ANATOMY AND PHYSIOLOGY

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UNIT - I

ANATOMY AND PHYSIOLOGY

Anatomy

The word anatomy is derived from a Greek word "*Anatome*" meaning to cut up. It is the study of structures that make up the body and how those structures relate with each other. The study of anatomy includes many sub specialties. These are Gross anatomy, Microscopic anatomy, Developmental anatomy and Embryology.

Gross anatomy

Studies body structure without microscope. *Systemic anatomy* studies functional relationships of organs within a system whereas *Regional anatomy* studies body part regionally. Both systemic and regional approaches may be used to study gross anatomy.

Microscopic anatomy (Histology)

Requires the use of microscope to study tissues that form the various organs of the body.

Physiology:

The word physiology derived from a Greek word for study of nature. It is the study of how the body and its part work or function. Hence, Anatomy and physiology are studied together to give students a full appreciation and understanding of human body.

- *Histology* is the study of tissues at the microscopic level.
- *Cytology* is the study of cells at the microscopic level.
- *Neurophysiology* is the study of how the nervous system functions.

Organizations of living systems

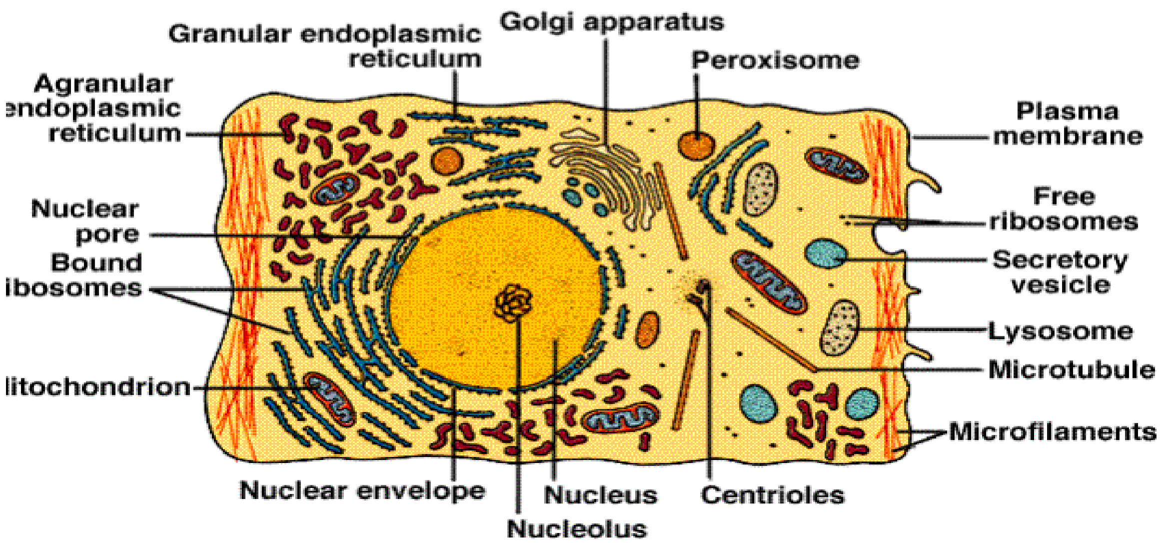
Living systems can be defined from various perspectives, from the broad (looking at the entire earth) to the minute (individual atoms). Each perspective provides information about how or why a living system functions:

- At the chemical level, ***atoms**, molecules* (combinations of atoms), and the chemical bonds between atoms provide the framework upon which all living activity is based.
- The ***cell*** is the smallest unit of life. **Organelles** within the cell are specialized bodies performing specific cellular functions. Cells themselves may be specialized. Thus, there are nerve cells, bone cells, and muscle cells.
- A ***tissue*** is a group of similar cells performing a common function. Muscle tissue, for example, consists of muscle cells.
- An ***organ*** is a group of different kinds of tissues working together to perform a particular activity. The heart is an organ composed of muscle, nervous, connective, and epithelial tissues.
- An ***organ system*** is two or more organs working together to accomplish a particular task. The digestive system, for example, involves the coordinated activities of many organs, including the mouth, stomach, small and large intestines, pancreas, and liver.
- An ***organism*** is a system possessing the characteristics of living things—the ability to obtain and process energy, the ability to respond to environmental changes, and the ability to reproduce.

Cells

Cells are a major part of our bodies. In this section we will review the major parts of a cell and investigate cellular transport mechanisms. The human body has something on the order of 10 trillion cells all working in harmony to keep us alive. Cells are fundamental building blocks for many of the tissues and organs of our bodies. In this section we will primarily be concerned with studying cells that contain a nucleus known as eukaryotic cells. The lowest level of organization was the atom followed by molecules and tissues. Then there were organelles and cells. So cells contain smaller structures called organelles. These are much like the organs in our bodies. The organelles have various functions that are important in maintaining the cell.

Human Cell



Functions of Cell

- **Cell wall** support (grow tall), protection, allows H_2O, O_2 and CO_2 to diffuse in & out of cell
- **Cell membrane-** support protection, controls movement of materials in/out of cell, barrier between cell and its environment, maintains homeostasis
- **Nucleus-** controls cell activities, contains the hereditary material of the cell,
- **Nuclear membrane -** controls movement of materials in/out of nucleus
- **Cytoplasm -** supports and protects cell organelles
- **Endoplasmic reticulum (ER) --** carries materials through cell, aids in making proteins
- **Ribosome -** synthesizes proteins
- **Mitochondria -** breaks down sugar (glucose) molecules to release energy, site of aerobic cellular respiration
- **Vacuole -** store food, water, metabolic & toxic wastes, store large amounts of food or sugars in plants

- **Lysosome -** breaks down larger food molecules into smaller molecules, digests old cell parts
- **Chloroplast -** uses energy from sun to make food (glucose) for the plant, process called photosynthesis, release oxygen
- **Nucleolus** - make ribosomes
- **Golgi apparatus -** modify proteins made by the cells, package & export proteins
- **Centrioles -** separate chromosome pairs during mitosis
- **Cytoskeleton -** strengthen cell & maintains the shape, moves organelles within the cell.

TISSUE

The body is packed with many different kinds of tissues. Some are highly organized and some are not. When studying tissