Afferent neurons*.** Also known as sensory neurons, afferent neurons transmit sensory signals to the central nervous system from receptors in the body.

2. ***Efferent neurons*.** Also known as motor neurons, efferent neurons transmit signals from the central nervous system to effectors in the body such as muscles and glands.

3. ***Interneurons*.** Interneurons form complex networks within the central nervous system to integrate the information received from afferent neurons and to direct the function of the body through efferent neurons.

- **Neuroglia**. Neuroglia, also known as glial cells, act as the "helper" cells of the nervous system. Each neuron in the body is surrounded by anywhere from 6 to 60 neuroglia that protect, feed, and insulate the neuron. Because neurons are extremely specialized cells that are essential to body function and almost never reproduce, neuroglia are vital to maintaining a functional nervous system.

The brain, a soft, wrinkled organ that weighs about 3 pounds, is located inside the cranial cavity, where the bones of the skull surround and protect it. The approximately 100 billion neurons of the brain form the main control center of the body. The brain and spinal cord together form the central nervous system (CNS), where information is processed and responses originate. The brain, the seat of higher mental functions such as consciousness, memory, planning, and voluntary actions, also controls lower body functions such as the maintenance of respiration, heart rate, blood pressure, and digestion.

The brain lies within the skull and is shaped like a mushroom. The brain consists of four principal parts:

- the brain stem
- the cerebrum
- the cerebellum
- the diencephalon

The brain weighs approximately 1.3 to 1.4 kg. It has nerve cells called the neurons and supporting cells called the glia.

There are two types of matter in the brain: grey matter and white matter. Grey matter receives and stores impulses. Cell bodies of neurons and neuroglia are in the grey matter. White matter in the brain carries impulses to and from grey matter. It consists of the nerve fibers (axons).

The brain stem

The brain stem is also known as the Medulla oblongata. It is located between the pons and the spinal cord and is only about one inch long.

The cerebrum

The cerebrum forms the bulk of the brain and is supported on the brain stem. The cerebrum is divided into two hemispheres. Each hemisphere controls the activities of the side of the body opposite that hemisphere.

The hemispheres are further divided into four lobes:

- Frontal lobe
- Temporal lobes
- Parietal lobe
- Occipital lobe

The cerebellum

This is located behind and below the cerebrum.

The diencephalon

The diencephalon is also known as the fore brain stem. It includes the thalamus and hypothalamus. The thalamus is where sensory and other impulses go and coalesce.

The hypothalamus is a smaller part of the diencephalon

Other parts of the brain

Other parts of the brain include the midbrain and the pons:

- the midbrain provides conduction pathways to and from higher and lower centers
- the pons acts as a pathway to higher structures; it contains conduction pathways between the medulla and higher brain centers

Spinal Cord

The **spinal cord** is a long, thin mass of bundled neurons that carries information through the vertebral cavity of the spine beginning at the **medulla oblongata** of the brain on its superior end and continuing inferiorly to the lumbar region of the spine. In the lumbar region, the spinal cord separates into a bundle of individual nerves called the**cauda equina** (due to its resemblance to a horse's tail) that continues inferiorly to the**sacrum** and **coccyx**. The white matter of the spinal cord functions as the main conduit of nerve signals to the body from the brain. The grey matter of the spinal cord integrates reflexes to stimuli.

Nerves

Nerves are bundles of axons in the peripheral nervous system (PNS) that act as information highways to carry signals between the brain and spinal cord and the rest of the body. Each axon is wrapped in a connective tissue sheath called the endoneurium. Individual axons of the nerve are bundled into groups of axons called fascicles, wrapped in a sheath of connective tissue called the perineurium. Finally, many fascicles are wrapped together in another layer of connective tissue called the epineurium to form a whole nerve. The wrapping of nerves with connective tissue helps to protect the axons and to increase the speed of their communication within the body.

- ***Afferent, Efferent, and Mixed Nerves*****.** Some of the nerves in the body are specialized for carrying information in only one direction, similar to a one-way street. Nerves that carry information from sensory receptors to the central nervous system only are called afferent nerves. Other neurons, known as efferent nerves, carry signals only from the central nervous system to effectors such as muscles and glands. Finally, some nerves are mixed nerves that contain both afferent and efferent axons. Mixed nerves function like 2-way streets where afferent axons act as lanes heading toward the central nervous system and efferent axons act as lanes heading away from the central nervous system.

- ***Cranial Nerves*****.** Extending from the inferior side of the brain are 12 pairs of cranial nerves. Each cranial nerve pair is identified by a Roman numeral 1 to 12 based upon its location along the anterior-posterior axis of the brain. Each nerve also has a descriptive name (e.g. olfactory, optic, etc.) that identifies its function or location. The cranial nerves provide a direct connection to the brain for the special sense organs, **muscles of the head**, neck, and shoulders, the heart, and the GI tract.

- ***Spinal Nerves*****.** Extending from the left and right sides of the spinal cord are 31 pairs of spinal nerves. The **spinal nerves** are mixed nerves that carry both sensory and motor signals between the spinal cord and specific regions of the body. The 31 spinal nerves are split into 5 groups named for the 5 regions of the vertebral column. Thus, there are 8 pairs of cervical nerves, 12 pairs of **thoracic nerves**, 5 pairs of**lumbar nerves**, 5 pairs of **sacral nerves**, and 1 pair of coccygeal nerves. Each spinal nerve exits from the spinal cord through the intervertebral foramen between a pair of vertebrae or between the **C1** vertebra and the **occipital bone** of the skull.

Meninges

The meninges are the protective coverings of the central nervous system (CNS). They consist of three layers: the dura mater, arachnoid mater, and pia mater

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- ***Dura mater*.** The **dura mater**, which means “tough mother,” is the thickest, toughest, and most superficial layer of meninges. Made of dense irregular connective tissue, it contains many tough collagen fibers and blood vessels. Dura mater protects the CNS from external damage, contains the cerebrospinal fluid that surrounds the CNS, and provides blood to the nervous tissue of the CNS.

- ***Arachnoid mater*.** The **arachnoid mater**, which means “spider-like mother,” is much thinner and more delicate than the dura mater. It lines the inside of the dura mater and contains many thin fibers that connect it to the underlying pia mater. These fibers cross a fluid-filled space called the subarachnoid space between the arachnoid mater and the pia mater.

- ***Pia mater*****.** The **pia mater**, which means “tender mother,” is a thin and delicate layer of tissue that rests on the outside of the brain and spinal cord. Containing many blood vessels that feed the nervous tissue of the CNS, the pia mater penetrates into the valleys of the sulci and fissures of the brain as it covers the entire surface of the CNS.

Cerebrospinal Fluid

The space surrounding the organs of the CNS is filled with a clear fluid known as cerebrospinal fluid (CSF). CSF is formed from blood plasma by special structures called **choroid plexuses**. The choroid plexuses contain many capillaries lined with epithelial tissue that filters blood plasma and allows the filtered fluid to enter the space around the brain.

Newly created CSF flows through the inside of the brain in hollow spaces called ventricles and through a small cavity in the middle of the spinal cord called the central canal. CSF also flows through the subarachnoid space around the outside of the brain and spinal cord. CSF is constantly produced at the choroid plexuses and is reabsorbed into the bloodstream at structures called arachnoid villi.

Cerebrospinal fluid provides several vital functions to the central nervous system:

1. CSF absorbs shocks between the brain and skull and between the spinal cord and vertebrae. This shock absorption protects the CNS from blows or sudden changes in velocity, such as during a car accident.

2. The brain and spinal cord float within the CSF, reducing their apparent weight through buoyancy. The brain is a very large but soft organ that requires a high volume of blood to function effectively. The reduced weight in cerebrospinal fluid allows the blood vessels of the brain to remain open and helps protect the nervous tissue from becoming crushed under its own weight.

3. CSF helps to maintain chemical homeostasis within the central nervous system. It contains ions, nutrients, oxygen, and albumins that support the chemical and osmotic balance of nervous tissue. CSF also removes waste products that form as byproducts of cellular metabolism within nervous tissue.

Sense Organs

All of the bodies' many sense organs are components of the nervous system. What are known as the special senses—vision, taste, smell, hearing, and balance—are all detected by specialized organs such as the **eyes**, **taste buds**, and olfactory epithelium. Sensory receptors for the general senses like touch, temperature, and pain are found throughout most of the body. All of the sensory receptors of the body are connected to afferent neurons that carry their sensory information to the CNS to be processed and integrated.

Functions of the Nervous System

The nervous system has 3 main functions: sensory, integration, and motor.

- ***Sensory*.** The sensory function of the nervous system involves collecting information from sensory receptors that monitor the body's internal and external conditions. These signals are then passed on to the central nervous system (CNS) for further processing by afferent neurons (and nerves).

- ***Integration*.** The process of integration is the processing of the many sensory signals that are passed into the CNS at any given time. These signals are evaluated, compared, used for decision making, discarded or committed to memory as deemed appropriate. Integration takes place in the gray matter of the brain and spinal cord and is performed by interneurons. Many interneurons work together to form complex networks that provide this processing power.

- ***Motor*.** Once the networks of interneurons in the CNS evaluate sensory information and decide on an action, they stimulate efferent neurons. Efferent neurons (also called motor neurons) carry signals from the gray matter of the CNS through the nerves of the peripheral nervous system to effector cells. The effector may be smooth, cardiac, or skeletal muscle tissue or glandular tissue. The effector then releases a hormone or moves a part of the body to respond to the stimulus.

Divisions of the Nervous System

Central Nervous System

The brain and spinal cord together form the central nervous system, or CNS. The CNS acts as the control center of the body by providing its processing, memory, and regulation systems. The CNS takes in all of the conscious and subconscious sensory information from the body’s sensory receptors to stay aware of the body’s internal and external conditions. Using this sensory information, it makes decisions about both conscious and subconscious actions to take to maintain the body’s homeostasis and ensure its survival. The CNS is also responsible for the higher functions of the nervous system such as language, creativity, expression, emotions, and personality. The brain is the seat of consciousness and determines who we are as individuals.

Peripheral Nervous System

The peripheral nervous system (PNS) includes all of the parts of the nervous system outside of the brain and spinal cord. These parts include all of the cranial and spinal nerves, ganglia, and sensory receptors.

Somatic Nervous System

The somatic nervous system (SNS) is a division of the PNS that includes all of the voluntary efferent neurons. The SNS is the only consciously controlled part of the PNS and is responsible for stimulating skeletal muscles in the body.

Autonomic Nervous System

The autonomic nervous system (ANS) is a division of the PNS that includes all of the involuntary efferent neurons. The ANS controls subconscious effectors such as visceral muscle tissue, cardiac muscle tissue, and glandular tissue.

There are 2 divisions of the autonomic nervous system in the body: the sympathetic and parasympathetic divisions.

- ***Sympathetic*.** The sympathetic division forms the body's "fight or flight" response to stress, danger, excitement, exercise, emotions, and embarrassment. The sympathetic division increases respiration and heart rate, releases adrenaline and other stress hormones, and decreases digestion to cope with these situations.

- ***Parasympathetic*.** The parasympathetic division forms the body's "rest and digest" response when the body is relaxed, resting, or feeding. The parasympathetic works to undo the work of the sympathetic division after a stressful situation. Among other functions, the parasympathetic division works to decrease respiration and heart rate, increase digestion, and permit the elimination of wastes.

Enteric Nervous System

The enteric nervous system (ENS) is the division of the ANS that is responsible for regulating digestion and the function of the digestive organs. The ENS receives signals from the central nervous system through both the sympathetic and parasympathetic divisions of the autonomic nervous system to help regulate its functions. However, the ENS mostly works independently of the CNS and continues to function without any outside input. For this reason, the ENS is often called the "brain of the gut" or the body's "second brain." The ENS is an immense system—almost as many neurons exist in the ENS as in the spinal cord.

Action Potentials

Neurons function through the generation and propagation of electrochemical signals known as action potentials (APs). An AP is created by the movement of sodium and potassium ions through the membrane of neurons.

- ***Resting Potential*.** At rest, neurons maintain a concentration of sodium ions outside of the cell and potassium ions inside of the cell. This concentration is maintained by the sodium-potassium pump of the cell membrane which pumps 3 sodium ions out of the cell for every 2 potassium ions that are pumped into the cell. The ion concentration results in a resting electrical potential of -70 millivolts (mV), which means that the inside of the cell has a negative charge compared to its surroundings.
- ***Threshold Potential*.** If a stimulus permits enough positive ions to enter a region of the cell to cause it to reach -55 mV, that region of the cell will open its voltage-gated sodium channels and allow sodium ions to diffuse into the cell. -55 mV is the threshold potential for neurons as this is the "trigger" voltage that they must reach to cross the threshold into forming an action potential.

- ***Depolarization.*** Sodium carries a positive charge that causes the cell to become depolarized (positively charged) compared to its normal negative charge. The voltage for depolarization of all neurons is +30 mV. The depolarization of the cell is the AP that is transmitted by the neuron as a nerve signal. The positive ions spread into neighboring regions of the cell, initiating a new AP in those regions as they reach -55 mV. The AP continues to spread down the cell membrane of the neuron until it reaches the end of an axon.
- ***Repolarization.*** After the depolarization voltage of +30 mV is reached, voltage-gated potassium ion channels open, allowing positive potassium ions to diffuse out of the cell. The loss of potassium along with the pumping of sodium ions back out of the cell through the sodium-potassium pump restores the cell to the -55 mV resting potential. At this point the neuron is ready to start a new action potential.

Synapses

A synapse is the junction between a neuron and another cell. Synapses may form between 2 neurons or between a neuron and an effector cell. There are two types of synapses found in the body: chemical synapses and electrical synapses.

- ***Chemical synapses.*** At the end of a neuron's axon is an enlarged region of the axon known as the axon terminal. The axon terminal is separated from the next cell by a small gap known as the synaptic cleft. When an AP reaches the axon terminal, it opens voltage-gated calcium ion channels. Calcium ions cause vesicles containing chemicals known as neurotransmitters (NT) to release their contents by exocytosis into the synaptic cleft. The NT molecules cross the synaptic cleft and bind to receptor molecules on the cell, forming a synapse with the neuron. These receptor molecules open ion channels that may either stimulate the receptor cell to form a new action potential or may inhibit the cell from forming an action potential when stimulated by another neuron.

- ***Electrical synapses*.** Electrical synapses are formed when 2 neurons are connected by small holes called gap junctions. The gap junctions allow electric current to pass from one neuron to the other, so that an AP in one cell is passed directly on to the other cell through the synapse.

Myelination

The axons of many neurons are covered by a coating of insulation known as myelin to increase the speed of nerve conduction throughout the body. Myelin is formed by 2 types of glial cells: Schwann cells in the PNS and oligodendrocytes in the CNS. In both cases, the glial cells wrap their plasma membrane around the axon many times to form a thick covering of lipids. The development of these myelin sheaths is known as myelination.

Myelination speeds up the movement of APs in the axon by reducing the number of APs that must form for a signal to reach the end of an axon. The myelination process begins speeding up nerve conduction in fetal development and continues into early adulthood. Myelinated axons appear white due to the presence of lipids and form the white matter of the inner brain and outer spinal cord. White matter is specialized for carrying information quickly through the brain and spinal cord. The gray matter of the brain and spinal cord are the unmyelinated integration centers where information is processed.

Reflexes

Reflexes are fast, involuntary responses to stimuli. The most well known reflex is the patellar reflex, which is checked when a physicians taps on a patient’s knee during a physical examination. Reflexes are integrated in the gray matter of the spinal cord or in the brain stem. Reflexes allow the body to respond to stimuli very quickly by sending responses to effectors before the nerve signals reach the conscious parts of the brain. This explains why people will often pull their hands away from a hot object before they realize they are in pain.

Functions of the Cranial Nerves

Each of the 12 cranial nerves has a specific function within the nervous system.

- The olfactory nerve (I) carries scent information to the brain from the olfactory epithelium in the roof of the nasal cavity.
- The **optic nerve** (II) carries visual information from the eyes to the brain.
- Oculomotor, trochlear, and abducens nerves (III, IV, and VI) all work together to allow the brain to control the movement and focus of the eyes. The **trigeminal nerve** (V) carries sensations from the face and innervates the muscles of mastication.
- The facial nerve (VII) innervates the muscles of the face to make facial expressions and carries taste information from the anterior 2/3 of the tongue.
- The vestibulocochlear nerve (VIII) conducts auditory and balance information from the ears to the brain.

- The glossopharyngeal nerve (IX) carries taste information from the posterior 1/3 of the tongue and assists in swallowing.
- The vagus nerve (X), sometimes called the wandering nerve due to the fact that it innervates many different areas, “wanders” through the head, neck, and torso. It carries information about the condition of the vital organs to the brain, delivers motor signals to control speech and delivers parasympathetic signals to many organs.
- The accessory nerve (XI) controls the movements of the shoulders and neck.
- The hypoglossal nerve (XII) moves the tongue for speech and swallowing.

Sensory Physiology

All sensory receptors can be classified by their structure and by the type of stimulus that they detect. Structurally, there are 3 classes of sensory receptors: free nerve endings, encapsulated nerve endings, and specialized cells. Free nerve endings are simply free dendrites at the end of a neuron that extend into a tissue. Pain, heat, and cold are all sensed through free nerve endings. An encapsulated nerve ending is a free nerve ending wrapped in a round capsule of connective tissue. When the capsule is deformed by touch or pressure, the neuron is stimulated to send signals to the CNS. Specialized cells detect stimuli from the 5 special senses: vision, hearing, balance, smell, and taste. Each of the special senses has its own unique sensory cells—such as rods and cones in the retina to detect light for the sense of vision.

Functionally, there are 6 major classes of receptors: mechanoreceptors, nociceptors, photoreceptors, chemoreceptors, osmoreceptors, and thermoreceptors.

- ***Mechanoreceptors*.** Mechanoreceptors are sensitive to mechanical stimuli like touch, pressure, vibration, and blood pressure.

- ***Nociceptors***. Nociceptors respond to stimuli such as extreme heat, cold, or tissue damage by sending pain signals to the CNS.

- ***Photoreceptors*.** Photoreceptors in the retina detect light to provide the sense of vision.

- ***Chemoreceptors***. Chemoreceptors detect chemicals in the bloodstream and provide the senses of taste and smell.
- ***Osmoreceptors***. Osmoreceptors monitor the osmolarity of the blood to determine the body's hydration levels.

- ***Thermoreceptors*.** Thermoreceptors detect temperatures inside the body and in its surroundings.

The Nervous System and Reflexes

In general, nerve function is dependent on both sensory and motor fibers, sensory stimulation evoking motor response. Even the autonomic system is activated by sensory impulses from receptors in the organ or muscle. Where especially sensitive areas or powerful stimuli are concerned, it is not always necessary for a sensory impulse to reach the brain in order to trigger motor response. A sensory neuron may link directly to a motor neuron at a synapse in the spinal cord, forming a reflex arc that performs automatically. Thus, tapping the tendon below the kneecap causes the leg to jerk involuntarily because the impulse provoked by the tap, after traveling to the spinal cord, travels directly back to the leg muscle. Such a response is called an involuntary reflex action.

Commonly, the reflex arc includes one or more connector neurons that exert a modulating effect, allowing varying degrees of response, e.g., according to whether the stimulation is strong, weak, or prolonged. Reflex arcs are often linked with other arcs by nerve fibers in the spinal cord. Consequently, a number of reflex muscle responses may be triggered simultaneously, as when a person shudders and jerks away from the touch of an insect. Links between the reflex arcs and higher centers enable the brain to identify a sensory stimulus, such as pain; to note the reflex response, such as withdrawal; and to inhibit that response, as when the arm is held steady against the prick of a hypodermic needle.

Reflex patterns are inherited rather than learned, having evolved as involuntary survival mechanisms. But voluntary actions initiated in the brain may become reflex actions through continued association of a particular stimulus with a certain result. In such cases, an alteration of impulse routes occurs that permits responses without mediation by higher nerve centers. Such responses are called conditioned reflexes, the most famous example being one of the experiments Ivan Pavlov performed with dogs. After the dogs had learned to associate the provision of food with the sound of a bell, they salivated at the sound of the bell even when food was not offered. Habit formation and much of learning are dependent on conditioned reflexes. To illustrate, the brain of a student typist must coordinate sensory impulses from both the eyes and the muscles in order to direct the fingers to particular keys. After enough repetition the fingers automatically find and strike the proper keys even if the eyes are closed. The student has "learned" to type; that is, typing has become a conditioned reflex.

Disorders of the Nervous System

A number of diseases can significantly affect the proper functioning of the nervous system. Parkinson's disease, Huntington's disease, myasthenia gravis, andamyotrophic lateral sclerosis (commonly known as Lou Gehrig's disease) are some of the more severe diseases affecting the nervous system. Strokes, which are related to circulatory disorders, also may have permanent effects on the nervous system. Certain plant derivatives, such as belladonna, cocaine, and caffeine, have a variety of stimulatory, inhibitory, and hallucinatory effects on the nervous system.

Sense organs

Aristotle (384 BC - 322 BC) is credited with the traditional classification of the five sense organs: sight, smell, taste, touch, and hearing. As far back as the 1760's, the famous philosopher Immanuel Kant proposed that our knowledge of the outside world depends on our modes of perception. In order to define what is "extrasensory" we need to define what is "sensory". Each of the 5 senses consists of organs with specialized cellular structures that have receptors for specific stimuli. These cells have links to the nervous system and thus to the brain. Sensing is done at primitive levels in the cells and integrated into sensations in the nervous system. Sight is probably the most developed sense in humans, followed closely by hearing.

An organ of the body which responds to external stimuli by conveying impulses to the sensory nervous system. The sense organs — eyes, ears, tongue, skin, and nose — help to protect the body. The human sense organs contain receptors that relay information through sensory neurons to the appropriate places within the nervous system.

Each sense organ contains different receptors.

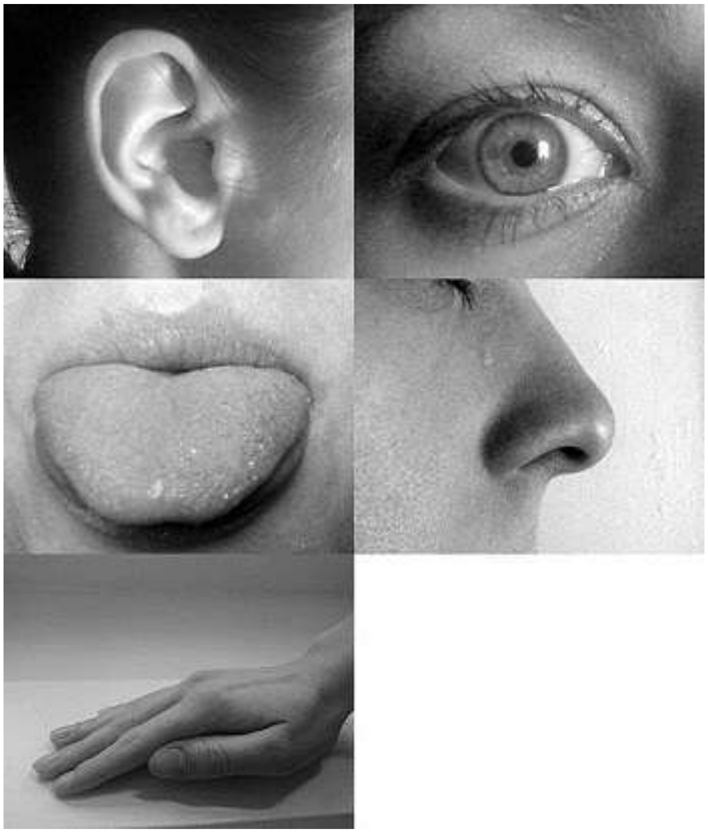
- ***General receptors*** are found throughout the body because they are present in skin, visceral organs (visceral meaning in the abdominal cavity), muscles, and joints.
- ***Special receptors*** include chemoreceptors (chemical receptors) found in the mouth and nose, photoreceptors (light receptors) found in the eyes, and mechanoreceptors found in the ears.

There are five senses: sight, hearing, taste, smell and touch. There are organs connected with these sense that take in information that is sent to the brain so that the body can act on it.

We use senses to gauge or understand the environment around us. In order for us to use our senses, we need**stimuli**. Stimuli are signals. These signals are gathered by **receptors**, and then **neurons** transmit the signal to the brain for interpretation. Your brain interprets the stimuli and responds accordingly. Sometimes, in response to stimuli, the brain will send back a signal for you to move your hand if something is too hot; or maybe the brain will tell you to continue to feel an object to get more information. Each of the senses has different receptors that gather stimuli before sending it to the neurons for transmission to the brain.

You can think of the process of stimuli getting to the brain as a relay race. The receptors are the first person in a relay race, and the stimuli is the baton that gets passed along. Neurons are the second person in the replay race, and receptors pass the baton or the stimuli to the neurons. Lastly, the neurons pass the stimuli to the brain for interpretation.

The **five senses** are the five main tools that humans use to perceive the world. Those senses are sight, smell, hearing, taste, and touch. We see with our eyes, we smell with our noses, we listen with our ears, we taste with our tongue, and we touch with our skin. Our brain receives signals from each of these organs, and interprets them to give us a sense of what's happening around us.



The Five Senses

Neurologists might argue that in reality there are far more than five senses - anywhere from 9 to 21. These include things like perception of heat, pressure, pain, and balance, among others.

But the five basic senses are still useful to know and far easier to remember. They're vitally important to how our bodies operate. Without our senses, we wouldn't have any idea what was going on around us and the human body would be functionally useless. Each of the senses therefore provides important functions and serves a particular intended purpose. Let's talk about some of those functions.

What Are the Functions of the Five Senses?

Eyes obviously allow us to see. But if you break it down, they do a more than just that. Using our eyes, we can judge depth, interpret new information, and identify color (the wavelengths of light that reflect off surfaces).

Seeing is believing: Sight

The eye is the organ of vision. It has a complex structure consisting of a transparent lens that focuses light on the retina. The retina is covered with two basic types of light-sensitive cells-rods and cones. The cone cells are sensitive to color and are located in the part of the retina called the fovea, where the light is focused by the lens. The rod cells are not sensitive to color, but have greater sensitivity to light than the cone cells. These cells are located around the fovea and are responsible for peripheral vision and night vision. The eye is connected to the brain through the optic nerve. The point of this connection is called the "blind spot" because it is insensitive to light. Experiments have shown that the back of the brain maps the visual input from the eyes.

The brain combines the input of our two eyes into a single three-dimensional image. In addition, even though the image on the retina is upside-down because of the focusing action of the lens, the brain compensates and provides the right-side-up perception. Experiments have been done with subjects fitted with prisms that invert the images. The subjects go through an initial period of great confusion, but subsequently they perceive the images as right side up.

The range of perception of the eye is phenomenal. In the dark, a substance produced by the rod cells increases the sensitivity of the eye so that it is possible to detect very dim light. In strong light, the iris contracts reducing the size of the aperture that admits light into the eye and a protective obscure substance reduces the exposure of the light-sensitive cells. The spectrum of light to which the eye is sensitive varies from the red to the violet. Lower electromagnetic frequencies in the infrared are sensed as heat, but cannot be seen. Higher frequencies in the ultraviolet and beyond cannot be seen either, but can be sensed as tingling of the skin or eyes depending on the frequency. The human eye is not sensitive to the polarization of light, i.e., light that oscillates on a specific plane. Bees, on the other hand, are sensitive to polarized light, and have a visual range that extends into the ultraviolet. Some kinds of snakes have special infrared sensors that enable them to hunt in absolute darkness using only the heat emitted by their prey. Birds have a higher density of light-sensing cells than humans do in their retinas, and therefore, higher visual acuity. Color blindness or "Daltonism" is a common abnormality in human vision that makes it impossible to differentiate colors accurately. One type of color blindness results in the inability to distinguish red from green. This can be a real handicap for certain types of occupations. To a colorblind person, a person with normal color vision would appear to have extrasensory perception. However, we want to reserve the term "extrasensory perception" for perception that is beyond the range of the normal.

When you look at an eye, the *iris* is the colored part. The iris actually is a pigmented muscle that controls the size of the *pupil*, which dilates to allow more light into the eye or contracts to allow less light into the eye. The iris and pupil are covered by the *cornea*.

Behind the pupil is an anterior chamber. Behind the anterior chamber is the*lens*. The ciliary body contains a small muscle that connects to the lens and the iris. The *ciliary muscle* changes the shape of the lens to adjust for far or near vision. The lens flattens to see farther away, and it becomes rounded for near vision. The process of changing the shape of the lens is called *accommodation*. People lose the ability of accommodation as they grow older, prompting the need for glasses.

Behind the lens of the eye is the *vitreous body*, which is filled with a gelatinous material called vitreous humor. This substance gives shape to the eyeball and also transmits light to the very back of the eyeball, where the *retina* lies. The retina contains *photoreceptors*, which detect light.

Two types of sensors detect light:

- ***Rods* detect motion**. The rods work harder in low light.
- ***Cones*** detect fine detail and color. The cones work best in bright light. There are three types of cones: one that detects blue, one that detects red, and one that detects green. Color blindness occurs when one type of cone is lacking.

When light strikes the rods and cones, nerve impulses are generated. The impulse travels to two types of neurons: first to *bipolar cells* and then to *ganglionic cells*. The axons of ganglionic cells form the *optic nerve*.

The optic nerve carries the impulse directly to the brain. Approximately 150 million rods are in a retina, but only 1 million ganglionic cells and nerve fibers are there, which means that many more rods can be stimulated than there are cells and nerve fibers to carry the impulses. Your eye must combine "messages" before the impulses are sent to the brain.

The eye is the organ of the sense of sight. Eyes detect light, and convert it to electro-chemical impulses in neurons.

Parts of the eye:

The transparent window at the front of the eye which is covered in a thin layer of tears.

Aqueous humor On the other side of the cornea is more moisture. This clear, watery fluid is the aqueous humor. It circulates throughout the front part of the eye and keeps a constant pressure within the eye.

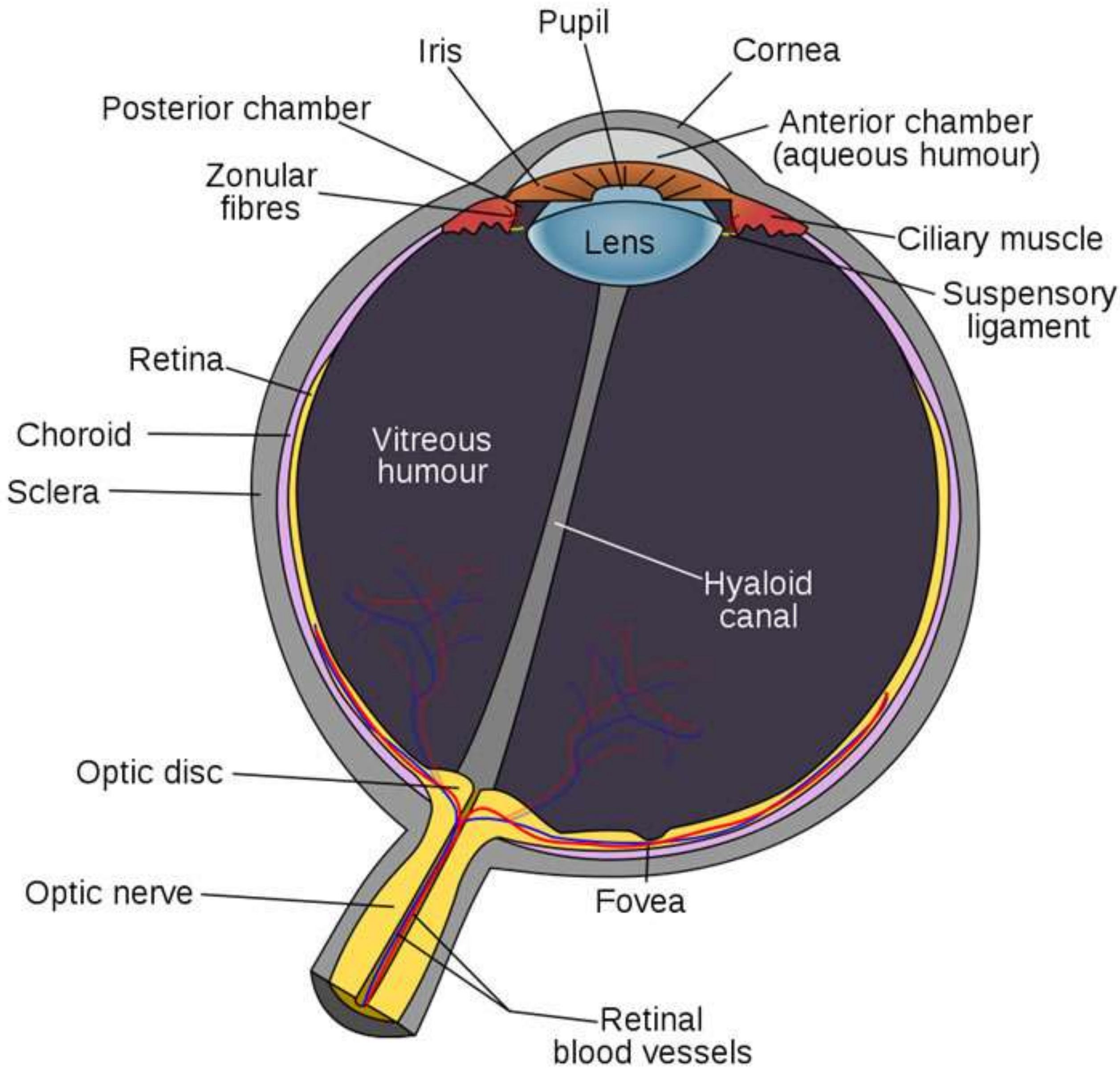
Pupil and iris:The pupil is the circular opening in the colored part of the eye which is the iris. The iris dilates or opens and contracts to let in more or less light.

Lens:Resembles the lens of a camera and focuses the light, changing shape as it takes in light reflected from objects near and far.

Vitreous:A clear jelly that the focused light passes through to the retina.

Retina: The inner lining at the back of the eye. It contains blood vessels which bring nutrients to the nerve cells. The macula is at the very center of the retina and contains the fovea. The photoreceptors of the retina are the rods and cones. The cones perceive color and finer elements. The retinal pigment epithelium, choroid and sclera are three more layers. The photoreceptors send light and images to a large nerve called the optic nerve. This carries the information to the occipital lobe of the brain where they are interpreted.

Eyelids and eyelashes: These protect the eye and along with tears keep the eye clear and moist.



Now hear this: Sound

The ear is the organ of hearing. The outer ear protrudes away from the head and is shaped like a cup to direct sounds toward the tympanic membrane, which transmits vibrations to the inner ear through a series of small bones in the middle ear called the *malleus*, *incus* and *stapes*. The inner ear, or cochlea, is a spiral-shaped chamber covered internally by nerve fibers that react to the vibrations and transmit impulses to the brain via the auditory nerve. The brain combines the input of our two ears to determine the direction and distance of sounds.

The inner ear has a vestibular system formed by three semicircular canals that are approximately at right angles to each other and which are responsible for the sense of balance and spatial orientation. The inner ear has chambers filled with a viscous fluid and small particles (otoliths) containing calcium carbonate. The movement of these particles over small hair cells in the inner ear sends signals to the brain that are interpreted as motion and acceleration.

The human ear can perceive frequencies from 16 cycles per second, which is a very deep bass, to 28,000 cycles per second, which is a very high pitch. Bats and dolphins can detect frequencies higher than 100,000 cycles per second. The human ear can detect pitch changes as small as 3 hundredths of one percent of the original frequency in some frequency ranges. Some people have "perfect pitch", which is the ability to map a tone precisely on the musical scale without reference to an external standard. It is estimated that less than one in ten thousand people have perfect pitch, but speakers of tonal languages like Vietnamese and Mandarin show remarkably precise absolute pitch in reading out lists of words because pitch is an essential feature in conveying the meaning of words in tone languages. The Eguchi

Method teaches perfect pitch to children starting before they are 4 years old. After age 7, the ability to recognize notes does not improve much.

The ear not only is the organ of hearing, but it also is responsible for maintaining equilibrium — or balance. To maintain equilibrium, the ear must detect movement. To hear, the ear must respond to mechanical stimulation by sound waves.

The outer ear is the external opening to the ear canal. Sound waves are shuttled through the ear canal to the middle ear. The eardrum sets the mechanics in motion:

1. When a sound wave hits the eardrum, the eardrum moves tiny bones — the malleus, incus, and stapes — which subsequently move.
2. This movement is picked up by the mechanoreceptors in the inner ear, which exist on hair cells containing cilia between the end of the semicircular canals and the vestibule.
3. When the cilia move, the cells create an impulse that is sent through the cochlea to the eighth cranial nerve, which carries the impulse to the brain.
4. The brain then interprets the information as a specific sound.

The fluid within the semicircular canals of the inner ear moves, and that movement is ultimately detected by the cilia. When the fluid doesn't stop moving, you can develop motion sickness. The cilia transmit impulses to the brain about angular and rotational movement, as well as movement through vertical and horizontal planes, which helps your body to keep its balance.The ear is the organ concerned with hearing. The ear has three parts: the outer ear, the middle ear and the inner ear.

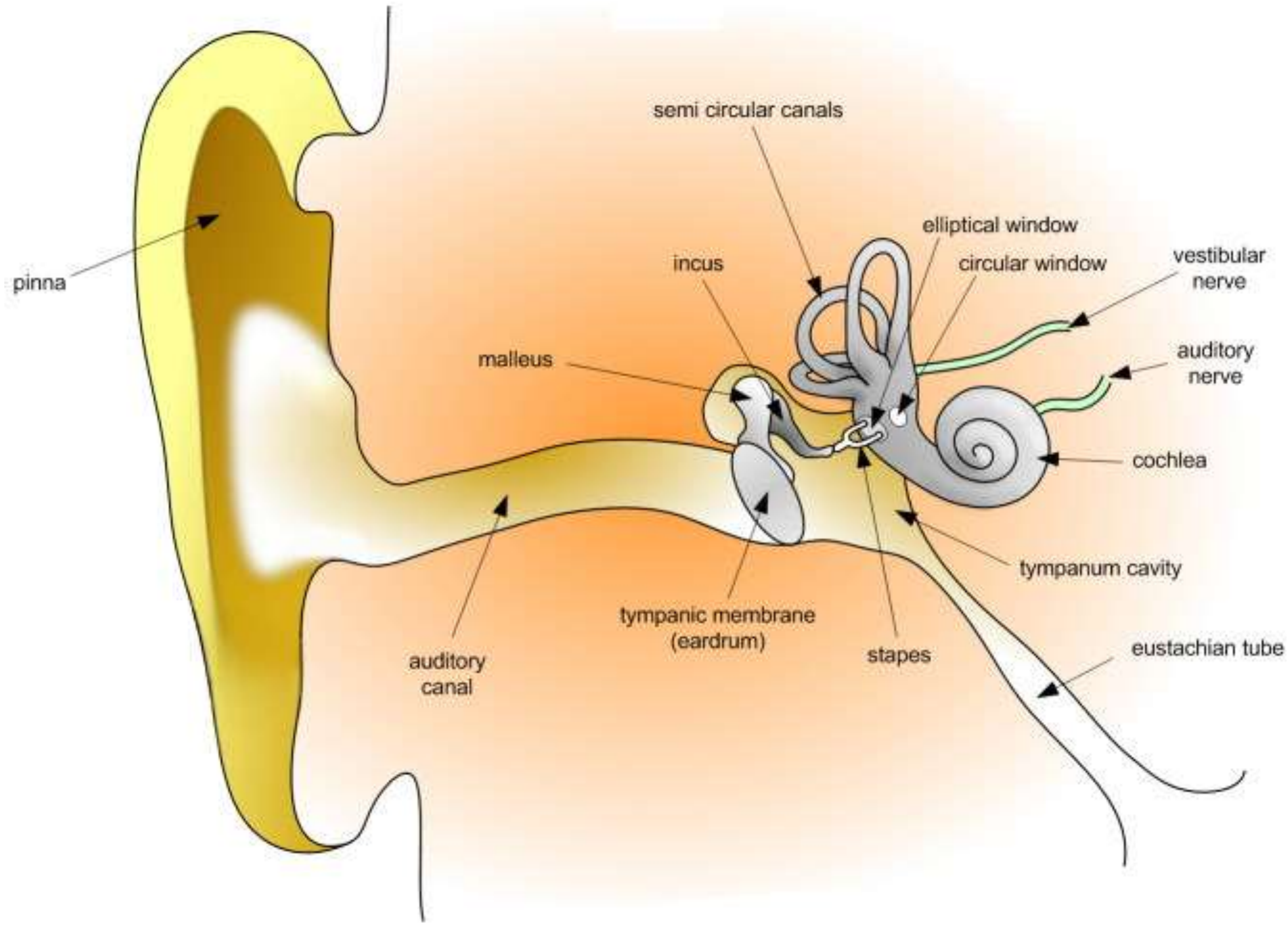
Outer ear: Pinna: The outermost part of the ear made of cartilage that is connected to the outer tube called the auditory canal. This leads to the eardrum.

Middle Ear Eardrum, stirrup, anvil and hammer: This membrane vibrates and along with the three tiny bones in the middle ear, the hammer, anvil and stirrup, and sends the stiumuli to the cochlea.

Inner Ear: Cochlea: Is spiral shaped and it transforms sound into nerve impulses that travel to the brain.

Semicircular canals: These fluid filled tubes attach to the cochlea and nerves in the inner ear. They send information on balance and head position to the brain.

Eustachian tube: Drains fluid from the middle ear into the throat behind the nose.

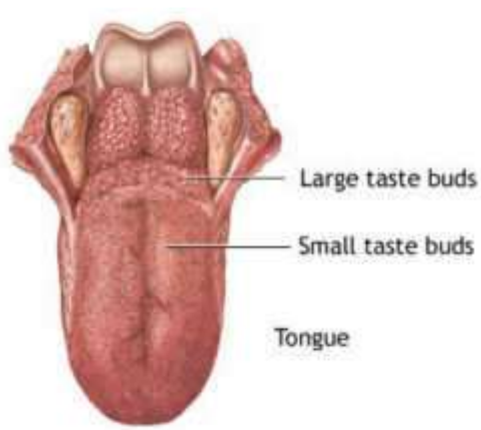


Mmm, mmm, good: Taste

Tongue:

The receptors for taste, called taste buds, are situated chiefly in the tongue, but they are also located in the roof of the mouth and near the pharynx. They are able to detect four basic tastes: salty, sweet, bitter, and sour. The tongue also can detect a sensation called "umami" from taste receptors sensitive to amino acids. Generally, the taste buds close to the tip of the tongue are sensitive to sweet tastes, whereas those in the back of the tongue are sensitive to bitter tastes. The taste buds on top and on the side of the tongue are sensitive to salty and sour tastes. At the base of each taste bud there is a nerve that sends the sensations to the brain. The sense of taste functions in coordination with the sense of smell. The number of taste buds varies substantially from individual to individual, but greater numbers increase sensitivity. Women, in general, have a greater number of taste buds than men. As in the case of color blindness, some people are insensitive to some tastes.

The senses of smell and taste work closely together. If you cannot smell something, you cannot taste it, either. Taste buds on your tongue contain chemoreceptors that work in a similar fashion to the chemoreceptors in the nasal cavity. However, the chemoreceptors in the nose will detect any kind of smell, whereas there are four different types of taste buds, and each detects different types of tastes: sweet, sour, bitter, and salty.



A common misconception is that the little bumps on your tongue are the taste buds. As with all misconceptions, this idea is wrong, too. The little bumps on your tongue are called papillae, and the taste buds actually lie down in the grooves between each papilla.

Foods contain chemicals, and when you put something into your mouth, the taste buds in your tongue can detect what chemicals you are ingesting. Each taste bud has a pore at one end with microvilli sticking out of the pore, and sensory nerve fibers attached to the other end. Chemicals from food bind to the microvilli, generating a nerve impulse that is carried through the sensory nerve fibers and eventually to the brain.

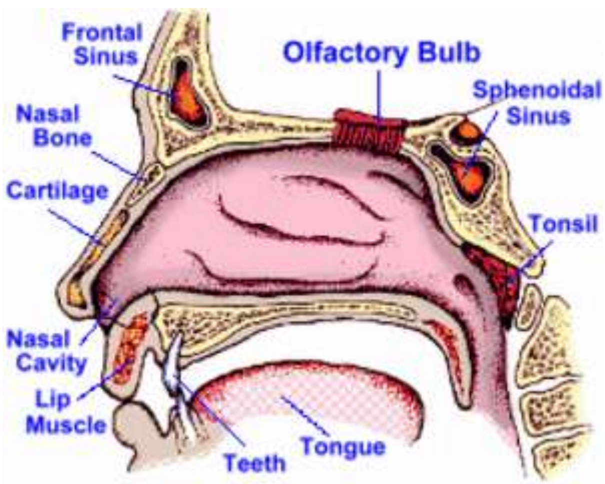
Is a muscular organ in the mouth. The tongue is covered with moist, pink tissue called mucosa and tiny bumps called papillae. Thousands of taste buds cover the surfaces of the papillae. Taste buds are collections of nerve-like cells that connect to nerves going into the brain. There are four types of taste buds: sour, sweet, bitter and salty. The tongue is vital in tasting and chewing food and in speech.

Oooh, that smell: Olfaction

Nose:

The nose is the organ responsible for the sense of smell. The cavity of the nose is lined with mucous membranes that have smell receptors connected to the olfactory nerve. The smells themselves consist of vapors of various substances. The smell receptors interact with the molecules of these vapors and transmit the sensations to the brain. The nose also has a structure called the vomeronasal organ whose function has not been determined, but which is suspected of being sensitive to pheromones that influence the reproductive cycle. The smell receptors are sensitive to seven types of sensations that can be characterized as camphor, musk, flower, mint, ether, acrid, or putrid. The sense of smell is sometimes temporarily lost when a person has a cold. Dogs have a sense of smell that is many times more sensitive than man's.

The nose, along with the mouth, lets air in and out of the body. It also helops us distinguish different smells in that air. The nasal root is the top of the nose, forming an indentation at the suture where the nasal bones meet the frontal bone. The anterior nasal spine is the thin projection of bone at the midline on the lower nasal margin, holding the cartilaginous center of the nose.[1] Adult humans have nasal hairs in the anterior nasal passage.



Olfactory cells line the top of your nasal cavity. On one end, olfactory cells have cilia — hair-like attachments — that project into the nasal cavity. On the other end of the cell, are olfactory nerve fibers, which pass through the ethmoid bone and into the olfactory bulb. The olfactory bulb is directly attached to the cerebral cortex of your brain.

As you breathe, anything that is in the air that you take in enters your nasal cavity: hydrogen, oxygen, nitrogen, dust, pollen, chemicals. You don't "smell" air or dust or pollen, but you can smell chemicals. The olfactory cells are chemoreceptors, which means the olfactory cells have protein receptors that can detect subtle differences in chemicals.

The chemicals bind to the cilia, which generate a nerve impulse that is carried through the olfactory cell, into the olfactory nerve fiber, up to the olfactory bulb and to your brain. Your brain determines what you are smelling. If you are sniffing something that you haven't experienced before, you need to use another sense, such as taste or sight, to make an imprint in your brain's memory.

A touchy-feely subject: Touch

The sense of touch is distributed throughout the body. Nerve endings in the skin and other parts of the body transmit sensations to the brain. Some parts of the body have a larger number of nerve endings and, therefore, are more sensitive. Four kinds of touch sensations can be identified: cold, heat, contact, and pain. Hairs on the skin magnify the sensitivity and act as an early warning system for the body. The fingertips and the sexual organs have the greatest concentration of nerve endings. The sexual organs have "erogenous zones" that when stimulated start a series of endocrine reactions and motor responses resulting in orgasm.

The skin contains general receptors. These receptors can detect touch, pain, pressure, and temperature. Throughout your skin, you have all four of these receptors interspersed. Skin receptors generate an impulse when activated, which is carried to the spinal cord and then to the brain.

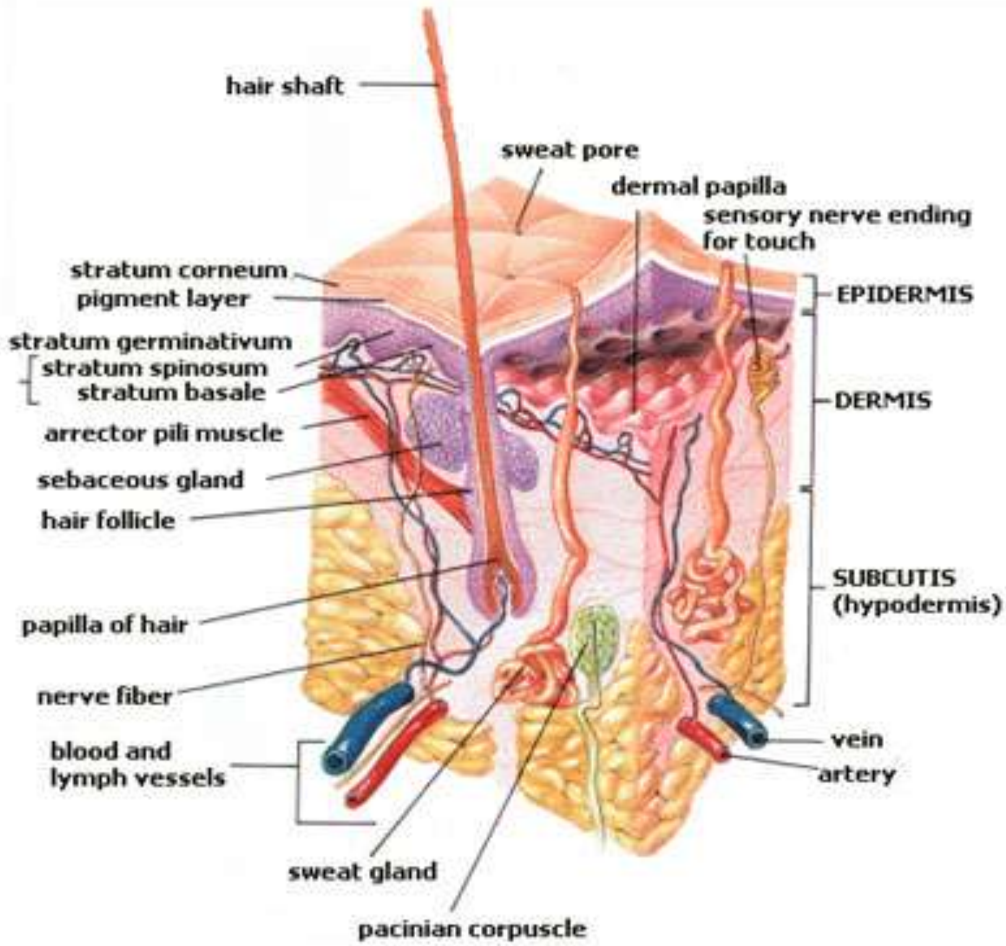
The skin is not the only tissue in the body to have receptors, however. Your organs, which are made of tissues, also have receptors. Joints, ligaments, and tendons contain *proprioceptors,* which detect the position and movement of the limbs.

Skin: The skin is the largest organ of the body, with a total area of about 20 square feet. The skin protects us from microbes and the elements, helps regulate body temperature, and permits the sensations of touch, heat, and cold. The epidermis, the outermost layer of skin, provides a waterproof barrier and creates our skin tone.

Layers: The dermis, beneath the epidermis, contains tough connective tissue, hair follicles, and sweat glands.

The deeper subcutaneous tissue (hypodermis) is made of fat and connective tissue.

The skin's color is created by special cells called melanocytes, which produce the pigment melanin. Melanocytes are located in the epidermis.



Beyond the five sense organs.

In addition to sight, smell, taste, touch, and hearing, humans also have awareness of balance (equilibrioception), pressure, temperature (thermoception), pain (nociception), and motion all of which may involve the coordinated use of multiple sensory organs. The sense of balance is maintained by a complex interaction of visual inputs, the proprioceptive sensors (which are affected by gravity and stretch sensors found in muscles, skin, and joints), the inner ear vestibular system, and the central nervous system. Disturbances occurring in any part of the balance system, or even within the brain's integration of inputs, can cause the feeling of dizziness or unsteadiness.

Kinesthesia is the precise awareness of muscle and joint movement that allows us to coordinate our muscles when we walk, talk, and use our hands. It is the sense of kinesthesia that enables us to touch the tip of our nose with our eyes closed or to know which part of the body we should scratch when we itch.

Synesthesia.

Some people experience a phenomenon called synesthesia in which one type of stimulation evokes the sensation of another. For example, the hearing of a sound may result in the sensation of the visualization of a color, or a shape may be sensed as a smell. Synesthesia is hereditary and it is estimated that it occurs in 1 out of 1000 individuals with variations of type and intensity. The most common forms of synesthesia link numbers or letters with colors.

Definition of physiology: A branch of biology that deals with the functions and activities of life or of living matter (as organs, tissues, or cells) and of the physical and chemical phenomena involved.

The organic processes and phenomena of an organism or any of its parts or of a particular bodily process

The scientific study of an organism's vital functions, including growth andde velopment, the absorption and processing of nutrients, the synthesis anddistri bution of proteins and other organic molecules, and the functioning ofdiffere nt tissues, organs, and other anatomic structures.

A physiology Studies the normal mechanical, physical, and biochemical process of animal’s and plants.

Physiology is the science of life. The discipline considers how molecules in cells interact to provide specific functions (molecular and cellular physiology) and how organs, which are collections of cell types, have local and distal actions via neural and humoral (e.g. hormones) communication to sustain the life of the organism. The latter represents systems or integrative physiology. Thus physiology is all about what makes our bodies work – how the organs – including the brain – function, how we grow and develop, how we sustain our bodily functions and what happens to these processes during disease and ageing. You can think of physiology as the functional side of biology – with the challenges and rewards of investigating living processes. Physiology contributes to all major aspects of biology, including comparative biology, neuroscience, and the allied disciplines of pharmacology, anatomy and pathology.

Physiological studies date back to ancient civilizations of India, Egypt alongside anatomical studies but did not utilize dissections and vivisection. The study of human physiology as a medical field dates back to at least 420 BC to the time of Hippocrates, also known as the "father of medicine." Hippocrates incorporated his belief system called the theory of humours, which consisted of four basic substances: earth, water, air and fire. Each substance is known for having a corresponding humour: black bile, phlegm, blood and yellow bile, respectively. Hippocrates also noted some emotional connections to the four humours, which Claudis Galenus would later expand on. The critical thinking of Aristotle and his emphasis on the relationship between structure and function marked the beginning of physiology in Ancient Greece. Like Hippocrates, Aristotle took to the humeral theory of disease, which also consisted of four primary qualities in life: hot, cold, wet and dry. Claudius Galenus (c. ~130–200 AD), known as Galen of Pergamum, was the first to use experiments to probe the functions of the body. Unlike Hippocrates though, Galen argued that humeral imbalances can be located in specific organs, including the entire body. His modification of this theory better equipped doctors to make more precise diagnoses. Galen also played off of Hippocrates idea that emotions were also tied to the humors, and added the notion of temperaments: sanguine corresponds with blood; phlegmatic is tied to phlegm; yellow bile is connected to choleric; and black bile corresponds with melancholy. Galen also saw the human body consisting of three connected systems: the brain and nerves, which are responsible for thoughts and sensations; the heart and arteries, which give life; and the liver and veins, which can be attributed to nutrition and growth.[10] To top it off, Galen was also the founder of experimental physiology. And for the next 1,400 years, Galenic physiology was a powerful and influential tool in medicine.

Physiology is the study of how molecules, cells and organs interact to form a whole being. The work of Physiological Society Members, advancing our knowledge of biological systems, is essential to the development of new treatments for disease. Since The Society's foundation in 1876, our membership has included more than 20 Nobel Prize winners from Ivan Pavlov to Andrew Huxley. The scientists who make up The Society have made many key discoveries, ranging from how our nervous system works, how our cells divide and the way in which our reflexes alter our behaviour. These have advanced our knowledge of biological systems and helped in the treatment of diseases such as cancer, cystic fibrosis and heart disease.

Human physiology, a branch of general physiology, is concerned with how the human body works. It is common to approach the study of human physiology through an organ-system approach. **Organ-systems** are collections of cells, tissues and organs, which have dedicated functions in the body. In the human body, the organ-systems are the nervous system, endocrine system, cardiovascular system, respiratory system, urinary system, musculoskeletal system, integumentary system, reproductive system, digestive system, and immune system. While the proper function of each organ-system is essential, it is the collective and integrative functions of all organ-systems that contribute to a healthy state. A thorough study of human physiology includes an understanding of the organ-systems as well as the underlying tissue, cellular, and molecular principles. Human physiology is a life science and a branch of animal physiology. It is specifically the study of how systems of the body function in a well state, and this analysis of function is often at the cellular level, not of single cells but of how cells work in concert to achieve a normal state of function. Basic human physiology studies the body's systems that function appropriately and as expected, while other disciplines like patho physiology may look at the way body systems develop disease in attempts to find insight into how to cure diseases.

There may be several main concerns in human physiology from a scientific standpoint. These concerns include the way interdependence between body systems occurs (such as the central nervous system and the musculoskeletal system). This is called integration.

Another point of interest is communication, which is how the body's systems send signals to function in specific ways. These signals could be electrical impulses or the release of chemicals. Lastly, the physiologist wants to define and observe homeostasis, in any of the systems studied. In other words how does the body maintain a normal state, and what are the processes by which it does so?

It might be oversimplification to say that human physiology attempts to answer the question of "how things work." However, this is fairly accurate, and it's an important question to answer. Understanding the normal function of the body's systems is valuable because it establishes baselines for understanding what is abnormal. It is very difficult to diagnose disease unless a clear deviation from the norm can be determined, and therefore establishing this norm is of great value in medicine and in human health.

For instance, over time, physiology and biochemistry have helped to determine what constitutes normal blood levels of certain substances. When something like sugar levels become too high, it may have impact on various systems in the body and be indication of diseases like diabetes. Only by knowing baseline levels for various sugar types in blood, can doctors determine whether diabetes is present. This knowledge has been extrapolated to allow patients to keep records of their own blood sugar at home. With testing they can be assured that they are regulating blood sugar appropriately or they can make medication adjustments when blood sugar levels are too high or too low.

It's suggested that early studies in human physiology and anatomy began over 2000 years ago, and names like Hippocrates and Aristotle are usually given as early physiologists. The trouble with early thought was it didn't allow for many examinations of humans, and most humans examined were dead. The idea of cells wouldn't be posited until much later in history. Much more was done in the field of anatomy, which is an intricately related discipline to human physiology, that describes the forms present in the body, and yet again, unless these forms were obvious and on the surface, they typically didn't get much exploration unless a person was dead.

More studies were possible on animals, and actually animal physiology is still used and extrapolated to human beings all of the time. Even today when medical science is much more delicate, most well humans would not consent to studies of some of the ways their body systems work. Few people would volunteer to have abnormal rhythms of their heart induced as part of electrophysiological cardiology studies to determine what causes arrhythmias, as this might be dangerous. However electro physiologists can induce arrhythmias in animals to determine what factors destroy balance in the electrical system in the heart.

Over time, human physiology has helped to define the major systems of the body and how they work to achieve wellness. Basic introductory courses tend to look at each of these systems, which may be roughly defined as the following: circulatory, respiratory, endocrine, reproductive, immune, musculoskeletal, nervous, integumentory, renal, and gastrointestinal.

While breaking the body into systems can help describe function, it isn't always so neat from a scientific standpoint. Systems are interdependent on each other. Lose renal or respiratory function, and everything else becomes affected. Moreover, many vital organs or parts of the body may participate in several systems.

The major systems covered in the study of human physiology are as follows:

- **Circulatory system:** including the heart, the blood vessels, properties of the blood and how circulation works in sickness and in health
- **Digestive/excretory system:** this domain charts the movement of solids from the mouth to the anus, and includes study of the spleen, liver and pancreas, the conversion of food into fuel and its consequent expulsion from the body
- **Endocrine system:** the study of endocrine hormones that carry signals throughout the organism, helping it to respond in concert. The principal endocrine glands - the pituitary, thyroid, adrenals, pancreas, parathyroid and gonads - are a major focus, but nearly all organs release endocrine hormones
- **Immune system:** the body's natural defense system comprises of white blood cells, the thymus and lymph systems. A complex array of receptors and molecules combine to protect the host from attacks by pathogens. Molecules such as antibodies and cytokines feature heavily
- **Integumentary system:** the skin, hair, nails, sweat glands and sebaceous glands (secreting an oily or waxy substance)
- **Musculoskeletal system:** the skeleton and muscles, tendons, ligaments and cartilage. **Bone marrow** - the site of red blood cell creation - and how bones store **calcium** and phosphate are included

- **Nervous system:** the central nervous system (brain and spinal cord) and the peripheral nervous system. Study of the nervous system includes research into the senses, memory, emotion and thought
- **Renal/urinary system:** including the kidneys, ureters, bladder and urethra, this system removes water from the blood, produces urine and carries away waste
- **Reproductive system:** consisting of the gonads and the sex organs. Study of this system also includes investigating the way a fetus is produced and nurtured for 9 months
- **Respiratory system:** consisting of the nose, naso pharynx, trachea, and lungs. This system brings in oxygen and expels carbon dioxide and water.

Other branches of physiology

Defense physiology investigates nature's natural defensive reactions.

There are a great number of disciplines that use the word physiology in their title. Below are some of the other physiological topics that have some relevance to medical science:

- **Cell physiology:** studying the way cells work and interact, cell physiology predominantly concentrates on membrane transport and neuron transmission
- **Systems physiology:** this discipline focuses on the computational and mathematical modeling of complex biological systems. It looks to describe the way individual cells or components of a system converge to respond as a whole. They often investigate metabolic networks and cell signaling
- **Evolutionary physiology:** studying the way systems or parts thereof have adapted and changed over multiple generations. Research topics cover a lot of ground including the role of behavior in evolution, sexual selection and physiological changes in relation to geographic variation
- **Defense physiology:** changes that occur as a reaction to a potential threat, such as preparation for the fight-or-flight response
- **Exercise physiology:** as the name suggests, this is the study of the physiology of physical exercise. This might include research into bioenergetics, biochemistry, cardiopulmonary function, biomechanics, hematology, skeletal muscle physiology, neuro endocrine function and nervous system function.

The topics mentioned above are but a small fraction of the available physiologies. The field of physiology is as essential as it is vast.

Exercise Physiology is the identification of **physiological** mechanisms underlying physical activity, the comprehensive delivery of treatment services concerned with the analysis, improvement, and maintenance of health and fitness, rehabilitation of heart disease and other chronic diseases and/or disabilities.

Sports science (also **sport science**) is a discipline that studies how the healthy human body works during exercise, and how sport and physical activity promote health from cellular to whole body perspectives. The study of sports science traditionally incorporates areas of physiology (exercise physiology), psychology (sportpsychology), anatomy, biomechanics, biochemistry and biokinetics. Sports scientists and performance consultants are growing in demand and employment numbers, with the ever-increasing focus within the sporting world on achieving the best results possible. Through the study of science and sport, researchers have developed a greater understanding on how the human body reacts to exercise, training, different environments and many other stimuli. **Exercise physiology** is the physiology of physical exercise. It is the study of the acute responses and chronic adaptations to a wide range of exercise conditions.

Exercise physiologists study the effect of exercise on pathology, and the mechanisms by which exercise can reduce or reverse disease progression.

Exercise **Physiology** is the study of how exercise alters the function and structure of the body. A **sports physiologist** examines the acute responses and chronic adaptations to athletic performance in a variety of environments.

Sports physiology is the study of the long-and short-term effects of training and conditions on athletes. This specialized field of study goes hand in hand with human anatomy. Anatomy is about structure, where physiology is about function.

Sports Training Principles are heavily rooted in this field. Effects of body composition, flexibility training, hydration, environmental conditions, and carbohydrate loading on athletic performance are only a few of the topics explored in this field.

Exercise physiologists, physicians, and athletic trainers can apply research findings from studies to advise athletes on topics concerning nutrition, sport-related injuries, and other issues related to sports medicine.

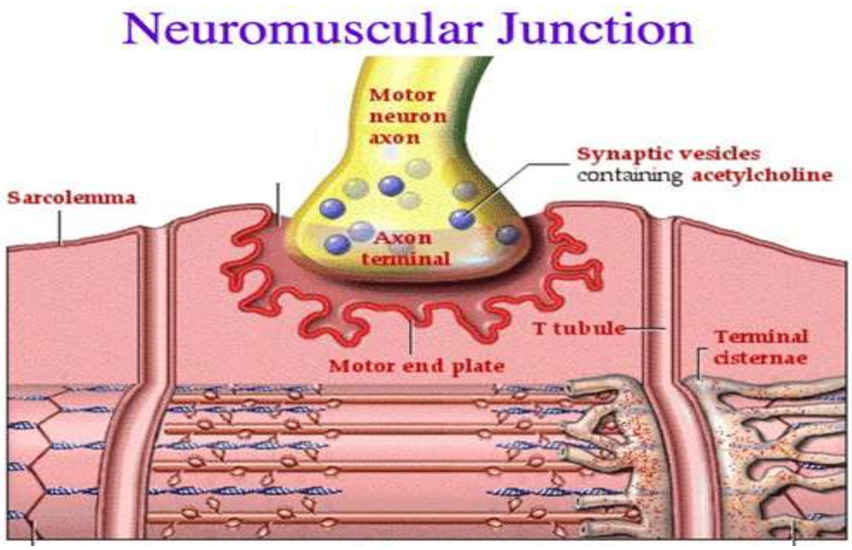
Exercise Physiology is the study of how exercise alters the function and structure of the body. A sports physiologist examines the acute responses and chronic adaptations to athletic performance in a variety of environments. The physiologist possesses a wide-ranging understanding of the body, enabling them to advise athletes and coaches of how training and preparation influence competition performance.

Testing can take place in the lab, which ensures a controlled environment to compare exercise test results. However, it is not always possible to simulate sporting activity in a lab and with advances in technology physiologists use field-based testing as much as possible. This work is vital as it can evaluate training as it happens; allowing the athlete and coach to objectively monitor what impact a particular session has had on the body.

Physiology can improve an athlete’s performance by giving important objective information which can help coaches to adapt training programmes to maximize their desired outcome. This will depend on many factors including the environment, diet, gender, age and health.

Exercise Physiology is the identification of physiological mechanisms underlying physical activity, the comprehensive delivery of treatment services concerned with the analysis, improvement, and maintenance of health and fitness, rehabilitation of heart disease and other chronic diseases and/or disabilities, and the professional guidance and counsel of athletes and others interested in athletics, sports training, and human adaptability to acute and chronic exercise.

What Is Neuromuscular Junction?



A motor neuron is responsible for causing a skeletal muscle to contract, by stimulating it. The gap or space present between this motor neuron and the skeletal muscle cell is called as a synapse. This synapse, specifically between the skeletal muscle cell and motor neuron is called neuromuscular junction or myoneural. Myo means Muscle and Neural means Nerves. When an impulse travels between this space, muscle contraction happens.

There are around 100-500 trillion such connections in the human brain, between two nerves or nerves and glands. In this article we will discuss only the neuromuscular junction.

Structure of Neuromuscular Junction

As we have read, a neuromuscular junction consists of a neuron and a skeletal muscle cell. The neuron in the combination is referred to as spinal motor neuron. The motor neurons, who originate from the spinal cord, innervate the skeletal muscle fibers. The innervations happens by very fine processes of the axon. The synapses are present along these processes and are also known as motor endplate, because of its specific structure.

The neuromuscular junction synapse has 3 characteristic features:

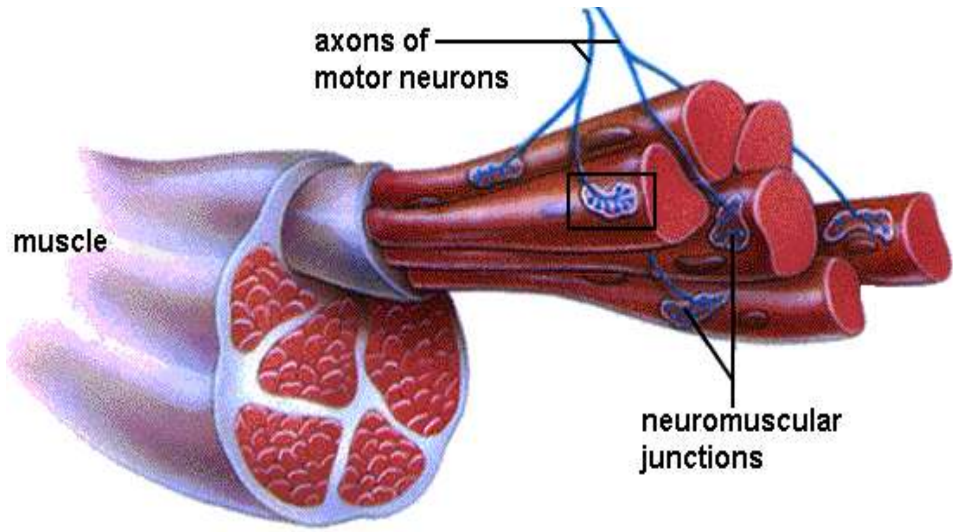
1. There are two membranes called the pre and post synaptic membranes. There exists a distinct space between these membranes and is known as Synaptic Cleft.

2. High density of small spherical vesicles is present, which contain neurotransmitter substances.

3. A thickened post synaptic membrane is present, which has high density of receptors that are responsible for binding the chemical substances which transmit the signal from the pre synaptic neuron.

Functions of Neuromuscular Junction

Before going in detail, let us remember the broad action of this junction. It is to act like a bridge between a neuron and muscle cell to transmit the signals.



Motor Neuron—Synaptic Cleft—Skeletal Muscle Cell

Calcium makes an entry in the excited motor neuron, which in turn causes exocytosis of the neurotransmitter. Which means the neurotransmitter gets transported to the only place available – the synaptic cleft. Acetylcholine is the neurotransmitter secreted by the somatic motor neurons.

There are receptors of acetylcholine present in the skeletal muscle cells. So this secreted acetylcholine then passes the cleft by diffusion and bind with the receptors. They are like puzzle pieces which fit or key which opens the door. This process opens an ion channel through which sodium ions pass to the muscle cells. At that time potassium ions diffuse out of muscle cells. However, the amount of Sodium ions entering is higher than the number of potassium ions leaving. Once the sodium ion reaches the muscle cell, it depolarizes, because it is a positive ion. This causes the skeletal muscle cell membrane to get excited and contract. This is referred to as Action Potential being triggered.

The acetylcholine does not remain in the synaptic cleft of the neuromuscular junction forever. This is to ensure that it does not cause over contraction of the muscle or keep the muscle contracted for longer than required. An enzyme called as Acetyl cholinesterase is responsible in acting as a catalyst in breaking down the acetylcholine present in the synaptic cleft. It gives rise to acetate and choline, which are then transported back to the synaptic cleft, where they are re-synthesized. This is called as Active Reuptake.

Neuromuscular Junction Disorders ‘

Some of the disorders affecting the neuromuscular junction are Myasthenia Gravis, Botulism, Eaton-Lambert syndrome etc. The neuromuscular junction can also malfunction when exposed to certain antibiotics, organophosphates which are type of insecticides, curare which is a toxin derived from plants and gases used in chemical warfare. Some of these things work by preventing the breakdown of acetylcholine after the transmission of the nerve impulse. While some of the disorders cause over activity of the muscles as described below:

- **person syndrome:** Antibodies attack nerve cells – responsible for muscle regulation - present in the brain and spinal cord and cause them to be continuously stimulated. Due to this they become stiff.
- **Isaacs’s syndrome:** In this the nerves keep sending impulses to the muscles which causes them to be over stimulated and ultimately stiffen. They also tend to twitch, due to which they find exercising and normal activities difficult to perform.

Fuel for muscular activity.

Your body is your vehicle, so you have to keep your engine — your heart — running when you work out.

That means fueling up your tank with the right foods and your radiator with the right fluids, using with right amounts at the right times. The American College of Sports Medicine says, "Adequate food and fluid should be consumed before, during, and after exercise to help maintain blood glucose concentration during exercise, maximize exercise performance, and improve recovery time. Athletes should be well hydrated before exercise and drink enough fluid during and after exercise to balance fluid losses."

Not fueling up before you work out is like "driving a car on empty," said Platt, an American Heart Association volunteer. You also won't have enough energy to maximize your workout and you limit your ability to burn calories.

Ideally, fuel up two hours before you exercise by:

- Hydrating with water.
- Eating healthy carbohydrates such as whole-grain cereals (with low-fat or skim milk), whole-wheat toast (without the fatty cream cheese), low-fat or fat-free yogurt, whole grain pasta, brown rice, fruits and vegetables.
- Avoiding saturated fats and even a lot of healthy protein — because these types of fuels digest slower in your stomach and take away oxygen and energy-delivering blood from your muscles.

If you only have 5-10 minutes before you exercise, eat a piece of fruit such as an apple or banana.

"The key is to consume easily digested carbohydrates, so you don't feel sluggish,"

Whether you're a professional athlete who trains for several hours or you have a low to moderate routine, keep your body hydrated with small, frequent sips of water.

According to researchers don't need to eat during a workout that's an hour or less. But, for longer, high intensity vigorous workouts, she recommends eating 50-100 calories every half hour of carbohydrates such as raisins, an energy bar or banana.

- **Fluids.** Drink water, of course. Blend your water with 100% juice such as orange juice which provides fluids, carbohydrates.

- **Carbohydrates.** You burn a lot of carbohydrates — the main fuel for your muscles — when you exercise. In the 20-60 minutes after your workout, your muscles can store carbohydrates and protein as energy and help in recovery.

- **Protein.** Eat things with protein to help repair and grow your muscles. It's important to realize that these are general guidelines. We have different digestive systems and "a lot depends on what kind of workout you're doing," Platt said.

So do what works best for you. Know that what you put in your body (nutrition) is as important as you what you do with your body (exercise). Both are crucial to keeping your engine performing at its best.

How to Fuel Muscles during Exercise – Understanding the Importance of Carbohydrates

Adopting a regular exercise routine is one of the best things that you can do for your long-term health.

Exercise benefits all tissues in the body, and with each passing year research continues to learn more about the benefits of frequent and consistent movement. Over the course of 10 years of nutrition and fitness research science, I've developed a huge appreciation for the benefits of exercise, that seem almost too numerous to count.

Simply stated, exercise benefits all organ systems in the human body, including your heart, blood vessels, muscles, bones, ligaments, tendons, immune system, intestines, liver, pancreas and brain. That's right, even tissues that have nothing to do with performing exercise receive the benefit of frequent activity. Understanding how to fuel muscle during exercise is the first step in optimizing your individual athletic recovery program.

Exercise is a Beneficial Stress

Exercise is considered a "stress" too many organ systems, but differs from the negative stress of everyday life in that it stimulates the breakdown, repair and growth of muscles, ligaments, tendons and bones in the process of creating a stronger and more resilient body.

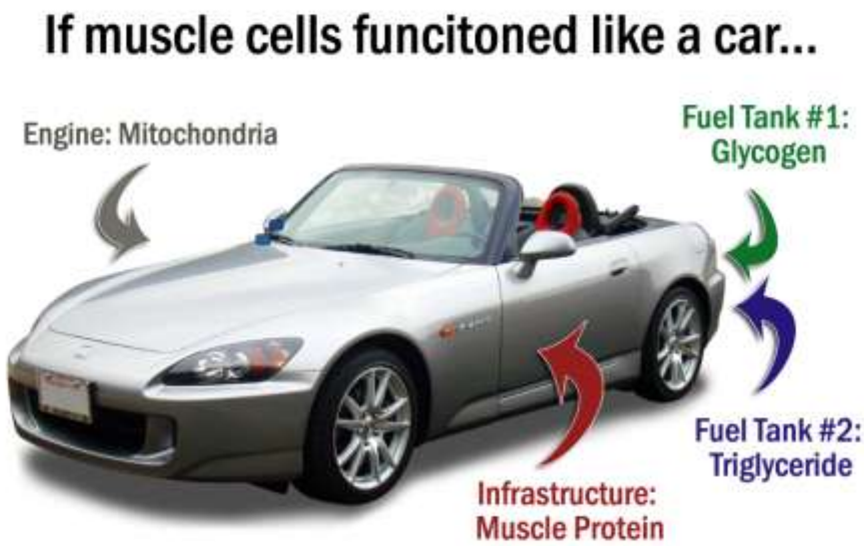
During exercise, muscles must perform two main tasks: Oxidize or "burn" available fuel for energy. Contract in response to a rush of electrical signals from the brain

By accomplishing both tasks simultaneously, the muscle performs work, generating heat, waste products and the need for increased blood flow. Here's a behind-the-scenes look at what fuels your muscles are using to power you during your workouts.

Muscle Fuel during Exercise

The muscle is capable of burning multiple fuels during exercise, including glucose (from carbohydrates), fatty acids (from fat) and amino acids (from protein).

In the same way that a car stores fuel in a fuel tank, muscles have evolved the ability to store glucose, fatty acids and amino acids on-board. All three fuels are burned for energy in the mitochondria, organelles within muscle cells that function much like a car engine.



Even though a car only has one engine, a single muscle cell often contains hundreds of mitochondria in order to generate large amounts of energy during exercise. In this way, the muscle is specifically designed to generate massive amounts of energy on the fly.

Glucose is Stored as Glycogen

Glucose is stored within each muscle cell as glycogen. Glycogen is specifically designed for quick-burning energy, and fast acting enzymes in the muscle cell allow for easy access to this large reservoir of fuel.

Many people believe that carbohydrates are the enemy and should be avoided at all costs. On the contrary – dietary carbohydrates contribute to glycogen stores, literally fueling your muscle tissue.

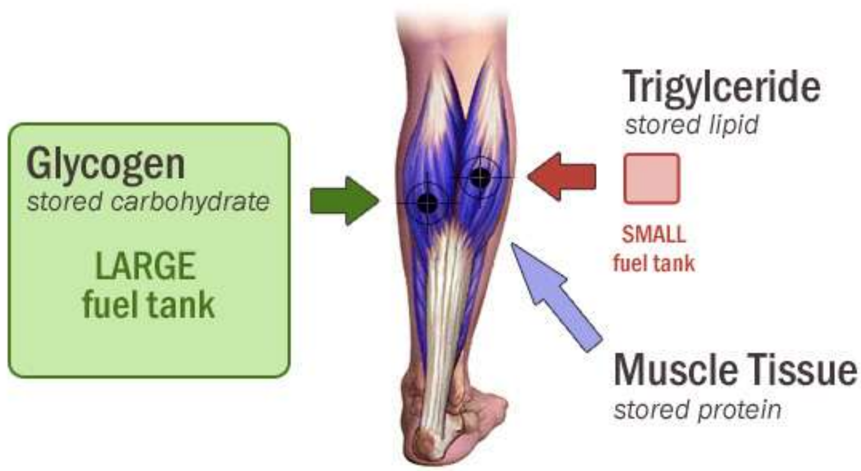
Just make sure that your carbohydrates come from REAL sources, and not from fake and refined products.

Fatty Acids are Stored as Triglyceride

Fatty acids are stored within muscle cells as triglycerides. Muscle triglycerides are stored in a lipid droplet that can be accessed by a different set of enzymes, providing a secondary fuel source during exercise.

Amino Acids are Stored as Muscle Protein

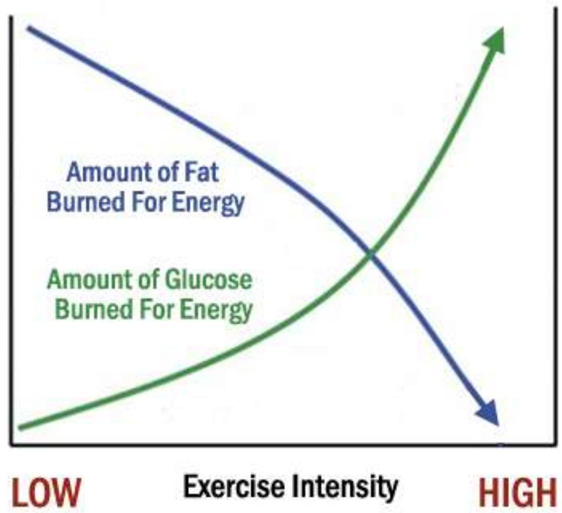
Finally, amino acids are stored within the muscle tissue as muscle protein. If a muscle cell were a car, the muscle protein is the metal frame of the car that provides structure and rigidity. Think of muscle protein as the infrastructure of the muscle tissue itself. Unlike glucose and fatty acids, there is no storage tank for amino acids in the muscle tissue. The muscle itself is the storage tank.



The Choice of Fuel Depends on Exercise Intensity

Even though all three muscle fuels are available for use during exercise, the muscle is making moment-by-moment decisions on which fuel to burn, depending mainly on the intensity and duration of exercise being performed.

At low intensities, fatty acids are the main fuel source and only small amounts of glycogen are broken down. As the intensity of exercise increases, larger amounts of glycogen are broken down and burned for energy, making glucose the predominant fuel source. As you can see in the graph below, as the intensity of exercise increases, the dependence on carbohydrate goes up and the dependence on fatty acids goes down.



You may notice that only carbohydrate and fat are fuel sources shown in the above graph. That's because amino acids are the lowest priority fuel, given that it is the infrastructure of the muscle tissue itself. In order to preserve muscle mass, the muscle will burn glucose and fatty acids before resorting to amino acids.

Muscle Micro trauma

Even though amino acids from muscle protein are the last choice for fuel during exercise, microscopic tears result from repeated muscle contractions, called micro trauma. These microscopic tears are one of the signals that the muscle requires in order to repair during rest.

Think of micro trauma as the repeated wear-and-tear that your car experiences from driving long distances. In the same way that you replace damaged engine parts with newer and more efficient technology, micro trauma to muscle protein requires repair immediately following exercise.

Lucky for you, when muscle tissue repairs itself, the muscle will overcompensate by creating stronger, more resilient muscle protein so that the risk of repeated damage is reduced.

Overcompensation is exactly why muscles get stronger over time. Enzymes that partake in the muscle repair process "overreact" to micro trauma in anticipation of future damage.

Amino acids from dietary protein are used as the building blocks for new muscle protein. This is why protein is often considered an essential component of your post-workout recovery meal.

Muscle is the largest type of tissue in your body, and is extremely malleable because it responds to the type, duration and intensity of exercise that you perform. Frequently exercised muscle tissue is in a constant state of remodeling, leading to increases in endurance, strength, flexibility and power.

The next time you perform a workout, keep in mind that your muscle is performing a number of tasks at the same time, including the following:

- Choosing between glucose and fatty acids for energy
- Protecting muscle protein from being used as a fuel source
- Contracting repeatedly, hundreds to thousands of times in a single exercise session
- Role of oxygen- physical training, oxygen debt, second wind, vital capacity.

The day-to-day variability in oxygen consumption in most physical actions is about 5%, and differences of 10% of this percentage among individuals can be expected. Energy costs vary greatly in different sports; eg, for a 150-lb player, 4.4 kcal/minute in archery, 9.1 kcal/minute in field hockey, 13.3 kcal/minute in judo, and 18.6 kcal/minute in squash.

Energy output also varies in the same sport depending on such factors as intensity of competition, neuromuscular skill level, position demands, performance level, age, body type, atmospheric conditions, and field conditions. In exercise physiology, however, it has been shown to be valid to measure energy expenditure of muscle tissue in terms of oxygen consumption in liters/minute but not valid to convert such data into energy units of watts or kilocalories/minute.

Metabolic capacity, maximum oxygen-intake capacity, and maximum oxygen-debt capacity are the current priority concerns of exercise physiologists.

1. Metabolic capacity determines the amount of activity possible for approximately 2-3 hours through the maximum quantity of energy-yielding substrates available from body reserves during maximum aerobic demands.

2. Maximum oxygen-intake capacity (aerobic power) determines the amount of activity possible for approximately 15-30 minutes through coordinated circulatory and respiratory adjustments producing the maximum amount of tissue oxygen.

3. Maximum oxygen-debt capacity (anaerobic power) determines the amount of activity possible with all-out effort for approximately 50 seconds through anaerobic release mechanisms.

When muscular effort must be prolonged longer than a minute, performance becomes increasingly dependent upon the demands of holistic homeostasis and not just that of active tissues. Basically, this involves oxygen supply, carbon dioxide removal, heat balance, and the replenishment of nutrients.

Metabolism

To maintain health, stored resources (potential energy) must be kept in balance with power expenditures (kinetic energy). While carbohydrate and fat are normally oxidized almost completely in the human body, protein is not. Protein derivatives of uric acid, urea, and creatinine are excreted in the urine. In addition, not all food ingested is absorbed; that is, 97% of carbohydrate, 95% of fat, and 92% of protein ingested is absorbed, and these numbers do not consider the "coarseness" of foodstuffs such as coarse corn meal or roughly ground whole grains.

Metabolic Rate. Metabolic rate is directly proportional to gross body weight. Such factors as lean body mass, age, diet, sex, height, surface area, and race do not have a significant influence on metabolic rate during physical activity. The greater the energy demands, the higher the requirement for oxygen consumption. Total energy is the result of the basal (waking state) metabolic rate plus the energy necessary for work. This offers a ratio that can be used as an index to measure exercise intensity and performance efficiency. In a given period of time, energy output intensity is directly related to mechanical performance, measured by oxygen consumption in a specified period. In this sense, oxygen consumption can be considered a reflection of metabolic power.

Metabolic Capacity. Metabolic capacity is directly related to performance capacity, reflecting the quantity of energy-yielding nutrients available (2-3 hours) from body reserves under aerobic conditions. Thus, one's maximum aerobic power and metabolic capacity are closely related, yet there are many individual differences. Besides metabolic capacity, other indices may be used such as those of glycogen storage, cardiac output, and water-balance efficiency.

Aerobic Power

To produce necessary energy, the body uses an aerobic (oxygen) pathway and an anaerobic (no oxygen) pathway. To maintain life, the primary factor is the continuous and adequate flow of oxygen.

Restricted oxygen flow quickly manifests in function deterioration as seen clinically following infarcts and strokes, underscoring why so much emphasis is placed on oxygen demands during physical, psychological, and environmental stress. Life signs and the degree of life are routinely evaluated from detectable arterial pulsation, breathing quantity and quality and rhythm, temperature, and reflexes -all of which are related to oxygen flow.

When oxygen demands exceed supply (oxygen debt) during and following prolonged exertion, lactic acid accumulates within muscle tissue and encourages fatigue. The greater the exercise intensity, the greater the lactic acid accumulation. Following maximum exercise, it may take an hour or longer to attain resting levels. Oxygen debt must be repaid rapidly such as through hyperpnoea.

Anaerobic Power

Short bursts of effort primarily using explosive strength requiring less than 120 seconds are considered anaerobic activities. Because blood, circulation, respiration, and all the other factors contributing to human function during effort cannot be produced on a moment's notice, nature provides certain limited anaerobic mechanisms to meet the metabolic demands of active cells. Even with minimal work intensity, there is a period of oxygen deficiency that disturbs homeostasis and sets in motion a call for restoration at a higher metabolic level.

Both aerobic and anaerobic mechanisms determine an individual's performance capacity, but anaerobic activity is maintained only for a short time. An anaerobic state exists when oxygen is not used to produce energy and when glucose and glycogen reserves are used. The greater the intensity of the effort, the greater the anaerobic energy contribution. This can be measured by the amount of oxygen intake during the recovery period, usually attaining its peak (maximum oxygen debt) in about 50 seconds after intense exercise begins. If performance demands are great enough to exceed maximum oxygen transport capabilities, performance proceeds only until anaerobic energy stores become exhausted.

An index of work capacity is mechanical power of an anaerobic nature. Common tests are (1) running staircases, as the energy requirement for maintaining speed in running a specified distance depends on mechanical performance during the period and (2) using a bicycle ergometer, where the mechanical work is calculated by recording through a photoelectric circuit the number of wheel revolutions. Activity examples also include weight lifting, throwing, 100-yard dash, 100-meter freestyle swim, a basketball fast break, or running bases in baseball.

Interval Training

Interval training was developed because of problems associated with lactic acid buildup. Workouts interspersed with rest periods diminish a large accumulation of lactic acid and delay fatigue. Sessions require strict administration. It consists of repetitive efforts in which distance is set and pace is timed with established intervals for recovery between efforts. Long runs increase aerobic capacity, and fast, short run increase anaerobic power and strength. As conditioning progresses, the time is shortened, the number of runs is increased, and the number of rest intervals is decreased.

The interval pattern of effort and rest for a specific amount of work and time critically determines the rise of excessive lactate levels, which, as previously explained, is a major cause of fatigue. In long-term events, it is important for an individual to keep high energy demands met by anti lactic acid reserves and try to tactically have the competition exceed their reserves.

Pace and recovery time is usually determined by pulse rate rather than time. Some authorities state that heart rate must be 60% of the available range from rest to the maximum attainable (eg, 140+ beats/minute during running) to develop a rate decrease of the working heart. Thus, they claim, an athlete's pulse below 140/minute indicates a need for a faster run or swim. Once pulse rate decreases to a desired level, rest intervals are ended. Such conclusions, however, fail to consider many unique individual factors.

The Pulmonary Apparatus

The level of oxygen saturation greatly determines the oxygen-carrying capacity of the blood, and oxygen saturation depends on factors determining the quality and quantity of oxygen diffusion in the lungs. These factors include

(1) the quality of pulmonary blood flow and neuromuscular mechanisms,

(2) the lung area available for the diffusing process,

(3) the time duration in which blood receives alveolar-capillary exposure,

(4) the thickness of the alveolar-capillary membrane,

(5) the alveolar air and pulmonary capillaries oxygen pressure differential, and

(6) respiratory frequency, which is often linked in the athlete with the rhythm of movement.

It therefore becomes apparent that the quality of oxygen transport is contingent on the blood, the cardiovascular system, and the pulmonary-respiratory system.

Ventilation. Lung function is evaluated by physiologists by measuring pulmonary residual volume and vital capacity -the components of total lung volume. As an index to breathing capacity, vital capacity is calculated from the maximum amount of air exhaled after a maximum inhalation. About 20% of vital capacity is used during rest. About 70% might be used during prolonged exercise. Up to a quarter of external ventilation is "wasted" in pulmonary "dead space" due to the incomplete mixing of alveolar and airway air, enhanced by an athlete's or a laborer's typically diminished respiratory rate.

Ventilation efficiency is assisted as tidal volume increases with decreased respiratory frequency for given total ventilation. More commonly, ventilation efficiency is judged by the quantity of air inhaled or exhaled in relation to the amount of oxygen absorbed. Such measurements must take into consideration varying atmospheric conditions and individual metabolic needs. Because adequate oxygen is essential for life, both oxygen demands and oxygen consumption must be considered.

Lactic Formation and "Choked" Performance. It has been described that during heavy exercise lactic acid accumulates within muscle as a result of oxygen demands exceeding oxygen supply. Choking of performance because of excessive competition or poor pacing may lead to early anaerobic demands on metabolism. The result is lactate accumulation, witnessed as a premature distressing hyperventilation. Local muscle weakness may also induce premature breathlessness.

Hyperventilation from premature lactate accumulation can cause a person to exceed normal ventilation adjustments where oxygen delivered to the circulation is less than the corresponding demand for oxygen consumption. It is thus important for an athlete to avoid lactate accumulation until late in activity. If local muscle weakness is the cause, the situation can be corrected by strengthening exercises so the athlete can operate nearer aerobic power before lactate accumulates sufficiently. Marathon runners usually operate just under their lactate threshold until the final sprint.

Second Wind. A "second wind" is considered an opposite reaction to that found with choked performance. While early lactate accumulation may be the result of physiologic forces (eg, cardio respiratory maladjustment), with prolonged activity systemic blood pressure rises, movement pace is steadied, ventilation diminishes, and the respiratory muscles become "warmed-up", which reduces respiratory resistance and awareness of breathing, and the level of circulating lactate is lowered. Other mechanisms may also be involved.

Diffusing Capacity. Many well-conditioned athletes, especially swimmers and other endurance-related participants, exhibit a large pulmonary diffusing capacity (larger pulmonary surface) that enhances oxygen transfer. These athletes also exhibit an increased ratio of oxygen intake to lung ventilation per minute, which decreases as exhaustion approaches. However, even with maximum effort, the equilibrium of pulmonary gases between the blood stream and alveolar spaces is fairly complete. Thus, a gain in diffusing capacity offers little benefit except for swimmers who deliberately hold their breath or for athletes performing at high altitudes.

Carbon-Dioxide Homeostasis. Both low and high levels of carbon dioxide affect normal tissue function. Excessive carbon dioxide elimination may be encountered in high altitudes, witnessed by intermittent ventilation and symptoms of mountain sickness; ie, dyspnea, headache, blood pressure and pulse rate changes, and neurologic disorders due to maladjustment to reduced oxygen pressure at high altitudes. Accumulation of carbon dioxide is unusual except for the scuba diver due to the increased rate of carbon dioxide production, the decreased maximum voluntary ventilation, the added external dead weight, and the possible inefficiency of the carbon dioxide-absorbing canisters.

The Circulatory System

Blood transports oxygen, energy substrates, and metabolic wastes. It also serves a vital role in temperature regulation. Reduced blood volume, reduced red cells, and reduced hemoglobin lower the body's capacity for aerobic activity. Each tissue has a range of functional response with definite limits of adaptation. In this sense, blood oxygen transport capability is limited by its capacity to carry oxygen (ie, hemoglobin content and oxygen saturation).

An individual's pulmonary blood flow, lung diffusing capacity, rate of oxygen removal, and total hemoglobin all have a close relationship with maximum oxygen intake. Total hemoglobin determines the potential arterial capacity to transport oxygen. For example, low hemoglobin levels in an athlete are often attributed to increased cell destruction, as shown by increases in circulating haptoglobins from increased rates in blood flow or extrinsic trauma (eg, runner's feet, boxer's abdomen). Dietary habits are more significant than the minute amounts of iron lost in perspiration.

Cardiac Output. Blood oxygen transport also depends on cardiac output. While evaluation of cardiac output during exertion is helpful in diagnosis, stroke volume is difficult to determine directly. Cardiac output increases with work intensity and is directly related to the quantity of oxygen intake: maximum heart output parallels maximum oxygen intake. Such factors as heat exposure and/or dehydration influence stroke volume and change the relationship between heart rate and stroke volume that alters the relationship between oxygen consumption and heart rate.

Cardiac output effectiveness is also determined by relative circulatory distribution among active muscles, viscera, and skin. The maximum limits of stroke volume are determined by the type of exercise and body posture. For example, in comparison to a runner or swimmer who uses most of the body, a cyclist, in not using his upper extremities for propulsion, often pools a large amount of blood within upper extremity veins. The consequence of this is a reduced stroke volume in the cyclist.

Oxygen Pulse. During exertion, cardiac stroke volume increases and the active cells take more oxygen from arterial blood. Both of these factors increase oxygen delivery to cells. The term "oxygen pulse" refers to the quantity of oxygen removed from the blood during each pulse. It is measured in a specified period by dividing oxygen intake by heart rate. Oxygen pulse increases during exertion, reaching its typical maximum of from 11 to 17 ml at about 135 pulses per minute and decreasing after further cardiac acceleration.

Heart Rate. Heart rate is closely correlated with maximum oxygen intake. Typically, heart rate is parallel with performance intensity, but maximum cardiac rate decreases with advancing age. There is a linear relationship between heart rate and metabolic rate. Due to the wide variance in individual balance between sympathetic and vagal drives to the cardiac pacemaker, the resting heart rate of the endurance-trained athlete may reach lows of 30 per minute. The maximum sustained heart rate during competition is about 185-195 per minute or less. In activities of high stress and isometric exertion (eg, skiing), peak heart rates of 250 per minute or more may be briefly encountered.

Blood and Pulse Pressures. Blood pressure and pulse pressure also have a close relationship with maximum oxygen intake. To meet oxygen demands during prolonged exertion, the blood quantity in the muscles and the blood flow within the lungs must be increased. By increasing the force of heart muscle contraction, systolic blood pressure is raised as heart rate increases. This increase is minimized in the well-trained athlete. This is attributed to decreased peripheral resistance because of vasodilatation.

Pulse pressure, the difference between systolic and diastolic pressures, offers an index to the efficiency of cardiac contraction and stroke volume. Difficulties in the exchange of oxygen and carbon dioxide in active tissues are rarely anticipated except in specific types of events. For example, an overland cyclist may complain of pain and weakness in leg muscles during hill ascents. This is apparently caused by local circulatory obstruction resulting from vigorous quadriceps contractions. However, if activity can be continued in spite of the pain, increased systemic blood pressure tends to overcome the local vascular occlusion. This phenomenon is thought to be a manifestation of the heart failing to develop an immediate and adequate increase in blood pressure.

EXCLUSION CRITERIA FOR POTENTIALLY HARMFUL ACTIVITY

While the scope of this paper cannot include all possible types of dysfunction and pathologic structural disorders that would exclude an individual from a specific activity, certain guidelines can be used to support the physician's decision. The base for discussion here is the athlete, but a person involved in strenuous physical labor would be just as appropriate.

2. Whatever the circumstances and pressures, no athlete should be allowed to risk permanent injury. An athlete is either capable from a health standpoint or not.

2. An athlete should be allowed to participate in the sport of his or her choice if practice and competition can be without danger to self or squad.

3. As all sports contain some risk, one sport or level of competition (intramural vs. varsity) should not be considered safer than another in itself. Impartiality must be constantly held. However, the risk of a disability must be differentiated between one sport or position, and the demands involved, and another sport or position. For instance, ankle weakness may be viewed differently in a running sport than in polo.

4. Before any screening, evaluation, diagnostic, or therapeutic procedure is used, informed consent must be given.

A physician wins no friends when he must disqualify a motivated athlete or a willing worker who depends on a particular job for his livelihood. Yet, any acute or chronic disease process is reason for disqualification until health is attained. A weakened player is not the equal of a healthy player, and the risk of injury is far higher.

Acquired Disorders

Self-limiting infections require only temporary exclusion. While competition during mild coryza may be permitted, fever is a strict reason for exclusion. A low-grade tonsillitis or dental sepsis may result in poor performance and greater risk. As a guide, the "step test" is often used for signaling if an athlete is ready to return to active competition after an infection.

The player steps on and off an 18-inch platform at a rate of 30 times per minute. The examiner records the player's pulse rate at 30 seconds, 1 minute, 2 minutes, and 3 minutes after the exercise. The following formula is then applied:

> Duration of exercise in seconds x 100/2 x sum of any 3 pulse counts during recovery

The higher the index, the better the person's status. An athlete is not ready to return to sports activity if the index is 65 or less, according to general opinion. However, both qualification and disqualification are serious matters that cannot be left to the conclusions of one or two tests. Physicians are held accountable to their clinical judgments, not to test results.

Surgical and Congenital Disorders

Gross structural deformity, malfunction, traumatic or surgical loss of a major part, a history of extensive pathology, three concussions resulting in unconsciousness of 1 minute or longer, active hernia, or recurring injury of a part are considered by most authorities to be disqualifying in contact sports regardless of body compensation and even if approved by player, parents, family doctor, specialist, psychologist, and coach. The risks are far too great. At the same time, a noncontact sport may be approved. The possibility of a change in team position can also be considered.

The postoperative athlete must be evaluated not as the average postoperative patient who is to return to a sedentary life-style but as one who will be subjected to forces far above those normally encountered. The extent of pathology and its complications, the extent of surgery and complications, and the type of incision are all variables that must be weighed.

In contact sports, a single eye, a limb loss, an un descended testis, or a unilateral renal dysfunction or malformation are usually considered reasons for automatic disqualification regardless of the outward health status of the functioning part. No athletic activity is worth the consequences of possible injury to a healthy part, although this point is controversial among many. Concern over a single ovary is not as great as the organ is well protected. Such conditions as recurring gleno humeral dislocations, acromio clavicular separations, and knee instability are usually considered disqualifying. Even with successful surgical repair, wires can break, screws can loosen, and plates can slide from severe stress. The physician's objective must be to avoid the risk of permanent impairment.

Non disabling congenital defects are judged relative to the risk involved. For example, non symptomatic spondylolis thesis without spin a bifida features would not bar participation in a contact sport, but severe low-back symptoms may be reasons for disqualification even if overt signs are not evident.

Respiratory Considerations

Asthma must be judged on its degree and the sport involved, and some asthmatics receive relief of their bronchi spasm during exercise. No asthmatic dyspnea is usually related in the healthy to effort expended during vigorous exercise, and it may be especially noticeable in cold weather. Mild, occasional hemoptysis is normal with some athletes after strong exertion, but profuse or commonly bloody sputum demands a full investigation.

Cardiovascular Considerations

The largest percentage of non traumatic deaths in sports can be attributed to ischemic heart disease, unsuspected preexisting cardiovascular anomalies, and infections having myocarditis in their repertoire. Occasionally, some conditions are first discovered by the sports physician such as aortic coarctation, asymptomatic atrial septal defects, dextrocardia, and rarely mitral insufficiency.

A finding of abnormal thrill, hum, pulse, blood pressure, murmur, or arrhythmia should be followed by simple exercise tests, and then reevaluated. Transient palpitations, tachycardia, cardiac flutters, and dizziness often cause diagnostic difficulties, and many ectopic arrhythmias disappear when the heart rate exceeds 140. Premature ventricular contractions are frequently noted by a team physician. These are often of minor concern and associated with emotional causes, gastrointestinal disturbances, and certain drugs (eg, caffeine).

Heart Disorders

A review of the literature reveals that there are wide differences in specific disqualifying criteria. Paroxysmal auricular tachycardia is strictly disqualifying for all competitive sports owing to the possibility of unpredictable fainting during stressful activity. This does not include the commonly witnessed psychogenic sinus tachycardia seen before competition. Many physicians feel that any significant heart enlargement is the basis for automatic sports exclusion. Compensated or repaired congenital cardiovascular defects must be evaluated on an individual basis according to cardiac reserve, and then only if a written clearance is obtained from the attending cardiologist.

An abnormality within the cardiovascular system of a youth should not cause automatic exclusion from sports. The concept of the need for a strictly normal heart has been proven a fallacy. Records show a champion swimmer with cyanotic heart disease, a famous long-distance runner who had a large aortic aneurysm, an U.S. Olympic skier who participated with a piece of shrapnel imbedded between the pericardium and the pulmonary artery, and many similar situations. The goal is to recognize a disorder, evaluate it, and establish the necessary guidelines to decrease risk and prevent serious complications.

Blood Pressure

In healthy athletes, blood pressure will be found in a wide range of short duration. A systolic pressure of 140+ constantly held is considered abnormal, while pressures of short duration in youth of 150 and college students of 220 are sometimes recorded. Abnormal levels in the healthy return quickly within a normal range with relaxation. Of greater concern is a rise in diastolic pressure. Many authorities believe that a resting pressure over 88 points to kidney disease, a reason for disqualification. Boxing examiners have recorded pressures of 65/40, indicating that hypotension requires a redefinition in athletics.

Renal Disorders

During vigorous physical activity, five problems are commonly associated with kidney function: dehydration, athletic pseudo nephritis, hemoglobinuria, ephroptosis, and trauma.

Dehydration

Losses of up to 21% of plasma water have been demonstrated after 4 hours of running. During high temperatures and humidity, it is virtually impossible during prolonged exercise to replace fluids from sweat loss, even though it is important to try to keep pace. From 200-300 ml of fluid are suggested for every 15 minutes of strenuous activity. Athletes presenting symptoms of chronic dehydration (eg, fatigue, decreased sweating, high core temperature) require several quarts of fluid each day despite a lack of thirst.

Sodium depletion, often accompanying dehydration, is rarely a problem in temperate climates under normal exercise conditions. It more often arises in very hot climates, with indoor sports, and where restrictive clothing causes increased perspiration. Typical features are thirst, headache, cramps, nausea, apathy, anorexia, sleepiness, postural giddiness, peripheral circulatory failure, and falling blood pressure. When ambient temperatures are known to be high, a slow-release sodium supplementation is sometimes used in maintaining electrolyte balance. Many authorities are against its use, however.

Effect of exercise and training on cardiovascular system.

Effect on Heart Rate:

Exercise uses up a lot of energy, which the cells derive from oxidizing glucose. Both glucose and oxygen have to be delivered by the blood. This means that the heart has to work harder to pump more blood through the body. This means it has to beat faster in order to achieve a higher throughput, as described by this equation:

blood flow = heart rate x stroke volume

Heart rate for a human being at rest is about **70 beats/min**. During vigorous exercise, heart rate can increase dramatically (the rule of thumb given for maximal heart rate is 220 minus your age). This will result in an increase in blood flow.

The circulatory system responds to an increased need for blood by adjusting the width of the blood vessels, primarily the arterioles and venules. The dependence of vessel resistance on the radius of the tube is described by Poiseuille's law and is described in detail in the exhibit,

As a complete system, the amount of blood that flows through the circulatory system is in terms of the pressure difference between the arteries and the veins times the quantity referred to as the total peripheral resistance. But what about at the local level? How much blood flows through an individual blood vessel? What are the quantities that affect the rate of blood flow? This exhibit discusses a physical relation known as Poiseuille's Law which partially answers this question.

Poiseuille's Law relates the rate at which blood flows through a small blood vessel (Q) with the difference in blood pressure at the two ends (P), the radius (a) and the length (L) of the artery, and the viscosity (n) of the blood. The law is an algebraic equation,

$$Q = \frac{\pi a^4 P}{8 L \eta}$$

From the formula given there, we see that blood flow depends very sensitively on the width of the blood vessels, so that changing the radius slightly has a large impact on the flow of blood.

The circulatory system exploits this property rather nicely; by constricting blood flow the organs that need less oxygen during exercise and widening the arterioles to the organs which need more. For instance, the brain may use up to 30% of total blood flow while you're doing your homework, but when you're at the gym less than 10% of total blood flow goes through it. On the other hand, muscles use less than 10% of blood flow when at rest, but can take up to 50% of it when they're working. This regulation is an essential mechanism for delivering oxygen and glucose to the tissues that need it most.

The cardiovascular system serves five important functions during exercise:

1) Delivers oxygen to working muscles

2) Oxygenates blood by returning it to the lungs

3) Transports heat (a by-product of activity) from the core to the skin

4) Delivers nutrients and fuel to active tissues

5) Transports hormones

Exercise places an increased demand on the cardiovascular system. Oxygen demand by the muscles increases sharply. Metabolic processes speed up and more waste is created. More nutrients are used and body temperature rises. To perform as efficiently as possible the cardiovascular system must regulate these changes and meet the body’s increasing demands.

Below we will examine the acute or immediate response to exercise and also the long-term adaptations that take place in the cardiovascular system with repeated exercise. The most important aspects of the cardiovascular system to examine include:

- Heart rate
- Stroke volume
- Cardiac output
- Blood flow
- Blood pressure
- Blood

Immediate Response of the Cardiovascular System to Exercise

Heart Rate

Resting heart rate averages 60 to 80 beats/min in healthy adults. In sedentary, middle aged individuals it may be as high as 100 beats/min. In elite endurance athletes heart rates as low as 28 to 40 beats/min have been recorded.

Before exercise even begins heart rate increases in anticipation. This is known as the **anticipatory response.** It is mediated through the releases of a neurotransmitters called **epinephrine** and **nor epinephrine** also known as adrenaline and nor adrenaline.

After the initial anticipatory response, heart rate increases in direct proportion to exercise intensity until a maximum heart rate is reached. Maximum heart rate is **estimated** with the formula **220-age**. But this is only an estimation, and not particularly accurate. The only direct method for determining maximum heart rate is to exercise at increasing intensities until a plateau in heart rate is found despite the increasing work rate.

Although heart rate increases rapidly with the onset of activity, providing exercise intensity remains constant, heart rate will level off. This is known as **steady-state heart rate** where the demands of the active tissues can be adequately met by the cardiovascular system. However, there is an exception to this

During prolonged steady-state exercise, particularly in a hot climate, a steady-state heart rate will gradually increase. This phenomenon is known as **cardiac drift** and is thought to occur due to increasing body temperature.

Stroke Volume

Stroke volume is the amount of blood ejected per beat from left ventricle and measured in ml/beat.

Stroke volume increases proportionally with exercise intensity. In untrained individuals stroke volume at rest it averages 50-70ml/beat increasing up to 110-130ml/beat beat during intense, physical activity. In elite athletes resting stroke volume averages 90-110ml/beat increasing to as much as 150-220ml/beat.

Stroke volume may increase only up to 40-60% of maximal capacity after which it plateaus. Beyond this relative exercise intensity, stroke volume remains unchanged right up until the point of exhaustion. But this is not conclusive and other studies suggest stroke volume continues to rise until the pint of exhaustion.

Interestingly, swimmers see a smaller increase in stroke volume compared to runners or cyclists for example. It is believed that the supine position prevents blood from pooling in the lower extremities enhancing venous return.

Why does stroke volume increase with the onset of exercise? One explanation is that the left ventricle fills more completely, stretching it further, with the elastic recoil producing a more forceful contraction. This is known as the **Frank-Starling mechanism**. Other contributing factors include increased contractility of the ventricles and reduced peripheral resistance due to greater vasodilatation of the blood vessels.

Cardiac Output

Cardiac output is the amount of blood pumped by the heart in 1 minute measured in L/min. It is a product of stroke volume and heart rate (SV x HR). If either hearts rate or stroke volume increase, or both, cardiac output increases also.

Cardiac output increases proportionally with exercise intensity - which is predictable from understanding the response of heart rate and stroke volume to activity. At rest the cardiac output is about 5L/min. During intense exercise this can increase to 20-40L/min.

Blood Flow

The vascular system can redistribute blood to those tissues with the greatest immediate demand and away from areas that have less demand for oxygen.

At rest 15-20% of circulating blood supplies skeletal muscle. During vigorous exercise this increases to 80-85% of cardiac output. Blood is shunted away from major organs such as the kidneys, liver, stomach and intestines. It is then redirected to the skin to promote heat loss .

Athletes are often advised not to eat several hours before training or competition. This is advice worth adhering to, as food in the stomach will lead to competition for blood flow between the digestive system and muscles. It has been shown that gastrointestinal blood flow during exercise shortly after a meal is greater compared to exercising on an empty stomach .

Blood Pressure

At rest, a typical **systolic** blood pressure in a healthy individual ranges from 110-140mmHg and 60-90mm **hemotocrit** .Hg for **diastolic** blood pressure.

During exercise systolic pressure, the pressure during contraction of the heart (known as systole) can increase to over 200mmHg and levels as high as 250mmHg have been reported in highly trained, healthy athletes.

Diastolic pressure on the other hand remains relatively unchanged regardless of exercise intensity. In fact an increase of more than 15 mm Hg as exercise intensity increases can indicate coronary heart disease and is used as marker for ceasing an exercise tolerance test.

Both systolic and diastolic blood pressure can rise to high, albeit brief, levels during resistance exercise. Values of 480/350mmHg (9) have been reported to coincide with a **Valsalva manoeuvre** - i.e. trying to exhale against a closed mouth, nose and glottis.

Blood

During resting conditions the oxygen content of blood varies from about 20ml of oxygen per 100ml of **arterial** blood to 14ml of oxygen per 100ml of **venous** blood (2). The difference in oxygen content of arterial and venous blood is known as **a-vO2 difference**.

As exercise intensity increase the a-vO2 difference increase also and at maximal exertion the difference between arterial and venous blood oxygen concentration can be three times that at a resting level.

Blood plasma volume decreases with the onset of exercise. The increase in blood pressure and changes in intramuscular osmotic pressures force water from the vascular compartment to the interstitial space. During prolonged exercise, plasma volume can decrease by 10-20% and by 15-20% in 1-minute bouts of exhaustive exercise (10). Resistance training with 40% and 70% one repetition maximum can cause a 7.7% and 13.9% reduction in blood plasma respectively (11).

A reduction in plasma increases the concentration of hemoglobin. Although no extra red blood cells have been produced, the greater concentration of hemoglobin per unit of blood significantly increases the bloods oxygen carrying capacity. This is one of the main adaptations during immediate acclimatization to altitude.

Blood pH can change from a slightly alkaline 7.4 at rest to as low as 6.5 during all-out sprinting activity. This is primarily due to an increased reliance on anaerobic energy systems and the accumulation or hydrogen ions (1).

Effect of exercise and training on respiratory system.

What is an increase in oxygen diffusion rate?

Oxygen diffusion is where the **oxygen** moves from the capillaries to the tissues and carbon dioxide moves from the cells to the blood. **Oxygen diffusion rate** increases after long term exercise and as a result the **oxygen** and carbon dioxide will start to diffuse much quicker.

How does exercise affect the heart rate?

Like all muscles, the **heart** becomes stronger as a result of **exercise**, so it can pump more blood through the body with every beat and continue working at maximum level, if needed, with less strain. The resting **heart** rate of those who **exercise** is also slower, because less effort is needed to pump blood.

Exercise or any physical activity has a special effect on respiratory system . We need oxygen at rest and during exercise , since energy supply to the active muscles increases demand of oxygen . Another important function of respiration is to eliminate carbon dioxide from the body. During exercise cellular oxidation increases and thereby carbon dioxide production increases. Respiratory system maintains an efficient balance between the oxygen and carbon dioxide in the blood at rest and also during exercise. There are some immediate changes that occur during exercise programme. Also, there are some relatively permanent changes following long-term physical training , the magnitude of changes being dependent on type , intensity and duration of exercise.

Immediate changes during exercise :

a) Tidal Volume : The amount of air which we inhale or exhale during quiet breathing is called tidal volume. It is around 500 ml. During exercise , this tidal volume increases. Depending on intensity it may be 1500-2000 ml for ordinary person and for well trained athlete it may be increased to 2500 ml.

b) Respiratory rate : Number of times one takes inspiration or expiration in each minute is called Respiratory rate. At rest , respiratory rate is around 16 per minute. During exercise , for ordinary persons it may be increased to 25-30 per minute and for well trained athlete it may be around 38-40 per minute.

c) Pulmonary Ventilation : The amount of air which passes through lungs is each minute is called Pulmonary ventilation . The Pulmonary ventilation (PV) = Tidal volume (TV) X Respiratory rate (RR) and therefore at rest it is around 8 lit / min . During exercise since both TV and RR increases , PV will also increase depending on the intensity of exercise . For ordinary person , the value of PV may be 40-50 lit / min and for well trained athlete , it may be around 100 lit / min .

d) Oxygen uptake : The amount of oxygen which we take inside the body from ambient air in each minute at rest is called resting oxygen uptake. It is around 200-300 ml / min . During exercise oxygen uptake increases to 3.5 lit / min for ordinary person and 4.5 lit/min for well trained athlete.

e) Lung diffusion capacity: Diffusion is the process of movement of gas molecules (O2 and CO2) that takes place in the lungs and tissues. During exercise there will be more movement of gas molecules and diffusion capacity increases.

f) Lung volume: For normal breathing at rest lung expand and there is a change in air pressure. During exercise due to rapid movement of diaphragm and inter costal muscles total area of lung expands to accommodate more exchange of gases.

Long-term effect of training on Respiratory system

a) Tidal Volume (TV) : Trained athlete’s capacity to inhale or exhale air during exercise increases to the tune of 2500 ml. Untrained persons cannot increase up to this level because their capacity is less than trained athletes.

b) Respiratory rate (RR): Trained athlete may increase their rate to 40 in each minute from 16 / min at rest. Untrained persons will not be able to reach to this level. They may increase their rate up to 25-28 / min.

c) Pulmonary ventilation (PV): A trained athlete may increase PV to around 100 lit/min. This is because their TV and RR both increases during exercise. Untrained persons may increase it up to 50-60 lit/min.

d) Oxygen uptake: During exercise, after long term training, a trained athlete may consume around 5 liter oxygen per minute. Untrained persons may go up to the level of 3.5 lit oxygen per minute.

e) Lung diffusion capacity: During exercise, the lung diffusion capacity increases in both trained and untrained persons. However, trained athletes may increase their diffusion capacity 30% more than that of an untrained person because athlete's lung surface area and red blood cell count is higher than that of the non-athletes.

f) Vital capacity: It is the maximum volume of air forcefully expired after a maximal inspiration. For a healthy adult male it is around 4.8 lit and for women 3.1 lit. The athletes who are under training for a long period may increase vital capacity to around 6 lit.

g) Efficiency of lung: An athlete's total efficiency of the lung remains at higher level than the non-athletes. This efficiency is the key factor for higher rate of oxygen uptake than non-athletes.

h) Second wind: This term is usually described as a sudden transition from an ill-defined feeling of distress or fatigue during the early portions of prolonged exercise to a more comfortable, less stressful feeling later in exercise. It has been observed that trained athletes get their second wind comfortably and easily than non-athletes.

The respiratory system comprises of the nose, mouth, throat, larynx, trachea, bronchi and lungs. The function of the respiratory system is to facilitate gaseous exchange to take place in the lungs and tissue cells of the body.

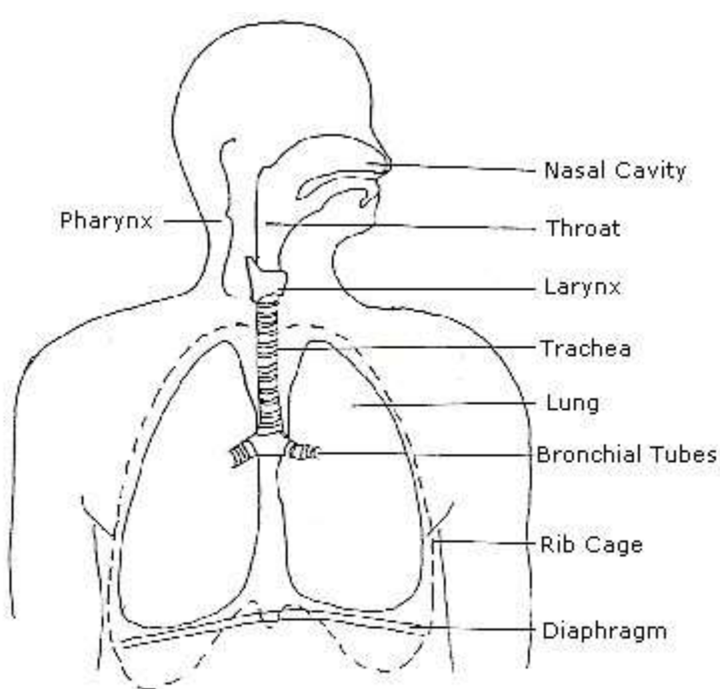
Oxygen is required by cells in the body to allow various metabolic reactions to take place and to produce energy and is therefore essential to life.

The respiratory system may be defined as the organs and tissues through which air is passed into and out of the body to allow the necessary gaseous exchanges to take place.

External respiration is the means by which oxygen from the air passes into the blood stream for transportation to the tissue cells and carbon dioxide is collected and transferred back to the lungs and expelled from the body.

Internal respiration involves the vital chemical activities that take place in every living cell requiring oxygen and glycogen to combine and release energy, water and carbon dioxide.

Organs of the respiratory system



The normal rate of inspiration and expiration, the respiration rate, is about 16 times a minute in an adult. Breathing is controlled by specialized centers in the brain stem, which automatically regulate the rate and depth of breathing depending on the level of carbon dioxide in the blood.

A-VO_2 diff

Arterio-venous oxygen difference (A-VO_2 diff) is the difference between oxygen concentration in the arteries and the oxygen concentration in the veins.

Hemoglobin and Myoglobin

Hemoglobin is a protein in red blood cells which enables the cells to carry oxygen and myoglobin is an oxygen-binding protein found in heart and skeletal muscles.

Effect of exercise on the respiratory system

In the Cardiovascular system, the benefits of exercise were discussed in relation to the improved functioning of the heart and the lowering of blood pressure. Combined with increased maximum oxygen consumption (VO_2 max), or lung capacity, these are all vital contributors to being fit and healthy.

An athlete who has not properly trained their cardiovascular system is likely to incur other injuries more easily by the rapid onset of fatigue and the consequent lowering of motivation and mental awareness. For anyone competing at varying altitudes, they must allow themselves a considerable period to acclimatize before an event. Even climbing to a moderate altitude decreases the maximum uptake by 7% to 8% due to the change in atmospheric pressure. This decrease in oxygen being supplied to the muscles may decrease performance by 4 to 8% depending on the duration of competition, a considerable disadvantage at the finish line. Even the athlete who prepares and acclimatizes well may still not match natives of high altitude areas such as the Andes, who have a larger chest capacity, more alveoli, larger capillary beds and higher red blood cell count. Since people may suffer from altitude sickness when moving from low to high altitudes, sufficient time must also be allowed for these symptoms to disappear before starting intensive training.

Effect of exercise and training on muscular system

All muscles in the body, including those of the skeletal system and cardiac muscle, may benefit from regular exercise. Various involuntary systems and processes combine their effort to bring oxygenated blood to the working muscles. The result may be improved strength, a slimmer body and better overall health.

There are three types of muscles, including skeletal, cardiac and smooth. Both skeletal muscles, which assist in locomotion and posture and cardiac, found in the heart, benefit from regular activity. Hypertrophy is an increase in skeletal muscle size, one of the most obvious effects of exercise on the muscular system, especially from resistance or strength training. Smooth muscle such as in the stomach and intestines is controlled by the autonomic nervous system and isn't affected.

The body's muscular, cardiopulmonary, and nervous systems all respond to increased demand of the muscles for oxygenated blood. This gets diverted from non-vital organs to increase energy within the muscles. Byproducts from the increased activity such as lactic acid, hydrogen ions and carbon dioxide stimulate the respiratory system to increase breathing for better oxygen exchange.

Effects of exercise on the muscular system show up in cardiac muscle too. A strong heart can pump more blood each time it beats, carrying nutrients and oxygen to all parts of the body. The pulse rate of a person who exercises regularly will be slower than most people, because the heart doesn't need to pump as much to move the same amount of blood. Steady aerobic exercise using the major muscle groups, enough to cause an obvious increase in respiration, is best for continued cardiac health.

Two interesting effects of exercise on the muscular system are the decrease of inhibitory neural feedback and synchronous activation. The first process means the nervous system lets the muscle work longer and harder than it would if the muscle were untrained, where it might be injured. Synchronous activation allows more muscle fibers to work in tandem, giving the muscle an enhanced ability to handle the increased activity and perform at a higher level. The result is a measurable strength gain, particularly in women's muscles and those of adolescents. In addition, strength training with weights and resistance bands can reverse muscular decline that comes with aging.

Warming up and cooling down can be vitally important to a proper workout. These may prevent adverse effects of exercise on the muscular system like strain injuries resulting from a lack of good preparation. The muscles need adequate blood and oxygen flow to begin vigorous activity. Stretching after the workout keeps them from tightening up and also keeps them flexible long after the workout is finished.

Weight-bearing exercises also contribute to bone density, a primary concern especially for women, who are more prone to osteoporosis. Tension on muscles improves strength and balance, which when combined with higher bone density makes fall injuries less likely. Strong, conditioned muscles at rest burn more calories than weak muscles. Regular exercise also helps prevent obesity, a major cause of health problems at any age.

Hypertrophy – the muscle increases in size and bulk. Hypertrophy is a result of an increase in the volume of contractile proteins (Actin & Myosin) within the muscle cell so they can contract with greater force. The number of muscle fibers stays the same. In general males have a greater potential for increases in muscle bulk due to higher levels of the hormone testosterone.

Increases in tendon strength - tendons are tough bands of fibrous connective tissue designed to withstand tension forces along their length. Like muscles, tendons adapt to the mechanical loading of regular exercise. A general adaptation is increased strength but different types of training will exert differing effects on muscle – tendon complexes. Ligaments and tendons will increase in flexibility and strength with exercise. Articular cartilage also becomes thicker.

Muscle stores & Mitochondria - Muscles increase their oxidative capacity (their ability to use oxygen to produce energy) with regular training. This is achieved by an increase in the number of mitochondria (an organelle where aerobic energy is produced) within the muscle cells which will increase the supply of ATP and an increase in the quantity of enzymes involved in the production of ATP. The ability of the muscle to store myoglobin is increased (myoglobin is like hemoglobin and carries oxygen).

Lactic acid anaerobic training stimulates the muscles to become better able to tolerate lactic acid and clear it away more efficiently. With endurance training the capillary network extends allowing greater volumes of blood to supply the muscles with oxygen and nutrients. The muscles are able to use more fate as a fuel source and become more efficient at using oxygen.

Exercise has both short and long term effects to muscular system. Exercise works as a stimulus and gives stress to muscles.

After exercise you may feel short term effects like:

- **Blood flow** because of increased volume of blood that is pumped to muscle tissue.
- **Muscle fatigue** is short-term decline in the ability of a muscle to generate force. Another way to describe muscle fatigue is as the short-term inability to continue to repeat muscular contractions with the same force.
- **Muscle exhaustion** when exercise continues through muscle fatigue without rest after time it can lead to muscle exhaustion.
- **Muscle damage** often happens, because of over-stretching without a proper warming-up or no warming-up before intense exercise.
- **Cramp** uncontrollable and very painful muscle contraction**.**

After some time passes then long term effects on muscles takes place like:

- **Muscle size** increases mainly due to muscle ability to adapt to stress over a period of time which increases them in size.
- **Muscle coordination** increases when doing exercises which require skill and technique e.g.: dribbling ball.
- **Blood supply** to muscles increases due to long-term exercise by that improving delivery of various nutrients, minerals and vitamins to muscles and making them more effective and faster at regenerating after injury or workout.

Short term effects such as:

- **Blood flow** – after exercise you can notice that muscle tissue (warm muscle) is bigger than cold muscle, because of blood flow into them. It can increase by up to 25 times, because muscle requires more energy and oxygen.
- **Muscle fatigue** – is the decline in ability of a muscle to generate force. It can be a result of intense exercise, but abnormal fatigue may be caused by barriers to or interference with the different stages of muscle

contraction. There are two main causes of muscle fatigue. The limitations of a nerve's ability to generate a sustained signal (neural fatigue) and the reduced ability of the muscle fiber to contract (metabolic fatigue).

- **Muscle exhaustion –** general exhaustion often occurs after you have done too much activity at one time, such as by taking an extra-long hike. You may feel weak and tired, or your muscles may be sore. These sensations usually go away within a few days. In rare cases, generalized muscle weakness may be caused by another health problem, such as problems with body regulating the distribution of energy to muscles and organs.
- **Muscle damage –** any effort beyond muscle ability level or accident can tear the fibers and cause muscle damage. When muscle fibers are damaged, the body immediately starts to repair it at the cellular level. Muscles most of the time repairs by themselves (if body is functioning properly) through time. If damage or injury is critical, surgery might be needed.
- **Cramp –** because of over-exercise, lack of nutrients like magnesium or bad blood circulation when muscles don't receive enough oxygen. It is very painful and can be dangerous if doing exercise that involves heavy weights alone.

Long-term effects of exercise

- **Muscle size** – is mostly determined by persons genetics, but can be affected with life choices like: anabolic steroids, exercise, and healthy food. Exercising specific muscles regularly can increase their size by up to 60%. This increase in muscle size is mainly due to increased diameter of individual muscle fibres.
- **Muscle coordination** – It trains muscles to work more efficient and effectively by working together. E.g.: when the prime mover contracts more rapidly the antagonist (muscle) must also relax as quickly to prevent blocking the movement.
- **Blood supply** – As a result of frequent exercise over a sustained period of time both the quantity of blood vessels and the extent of the capillary beds increases.

Effects of exercise on muscular system would benefit by increasing size and number of mitochondria, improved perception of muscle tone and also overall improved:

- Coordination
- Power
- Balance
- Speed
- Agility
- Body composition
- Reaction time
- Muscular endurance
- Flexibility

Physiological concept of physical fitness,

Warming up, Conditioning and fatigue.

Introduction

The formal dance class has long been considered the cornerstone of training, providing all the technical, physical and aesthetic requirements of dance. In recent years a considerable amount of research has been carried out regarding the health of dancers. Findings from this research indicate that many dancers are not as fit and healthy as they could be. It has also been found that there is a discrepancy in the physical intensity level between training, rehearsal, and performance. This means that training methods, which are generally based on tradition, are not sufficient to help prepare dancers for the higher, more physically demanding aspects of performance. In light of these studies, and with increased understanding of the artistic and athletic needs of dancers in different genres, it is no longer acceptable to train dancers without preparing them physiologically for the demands of current choreographic work.

What is Fitness, and why is it Beneficial?

For dancers, the whole body (physical and psychological) is their instrument, their means of artistic expression. Dance calls upon all aspects of fitness. Good fitness is key to reducing the risk of injury, enhancing performance, and ensuring longer dancing careers. A healthy dancer is one who is in a state of being 'well' in both body and mind. A physically fit dancer is one who has the ability to meet the demands of a specific physical task at an optimal level. The goal of improving dancers' fitness is to minimize the difference between the dancer's individual maximal abilities and their performance requirements, so that they can become the best dancer possible.

What Types of Fitness Are Most Important for a Dancer and Why?

While research indicates that some dance styles require certain elements of fitness more explicitly than others, in a well-rounded dance training program, it is necessary to consider all the components of fitness.

The components of fitness are:

- **Aerobic fitness** – associated with moderate, longer-term levels of activity.
- **Anaerobic fitness** – associated with high intensity, maximal, short bursts of activity.
- **Muscle endurance** – the ability of a muscle to produce continuous movement.
- **Strength** – the ability of a muscle to produce a maximal force on one occasion.
- **Power** – the explosive (speed-related) aspect of strength.
- **Flexibility** – the range of motion at a joint in association with the pliability of a muscle.
- **Neuromuscular coordination** – associated with balance, agility, coordination and skill.
- **Body composition** – the make-up of body weight by percentage of muscle and fat.
- **Rest** – a period of no activity, to allow for recovery and regeneration.

While any change in traditional dance training regimens must be approached cautiously to ensure that enhanced artistry and expression remain the primary goals, it may be suggested that unless dancers are physiologically honed to the same extent as they are artistically, their physical conditioning may potentially be the limiting factor in their development. Ignoring the physiological training of today's dancers could eventually hamper the development of the art form. It is the continual responsibility of dance teachers and educators to develop their knowledge and understanding of the physiological demands of dance, and be aware of the options for either integrating physical fitness training into the technique class itself or providing it through supplementation.
In a recent study, full time contemporary dance students completed a year of weekly dance fitness classes alongside their regular technique training. Students perceived positive physiological adaptations such as reductions in fatigue, improvement in general energy levels and an improved capacity in their dance classes to sustain technique and jumping ability. The importance

of warm up and cool down was also commonly cited and the recognition of the relationship between fitness and injury prevention was highlighted.

More than twenty years ago it was stated that the best dancers have an integrated combination of two talents: knowledge of what is to be expressed and the physical and mental tools to accomplish that expression. A dancer who is able to jump higher, balance longer and create illusions such as floating may not necessarily be a better dancer, but she does have the advantage of a greater range of tools with which to produce the desired images of dance choreography. Although a topic of continual debate, more recent research has since indicated that a fitter dancer is a better dancer.

Which Activities Improve Various Types of Fitness?

Aerobic Training

The greater a dancer's aerobic capacity, the longer they can work at moderate heart rates before becoming fatigued. Research suggests that dance will only elicit an improvement in aerobic capacity in a very unfit group of people, or if an aerobic dance class is taken. The average dance technique class is too intermittent in nature for any positive aerobic effect to occur. In order to improve aerobic capacity, the body needs to work hard enough to bring about change or adaptation within the body. Specifically, a rise in heart rate to approximately 70 – 90% of maximum (HRmax) will stress the aerobic energy system. This elevation in heart rate has to be maintained between 20 and 40 minutes, three times a week. Continuous movement activities, such as running, aerobics classes, swimming, cycling, and skipping, are good examples of aerobic exercise.

Although there are variations among teachers, a primary intention of the technique class is dance skill acquisition. Developing high levels of technical skill and movement economy requires a different focus from developing the aerobic capacity of the dancer. However, technique classes can be modified to involve some degree of aerobic work, using simple repetitive movements. Simple movement repetition helps to stress the aerobic energy system rather than stress skill acquisition. Warm up could be conducted in a continuous manner at a higher intensity than normal, and center or traveling sequences could be longer, with less rest time, allowing an aerobic foundation to develop. Familiar movement combinations might be performed over consecutive classes, purely for the benefit of continuous repetition rather than artistic effect.

Anaerobic Training

Anaerobic training utilizes activity that is of a maximal, 'all-out' effort for short periods of time. An exercise-to-rest ratio of 1:3 is recommended for training the threshold at which lactate starts to accumulate in the blood stream, thus hindering muscle function. An exercise-to-rest ratio of 1:5 is recommended for training the source of the fastest muscle actions: high energy phosphates, adenosine triphosphate (ATP) and creatine phosphate (CP). Optimum exercise time for each bout can gradually increase from 10 – 50 seconds. The intensity of activity for the whole duration should be near maximal heart rate (95 – 100% HRmax). Rest periods should be at a low intensity exercise, as this promotes faster recovery. Examples of anaerobic exercises include sprints, quick steps, jumps, and fast skipping.

Strength/Endurance Training

The role of strength training in dance has frequently been misunderstood. There are still concerns in the dance world that increased muscle strength will negatively affect flexibility and aesthetic appearance. However, research has demonstrated that supplemental strength training can lead to better dancing and reduced occurrences of dance injuries, without interfering with key artistic and aesthetic requirements.

For an optimal strength training program, it has been suggested that exercises be specific to the desired outcome. Strength training can involve very heavy weights/resistance with minimal repetitions for a relatively short amount of time, or exercises can involve light weights/resistance with many repetitions for a prolonged time. Each program targets a specific goal. A combination of high intensities (70 – 100% of maximum) and low volumes of work, two to three times a week, aims to increase muscle strength. A full recovery period (5 – 6 minutes) is essential between sets in this instance. Dancers wanting to increase muscle endurance are prescribed a combination of moderate intensities (60 – 70% maximum) and high volumes of work, three to four times a week. The rest periods are then shorter (2 – 4 minutes) so that the next set of exercises begins before full recovery.

Power Training

Jumping is an integral part of most dance performances and involves the use of both muscular strength and elasticity. Studies report that polymeric (jump) training has been shown to have a positive effect in dancers. However, there are warnings that polymeric training must be approached gradually and systematically to avoid injury. A good starting point is to design exercises in which dancers are encouraged to jump in a neutral position without emphasizing artistic skill, but instead simply focusing on jumping higher. Once the dancers have gained greater understanding of how to elevate themselves, they can bring correct dance technique back into the movements while trying to maintain as much height as possible.

Flexibility Training

Flexibility is an important element of physical fitness. It is crucial in complimenting muscular strength, building efficiency in movement, coordination, and preventing injuries. Holding muscles in a stretched position for a prolonged amount of time causes the muscle fibers to become accustomed to the new length, therefore increasing flexibility. For it to be beneficial, the specific muscle group being stretched needs to be isolated. For example, when stretching the hamstrings, spinal movement should be reduced. Relaxation is also important. It is advised that stretches happen slowly and gently with coordinated inhalation and exhalation at the moment of maximum stretch (*i.e.*, refrain from holding the breath).

There are many different types of stretching including static (holding), dynamic (moving through the stretch), and proprioceptive neuromuscular facilitation (PNF; a method utilizing alternate contraction and relaxation). It is important to be aware of the advantages and disadvantages of each. For example, ballistic (bouncing) stretches are not considered useful and can lead to muscle soreness and injury. Contrary to the practice of many dancers, stretching to full range should be carried out when the body is warm, preferably after class.

Neuromuscular Coordination

Moving beyond the purely physiological parameters, dance fitness also involves balance, agility, coordination and skill. Out of all the components of fitness, it is likely that neuromuscular coordination is addressed most often in the actual dance technique class. Through the use of imagery and visualization, improved neural pathways can help facilitate and develop efficiency in movement. Neuromuscular coordination can positively affect levels of muscle strength by controlling the recruitment of the right number of muscle fibers at the right time. In others words, dancers can become more skillful in recruiting only the muscles required to produce a certain movement and thus sustain sufficient energy levels and reduce fatigue. Research into motor control and motor learning also offers invaluable information that can enhance neural re-patterning, coordination and muscle relaxation.

Body Composition

Body composition plays an important role in dancers' health. Appropriate and healthy ratios of lean muscle mass to fat mass are key factors that can contribute to optimizing physical performance. Body composition is often expressed as a percentage of body fat and healthy recommendations suggest that dancers' body fat be at a certain level in order reach their potential. According to the World Health Organization, healthy body compositions range from 17 to 25% for females and below 15% for males (but not too low as a certain amount of fat is essential for daily healthy function). Optimal body composition is going to vary from activity to activity. These measurements are useful to determine what the best make-up is for dancers so that they can jump higher, turn faster, and physically survive long days of training, rehearsing, and performing. A balance of appropriate energy intake (nutrition) and energy expenditure (physical activity) will help dancers achieve the body composition that is right for them.

Rest

The importance of rest in dance training cannot be stressed enough. Proper recovery from physical training has many benefits. Rest helps to accelerate muscle regeneration between training sessions, to decrease fatigue, and to decrease the incidence of injury. It has been appreciated relatively recently that continuous training beyond a certain threshold of physical activity, without sufficient rest, can negatively impact both the health and performance of dancers. This concept refers to overtraining – excessive training that results in no effect or even negative effects on a dancer's performance. When there is an imbalance between habitual exertion (training) and recovery, symptoms such as severe and prolonged fatigue, changes in behavior and a loss of motivation can result. Recommendations to prevent or reverse overtraining include monitoring dance quality versus quantity, diet, hydration, rest, and sleep patterns.

General Training Principles

The following variables of exercise training also need to be understood in constructing balanced training plans. Depending on the dancer's training/performance goal, it is often necessary to progress to a higher level of difficulty by increasing the intensity, volume and/or frequency of training over time. Otherwise, the body simply adapts to the training and fitness levels plateau. Also fundamental to training is the concept of overload, which means that the body must be challenged above a certain threshold to provide sufficient stimulus for improvement to occur. Normally encountered stress will maintain but not increase the level of conditioning. For example, if the demands of a dance class are too similar from day to day there will be insufficient overload for desired improvement to take place. Sport literature describes another principle called specificity, and recommends that to develop motor abilities; training exercises should use similar technical patterns and kinematic structure to the particular activity for which it is preparing the athlete/dancer.

What is Physical Fitness?

Physical fitness is an important concept as related to the fields of physiology and exercise physiology. You should take a few minutes and read this brief history of Fitness. You'll note that this *fitness idea* is not something that just recently burst onto the scene.

There are a number of definitions for physical fitness but I developed the following general definition many years ago:

Physical fitness is the relative state of optimal function. All humans are able to be active because of the physiology / function of multiple body systems. Each of us has an *optimal function* which is unique to us and based largely on genetic endowment. We can improve that function by systematically engaging in various activities. The term *relative* is comparative in nature and so we may be *more or less* fit than we were or *more or less fit* than others with similar genetic endowment.

Other definitions of physical fitness include the following:

- If you are physically fit, you are free from illness, and able to function efficiently and effectively, to enjoy leisure, and to cope with emergencies. Health-related components of physical fitness include body composition, cardiovascular fitness, flexibility, muscular endurance, and muscle strength. Skill-related components include agility, balance, coordination, power, reaction time, and speed.
- *Physical fitness* comprises two related concepts: general fitness (a state of health and well-being) and specific fitness (a task-oriented definition based on the ability to perform specific aspects of sports or occupations). Physical fitness is generally achieved through exercise, correct nutrition and enough rest. It is an important part of life.
- The state or condition of being fit; suitability or appropriateness. Good health or physical condition, especially as the result of exercise and proper nutrition.

When considering physical fitness we usually consider it as having two components, *health related fitness* and *skill related fitness.*

As a physical education professional you will be responsible for knowing these concepts and later, for being able to describe how would one would exercise or *train* in such a way as to improve any of these components.

Types of physical fitness

Physical fitness is a general concept and is defined in many ways by different scientists. Physical fitness is discussed here in two major categories: health-related physical fitness and motor-performance physical fitness. Despite some overlap between these classifications, there are major differences, as described below.

Health-related physical fitness

Health-related physical fitness is defined as fitness related to some aspect of health. This type of physical fitness is primarily influenced by an individual's exercise habits; thus, it is a dynamic state and may change. Physical characteristics that constitute health-related physical fitness include strength and endurance of skeletal muscles, joint flexibility, body composition, and cardio respiratory endurance. All these attributes change in response to appropriate physical conditioning programs, and all are related to health.

Strength and endurance of skeletal muscles of the trunk help maintain correct posture and prevent such problems as low back pain. Minimal levels of muscular strength and endurance are needed for routine tasks of living, such as carrying bags of groceries or picking up a young child. Individuals with very low levels of muscular strength and endurance are limited in the performance of routine tasks and have to lead a restricted life. Such limitations are perhaps only indirectly related to health, but individuals who cannot pick up and hug a grandchild or must struggle to get up from a soft chair surely have a lower quality of life than that enjoyed by their fitter peers.

Flexibility, or range of motion around the joints, also ranks as an important component of health-related fitness. Lack of flexibility in the lower back and posterior thigh is thought to contribute to low back pain. Extreme lack of flexibility also has a deleterious effect on the quality of life by limiting performance.

Body composition refers to the ratio between fat and lean tissue in the body. Excess body fat is clearly related to several health problems, including cardiovascular disease, type II (adult-onset) diabetes mellitus, and certain forms of cancer. Body composition is affected by diet, but exercise habits play a crucial role in preventing obesity and maintaining acceptable levels of body fat.

Cardio respiratory endurance, or aerobic fitness, is probably what most people identify as physical fitness. Aerobic fitness refers to the integrated functional capacity of the heart, lungs, vascular system, and skeletal muscles to expend energy. The basic activity that underlies this type of fitness is aerobic metabolism in the muscle cell, a process in which oxygen is combined with a fuel source (fats or carbohydrates) to release energy and produce carbon dioxide and water. The energy is used by the muscle to contract, thereby exerting force that can be used for movement. For the aerobic reaction to take place, the cardio respiratory system (*i.e.*, the circulatory and pulmonary systems) must constantly supply oxygen and fuel to the muscle cell and remove carbon dioxide from it. The maximal rate at which aerobic metabolism can occur is thus determined by the functional capacity of the cardio respiratory system and is measured in the laboratory as maximal oxygen intake. As will be discussed in detail below, aerobic fitness is inversely related to the incidence of coronary heart disease and hypertension.

Motor-performance physical fitness

Motor-performance fitness is defined as the ability of the neuromuscular system to perform specific tasks. Test items used to assess motor-performance fitness include chin-ups, sit-ups, the 50-yard dash, the standing long jump, and the shuttle run (a timed run in which the participant dashes back and forth between two points). The primary physical characteristics measured by these tests are the strength and endurance of the skeletal muscles and the speed or power of the legs. These traits are important for success in many types of athletics. Muscular strength and endurance are also related to some aspects of health, as stated above.

There is disagreement among experts about the relative importance of health-related and motor-performance physical fitness. While both types of fitness are obviously desirable, their relative values should be determined by an individual's personal fitness objectives. If success in athletic events is of primary importance, motor-performance fitness should be emphasized. If concern about health is paramount, health-related fitness should be the focus. Different types of fitness may be important not only to different individuals but also to the same individual at different times. The 16-year-old competing on a school athletic team is likely to focus on motor performance. The typical middle-aged individual is not as likely to be concerned about athletic success, emphasizing instead health and appearance. One further point should be made: to a great extent, motor-performance physical fitness is determined by genetic potential. The person who can run fast at 10 years of age will be fast at age 17; although training may enhance racing performance, it will not appreciably change the individual's genetically determined running speed. On the other hand, characteristics of health-related physical fitness, while also partly determined by inheritance, are much more profoundly influenced by exercise habits.

Principles of exercise training

Research in exercise training has led to the recognition of a number of general principles of conditioning. These principles must be applied to the development of a successful exercise program.

Specificity

The principle of specificity derives from the observation that the adaptation of the body or change in physical fitness is specific to the type of training undertaken. Quite simply this means that if a fitness objective is to increase flexibility, then flexibility training must be used. If one desires to develop strength, resistance or strengthening exercises must be employed. This principle is indeed simple; however, it is frequently ignored. Many fraudulent claims for an exercise product or system promise overall physical fitness from one simple training technique. A person should be suspicious of such claims and should consider whether or not the exercise training recommended is the type that will produce the specific changes desired.

Overload

Overload, the second important principle, means that to improve any aspect of physical fitness the individual must continually increase the demands placed on the appropriate body systems. For example, to develop strength, progressively heavier objects must be lifted. Overload in running programs is achieved by running longer distances or by increasing the speed.

Progression

Individuals frequently make the mistake of attempting too rapid a fitness change. A classic example is that of the middle-aged man or woman who has done no exercise for 20 years and suddenly begins a vigorous training program. The result of such activity is frequently an injury or, at the least, stiffness and soreness. There are no hard-and-fast rules on how rapidly one should progress to a higher level of activity. The individual’s subjective impression of whether or not the body seems to be able to tolerate increased training serves as a good guide. In general it might be reasonable not to progress to higher levels of activity more often than every one or two weeks.

Warm-up/cool down

Another important practice to follow in an exercise program is to gradually start the exercise session and gradually taper off at the end. The warm-up allows various body systems to adjust to increased metabolic demands. The heart rate increases, blood flow increases, and muscle temperatures rise. Warming up is certainly a more comfortable way to begin an exercise session and is probably safer. Progressively more vigorous exercises or a gradual increase in walking speed are good ways to warm up. It is equally important to cool down—that is, to gradually reduce exercise intensity—at the end of each session. The abrupt cessation of vigorous exercise may cause blood to pool in the legs, which can cause fainting or, more seriously, can sometimes precipitate cardiac complications. Slow walking and stretching for five minutes at the end of an exercise session is therefore a good practice. The heart rate should gradually decline during the cool down, and by the end of the five minutes it should be less than 120 beats per minute for individuals under 50 years of age and less than 100 beats per minute for those over 50.

Frequency, intensity, and duration

To provide guidance on how much exercise an individual should do, exercise physiologists have developed equations based on research. It is generally agreed that to develop and maintain physical fitness, the exercise must be performed on a regular basis. A frequency of about every other day or three days per week appears minimally sufficient. Many individuals exercise more frequently than this, and, of course, such additional exercise is acceptable provided that one does not become over trained and suffer illness or injury.

The intensity of exercise required to produce benefits has been the subject of much study. Many people have the impression that exercise is not doing any good unless it hurts. This is simply not true. Regular exercise at 45 to 50 percent of one's maximal capacity is adequate to improve one's physiological functioning and overall health. This level of intensity is generally comfortable for most individuals. A reliable way to gauge exercise intensity is to measure the heart rate during exercise. An exercise heart rate that is 65 percent of a person's maximal heart rate corresponds to approximately 50 percent of his maximal capacity. Maximal heart rate can be estimated by subtracting one's age in years from 220 (or, in the case of active males, by subtracting half of one's age from 205). Thus, a sedentary 40-year-old man has an estimated maximal heart rate of 180 beats per minute. Sixty-five percent of this maximal rate is 117 beats per minute; thus by exercising at 117 beats per minute, this individual is working at about 50 percent of his maximal capacity. To determine exercising heart rate, a person should exercise for several minutes, to allow the heart rate to adjust. The exerciser should then stop exercising, quickly find the pulse, and count the number of beats for 15 seconds. Multiplying this by four gives the rate in beats per minute. The pulse must be taken immediately after stopping exercise, since the heart rate rapidly begins to return to the resting level after work has been stopped. As noted above, exercising at the 50 percent level of intensity will improve physiologic functioning and provide health benefits. This level of exercise will not produce the maximum fitness needed for competitive athletics.

Overall conditioning

Much emphasis has been given in the foregoing discussion to aerobic fitness, because this form of conditioning is extremely important. It should be noted, however, that other types of conditioning also have benefits. A total exercise program should include strengthening exercises, to maintain body mass and appropriate levels of strength for daily functioning, and stretching exercises to maintain joint mobility and flexibility. The specificity principle described above indicates that no one exercise is likely to produce the overall conditioning effect. In general an exercise plan should consist of aerobics, exercises that increase the strength and endurance of various skeletal muscle groups, and flexibility exercises to maintain good joint function.

Individual differences

The principles of exercise training discussed above should be viewed as general guidelines. Individuals differ in both physiological and psychological adaptations to exercise. Two people who are similar in many respects and who start the same exercise program may have entirely different impressions of it. One person may feel that the exercise is too easy, while the other may believe that it is much too hard. It is certainly appropriate that the exercise plan be adjusted to account for preferences. Likewise some individuals will progress to more intense training levels far more rapidly than others do. As mentioned earlier, exercise progress should be adjusted according to the exerciser's own assessment.

Individuals also differ in the type of exercise they like or can tolerate. Jogging, for instance, is not for everyone. Many people who dislike jogging, or who suffer running injuries, can find other satisfactory exercise activities, such as cycling, walking, swimming, or participating in a sport. Many kinds of exercise activities are appropriate and can provide physiological and health benefits to the participant. There is no one best exercise. The important thing is to be regular in exercise participation and to follow the general guidelines outlined in this section.

Physiological effects of exercise

Neuromuscular effects

STRENGTH AND ENDURANCE

Appropriate exercise increases the strength and endurance of skeletal muscles. Increases in muscular strength are associated with increases in muscle mass; increases in muscular endurance are associated with improved blood flow to the working muscles. These results are achieved by resistance training. Any exercise that causes the muscle to increase its tension, whether or not the muscle actually shortens during contraction, provides an appropriate strength-training stimulus. Resistance can be applied to a muscle group by attempting to move an immovable object, by working one muscle group against another, by lifting heavy weights, or by using special strength-training machines and devices. There is a wide selection of strength-training equipment that, when used properly, can increase muscular strength and endurance. It is possible that some of the equipment is more efficient in developing maximal performance, which is important for competitive athletes. But for the average individual, who is training to maintain an acceptable level of muscular fitness, any one device or program is probably about as good as another.
Strength and endurance training is done by performing several “reps” (repetitions) of a given exercise, then moving on to another exercise for a different muscle group. Experts generally recommend that exercisers select a resistance that is approximately 65 percent of the maximum they can lift for that particular exercise. This load should allow the completion of 12 reps of that exercise in 24 to 30 seconds. Each group of eight to 12 reps is called a set, and two or three sets of a given exercise are recommended for each training session. The average individual should perform strength and endurance training two to three days per week. Super circuit weight training refers to a program in which running or other aerobic exercises are performed between sets; this training produces aerobic as well as strength benefits.

FLEXIBILITY

Muscles and tendons can be stretched to improve flexibility (the range of motion at a joint). Flexibility training follows a few, simple principles. To improve range of motion, the muscles and other connective tissue around a joint must be stretched. The preferred stretching technique is a slow increase in the range of motion. The exerciser should feel the muscle stretch, but not to the point of pain. The stretch should be performed gradually, and the body should be held for 10 to 20 seconds in the stretched position and then gradually returned to a relaxed posture. By stretching each muscle group in this fashion as a part of the strengthening and conditioning program, the participant will maintain good flexibility. Bouncing or explosive stretching movements should be avoided, as they can result in muscle or tendon tears.

Cardio respiratory effects

CARDIAC EFFECTS

Regular aerobic exercise training has a direct effect on the heart muscle. The muscle mass of the left ventricle, which is the pumping chamber that circulates blood throughout the body, increases with exercise training. This change means that the heart can pump more blood with each beat. In short, the heart becomes a bigger, stronger, and more efficient pump capable of doing more work with less effort.

CIRCULATORY EFFECTS

Regular exercise also produces changes in the circulation. As previously discussed, muscle endurance training serves to increase blood flow to the working muscles. This increased blood flow means that more oxygen and fuel can be delivered to the muscle cells. The number of red blood cells, which carry oxygen in the blood, also increases with training, as does blood volume. Taken together, these changes indicate a greater capacity to transport oxygen to the working muscles.

PULMONARY EFFECTS

The basic function of the lungs is to facilitate the transfer (1) of oxygen from the atmosphere into the blood and (2) of carbon dioxide from the blood into the atmosphere. To accomplish this, air must pass into and out of the lungs, and the respiratory gases must diffuse through the lungs into the circulation and vice versa. Although exercise has not been shown to affect this diffusing ability, exercise training does strengthen the muscles of respiration. This means that a trained individual can move more air through the lungs per time unit, and forced vital capacity (*i.e.,* the maximum volume of air that can be exhaled after a full inspiration) may be increased.

Warming up, conditioning and fatigue.

A warm-up is an activity or activities, which prepare you both mentally and physically for further more intense activity or training. It should be continuous movement utilizing a variety of movements, which will result in increased heart rate, core temperature, and dynamic range of motion. In a warm-up you basically want to get the entire body warm, loose, and a little sweat on the forehead. You should now be ready mentally and physically to begin an intense training session. The warm-up should increase your productivity in the work out and also reduce your risk of injury.

Purpose: Body movements, increase blood flow to muscles, joints, raise core temperature, active flexibility, teaching/learning of body awareness and control.

The warm up activities are a crucial part of any exercise regime or sports training. The importance of a structured warm up routine should not be under estimated when it comes to the prevention of sports injury.

The Warm Up

An effective warm up has a number of very important key elements. These elements, or parts, should all be working together to minimize the likelihood of sports injury from physical activity. Warming up prior to any physical activity does a number of beneficial things, but primarily its main purpose is to prepare the body and mind for more strenuous activity. One of the ways it achieves this is by helping to increase the body's core temperature, while also increasing the body's muscle temperature. By increasing muscle temperature you are helping to make the muscles loose, supple and pliable.

An effective warm up also has the effect of increasing both your heart rate and your respiratory rate. This increases blood flow, which in turn increases the delivery of oxygen and nutrients to the working muscles. All this helps to prepare the muscles, tendons and joints for more strenuous activity. Keeping in mind the aims or goals of an effective warm up, we can then go on to look at how the warm up should be structured.

Obviously, it is important to start with the easiest and most gentle activity first, building upon each part with more energetic activities, until the body is at a physical and mental peak. This is the state in which the body is most prepared for the physical activity to come, and where the likelihood of sports injury has been minimized as much as possible. So, how should you structure your warm up to achieve these goals?

There are four key elements, or parts, which should be included to ensure an effective and complete warm up. They are:

1. The general warm up
2. Static stretching
3. The sports specific warm up
4. Dynamic stretching

All four parts are equally important and any one part should not be neglected or thought of as not necessary. All four elements work together to bring the body and mind to a physical peak, ensuring the athlete is prepared for the activity to come. This process will help ensure the athlete has a minimal risk of sports injury. Let us have a look at each element individually.

1. General warm up

The general warm up should consist of a light physical activity. Both the intensity and duration of the general warm up (or how hard and how long), should be governed by the fitness level of the participating athlete. Although a correct general warm up for the average person should take about five to ten minutes and result in a light sweat. The aim of the general warm up is simply to elevate the heart rate and respiratory rate. This in turn increases the blood flow and helps with the transportation of oxygen and nutrients to the working muscles. This also helps to increase the muscle temperature, allowing for a more effective static stretch.

2. Static stretching

Static stretching is a very safe and effective form of basic stretching. There is a limited threat of injury and it is extremely beneficial for overall flexibility. During this part of the warm up, static stretching should include all the major muscle groups, and this entire part should last for about five to ten minutes. Static stretching is performed by placing the body into a position whereby the muscle or group of muscles to be stretched is under tension. Both the opposing muscle group (the muscles behind or in front of the stretched muscle), and the muscles to be stretched are relaxed. Then slowly and cautiously the body is moved to increase the tension of the muscle, or group of muscles to be stretched. At this point the position is held or maintained to allow the muscles and tendons to lengthen.

This second part of an effective warm up is extremely important, as it helps to lengthen both the muscles and tendons which in turn allow your limbs a greater range of movement. This is very important in the prevention of muscle and tendon injuries. The above two elements form the basis, or foundation for a complete and effective warm up. It is extremely important that these two elements be completed properly before moving onto the next two elements. The proper completion of elements one and two, will now allow for the more specific and vigorous activities necessary for elements three and four.

3. Sport specific warm up

With the first two parts of the warm up carried out thoroughly and correctly, it is now safe to move onto the third part of an effective warm up. In this part, the athlete is specifically preparing their body for the demands of their particular sport. During this part of the warm up, more vigorous activity should be employed. Activities should reflect the type of movements and actions which will be required during the sporting event.

4. Dynamic stretching

Finally, a correct warm up should finish with a series of dynamic stretches. However, this form of stretching carries with it a high risk of injury if used incorrectly. It should really only be used under the supervision of a professional sports coach or trainer.Dynamic stretching is more for muscular conditioning than flexibility and is really only suited for professional, well trained, highly conditioned athletes.

Dynamic stretching should only be used after a high level of general flexibility has been established. Dynamic stretching involves a controlled, soft bounce or swinging motion to force a particular body part past its usual range of movement. The force of the bounce or swing is gradually increased but should never become radical or uncontrolled. During this last part of an effective warm up it is also important to keep the dynamic stretches specific to the athlete's particular sport. This is the final part of the warm up and should result in the athlete reaching a physical and mental peak. At this point the athlete is most prepared for the rigors of their sport or activity.

Neck Rotation

- Relax
- Slowly roll your head around in a full circle, keeping your back straight
- You may feel the need to hold the stretch at a particular position if it feels tight, but do not strain
- Continue for approximately 10 seconds

Shoulder Rotation

- Slowly rotate one shoulder at a time
- Rotate in forward and backward directions in a large circular motion
- Continue for approximately 10 seconds in each direction

Trunk Rotation

- Place hands on hips

- Rotate trunk, bending forward, to right, backward and to left
- Continue for approximately 10 seconds

Rock Squat

- From a standing position, slowly lower hips to squatting position
- Rock back and forth several times, attempting to squat progressively lower
- Turn and face to the right, straightening right leg and stretch right hamstring
- Hold stretch for 10 seconds
- Repeat for left leg

Hamstrings Stretch

- From lunge position, place knee on ground, lean forward on top of thigh
- Slide back leg as far back as possible
- Keeping chest on thigh, move hips back, straightening out forward leg
- Relax and hold for 10 seconds
- Slowly return to standing position
- Repeat for opposite leg

Arms Back (Chest/Shoulder Stretch)

- From a seated position, place hands on ground with arms behind torso
- Slowly move hips forward until stretch is felt in chest and shoulders
- Hold stretch for 10 seconds

Knee Over (Back Stretch)

- Lay back with knees bent
- Pull right leg across your body
- Keep upper back, head and shoulders flat on the floor
- Hold for 10 seconds
- Repeat for other side

Modified Hurdle

- Sit with right leg straight, keeping foot upright
- Tuck left foot into the inside of the right thigh
- Slowly bend forward from the hips toward the right foot, keeping your back straight
- Bring your chest to your right thigh
- Relax and hold for 10 seconds
- Repeat for opposite leg

(Piriformis Stretch)

- Place left foot over right knee and lie back
- Grasp right shin and slowly bring right knee to chest
- Relax and hold for 10 seconds
- Repeat for opposite leg

Butterfly

- Sit with soles of your feet together, holding onto your toes
- Use your elbows to gently push to the inside of your thighs until you get a good, even stretch
- Relax and hold for 10 seconds
- Repeat

Lunge (Hip Flexor Stretch)

- Move right leg forward until right knee is directly over the right ankle
- Keeping back leg straight, gently lower your hips to create an easy stretch in the front of the hip
- Hold for 10 seconds
- Repeat for other leg

Quadriceps Stretch

- Maintain position with one knee on ground
- Grasp shin with and pull lower leg toward hamstrings

- Slowly lean back toward ground, keeping your back straight
- Relax and hold for 10 seconds
- Repeat for opposite leg

Calf Stretch

- With hands on ground, move feet back until left knee is nearly straight and cross right leg behind left leg
- Press left heel toward ground to create an easy stretch in the calf
- Hold stretch for 10 seconds
- Repeat for other leg

Basic concept of balanced diet – Diet before, during and after competition

What is a healthy diet?

The crucial part of **healthy** eating is a **balanced diet**. A **balanced diet** - or a good **diet** - means consuming from all the different good groups in the right quantities. Nutritionists say there are five main food groups - whole grains, fruit and vegetables, protein, diary, and fat & sugar. A **balanced diet** is a **diet** that consists of the right nutrients in the right quantities. Everyone's bodies are different and may require different amounts or types of nutrients. The following information is for general reference and may not apply to everyone. On this page. Fats. There is **good** evidence that **eating** a **healthy diet** can reduce your risk of obesity and illnesses such as diabetes, heart disease, stroke, osteoporosis and some types of cancer. The food you eat contains several different types of nutrients, which are all required for the many vital processes in your body.

What is a balanced diet?

A balanced diet needs to contain foods from all the main food groups in the correct proportions to provide the body with optimum nutrition. It should also be made up of the correct number of calories to maintain a healthy weight, and be low in processed foods. Every person is different and hence the correct diet for health may vary from person to person, however by following a diet that is varied, covers all foods groups and is low in undesirable nutrients such as sodium, saturated fats and sugar, you are well on your way to a healthy body.

Why is a balanced diet important?

A balanced diet is one that provides the body with all the essential nutrients, vitamins and minerals required to maintain cells, tissues and organs as well as to function correctly. A diet that is lacking in nutrients can lead to many different health problems ranging from tiredness and lack of energy to serious problems with the function of vital organs and lack of growth and development.

How to achieve a healthy balanced diet?

To achieve a healthy, balanced diet, it is important to eat at least three meals a day and **not to skip breakfast**. Each meal should be composed of a variety of foods from each food group and portion sizes should be moderated to control calorie intake. Limiting alcohol consumption is also recommended, the US guidelines being one standard drink per day for women and two for men with two alcohol free days per week.

The 2010 dietary guidelines from the U.S. Departments of Health and Human Services and Agriculture recommend that a **diet that is low in saturated and trans fats**, cholesterol, added sugar, salt and alcohol should be followed. A diet similar to the DASH (Dietary Approaches to Stop Hypertension or the Mediterranean diet) diet is recommended to fulfill these requirements. **Calorie intake should also be balanced** with physical activity and sedentary activities such as watching TV should be reduced.

What Are Calories?

The number of calories in a food is a measurement of the amount of energy stored in that food. Your body uses calories from food for walking, thinking, breathing, and other important functions. The average person needs to eat about 2,000 calories every day to maintain their weight.

However, a person's specific daily calorie intake can vary depending on their age, gender, and physical activity level. Men generally need more calories than women, and people who exercise need more calories than people who don't.

The following examples of daily calorie intake are based on United States Department of Agriculture (USDA) guidelines:

children ages 2 to 8: 1,000 to 1,400 calories
active women ages 14 to 30: 2,400 calories
sedentary women ages 14 to 30: 1,800 to 2,000 calories
active men ages 14 to 30: 2,800 to 3,000 calories
sedentary men ages 14 to 30: 2,000 to 2,600 calories
active men and women over 30: 2,200 to 3,000 calories

sedentary men and women over 30: 1,800 to 2,200 calories
The source of your daily calories is just as important as the number of calories you consume. You should limit your consumption of "empty calories," or those that provide little or no nutritional value. The USDA defines empty calories as calories that come from sugars and solid fats, such as butter and shortening.

According to the USDA, Americans consume empty calories most often in:

bacon
sausages
cakes
cheese
cookies
doughnuts
energy drinks
fruit drinks
ice cream
pizza
sports drinks and sodas

Why a Balanced Diet Is Important

A balanced diet is important because your organs and tissues need proper nutrition to work effectively. Without good nutrition, your body is more prone to disease, infection, fatigue, and poor performance. Children with a poor diet run the risk of growth and developmental problems and poor academic performance. Bad eating habits can persist for the rest of their lives.

Rising levels of obesity and diabetes in America are prime examples of the effects of a poor diet and a lack of exercise. The USDA reports that four of the top 10 leading causes of death in the United States are directly influenced by diet. These are:

heart disease

cancer

stroke

diabetes

How to Achieve a Balanced Diet

At the core of a balanced diet are foods that are low in unnecessary fats and sugars but high in vitamins, minerals, and other nutrients. The following food groups are essential parts of a balanced diet.

Fruits

Besides being a great source of nutrition, fruits make tasty snacks. Choose fruits that are in season in your area. They're fresher and provide the most nutrients.

Vegetables

Vegetables are primary sources of essential vitamins and minerals. Dark, leafy greens generally contain the most nutrition and can be eaten at every meal. A variety of vegetables will help you obtain the bountiful nutrients that all vegetables provide. Examples of dark leafy greens include:

spinach

kale

green beans

broccoli

collard greens

Swiss chard

Grains

According to the USDA, Americans consume refined white flour more than any other grain. Unfortunately, refined white flour contains poor nutritional value because the hull of the grain is removed during the refining process. The hull is the outer shell of the grain and is where the majority of the grain's nutrition lies. Whole grains, however, are prepared using the entire grain, including the hull, so they provide much more nutrition. Try switching from white breads and pastas to whole-grain products.

Proteins

Meats and beans are primary sources of protein, which is essential for proper muscle and brain development. Lean, low-fat meats such as chicken, fish, and certain cuts of pork and beef are the best options. Removing the skin and trimming off any visible fat are easy ways to reduce the amount of fat and cholesterol in meats. The health and diet of the animal are important and influence the fatty acid profile of the meat, so grass-fed choices are ideal.

Other good sources of protein, which contain many other health benefits, fiber and other nutrients, include nuts and beans, such as:

lentils
beans
peas
almonds
sunflower seeds
walnuts
Tofu, tempo, and other soy-based products are excellent sources of protein and are healthy alternatives to meat.

Dairy

Dairy products provide calcium, vitamin D, and other essential nutrients. However, they’re also major sources of fat, so it’s best to choose small portions of full-fat cheeses, and reduced-fat or fat-free milk and yogurt. Plant-based milks, such as those made from flaxseed, almond, or soy are typically fortified with calcium and other nutrients, making these excellent alternatives to dairy from cows.

Oils

Oils should be used sparingly. Opt for low-fat and low-sugar versions of products that contain oil, such as salad dressing and mayonnaise. Good oils, such as olive oil, can replace fattier vegetable oil in your diet. Avoid deep-fried foods because they contain a large number of empty calories.

The USDA has an online calculator that can help you determine how much of each food group you should consume daily.
Aside from adding certain foods to your diet, you should also reduce your consumption of certain substances in order to maintain a balanced diet and a healthy weight. These include:

alcohol
refined grains
solid fats
saturated fats
trans fats
salt
sugars

The key to a healthy, balanced diet is:

eating the right amount of food to achieve and maintain a healthy body weight

eating a wide variety of foods in the right proportions – this is what balanced means

The range of foods in your diet should include:

plenty of fruit and vegetables

plenty of bread, rice, potatoes, pasta and other starchy foods – choosing wholegrain varieties where possible

some meat, fish, eggs, beans and other non-dairy sources of protein

some milk and dairy foods – choosing lower-fat varieties where possible

just a small amount of foods high in fat and sugar

Carbohydrates are the body's main source of fuel during exercise. A diet high in carbohydrate-rich foods such as whole grain products, vegetables, fruits and legumes, can help you exercise longer and faster.

How should I eat before a competition?

One to six hours before a competition, eat a meal that is high in carbohydrates and low in fat, like rice and veggies. If the event is less than four hours away, eat enough so that you won't get hungry but not so much that you'll be full and uncomfortable.

Two hours before, drink at least two cups (16 ounces) of water or fruit juice. Avoid beverages that have caffeine. They can cause dehydration.

Within 15 minutes before, drink two cups (16 ounces) of cold water.

Hint: If your event is in the morning, eat a carbohydrate-rich dinner and bedtime snack like frozen grapes the night before. Then eat a light meal in the morning. This should be high in carbohydrates too.

The size and timing of a meal or snack before an intense workout depends on your individual needs. The longer the time between eating and activity the more you might be able to eat. Approximately 2 – 4 hours before an endurance event, drink plenty of fluids and try to eat a meal high in carbohydrates (e.g. grain products, fruits and vegetables), relatively low in protein (small servings of choices such as chicken, beans, or hummus), and fibre and low in fat. This may help to:

boost energy levels
prevent hunger
keep you hydrated
extend your time to exhaustion

Some people experience an upset stomach if they eat a meal before endurance activity. A liquid snack such as a sports drink or smoothie is a good alternative.

Carbohydrate-rich snack examples include some sport bars, fruit, and cereal with milk, lentils, bagels, pasta, yogurt, and homemade granola bars.

"Carbohydrate-loading" (for competitive activities that last longer than 90 minutes) has been found to build extra carbohydrate energy stores in the body (as muscle and liver glycogen). However, it may not offer additional benefits to performance if you follow a high-carbohydrate diet or eat a carbohydrate rich snack before and/or during exercise.

During a competition?

Every 15 minutes drink half a cup (4 ounces) of cold water.

Hint: If your event is an endurance event that lasts an hour or more, like long-distance running, you need carbohydrates as well as water, so drink a mix of half fruit juice and half water, rather than plain water, or have a sports drink.

During intense exercise that lasts longer than one hour, eating carbohydrate might help extend time to exhaustion and may improve performance in some activities such as sprints and agility drills. Approximately 30 – 70 g of carbohydrates per hour (such as in the form of a sports drink), in small amounts every 15 to 20 minutes, can improve exercise performance.

For activities lasting longer than an hour or in extreme heat, sports drinks provide hydration as well as carbohydrate. It is important that you drink enough during and after exercise to replace the fluid you lose in sweat. To find out how much you typically sweat during training or competition weigh yourself before and after exercise. Factor in how much you drank. The difference will be sweat losses.

After a competition?

Right away and throughout the rest of the day, catch up on the fluids you lost through sweating. Sweat is mostly water. Try to drink two cups of fluid that contain carbohydrates (fruit juice, milk, soy milk, sports drinks, or watery foods, like soup) for every pound you lose during your activity. To do this, you need to weigh yourself before and after the event. Otherwise, just drink several cups of fluid. You can't overdo it. Your body will just get rid of the extra fluid.

Within several hours, eat a high-carbohydrate meal. This will refill your muscles' supply of glycogen. Once your activity is finished, your body is ready to store energy again, repair muscles and fill up with fluids. Carbohydrate eaten within 30 minutes of exercise and again every two hours for four to six hours will replenish glycogen stores. Meals or snacks should also contain protein for building and repairing muscle and fluids for rehydrating.

Immediately after endurance exercise, good choices would be a smoothie (blend milk, fruit and ice together), sport drink, chocolate milk and water. Soon after exercise choose a meal or snack rich in carbohydrate and protein. For example: chicken or fish with brown rice and tender-crisp steamed vegetables pasta and meat sauce with a leafy green salad vegetarian chili with a whole grain roll.

It's great to have exercise goals and challenges, especially with endurance activities. Well-planned healthy eating before, during and after your long exercise events can help make your experience even more enjoyable!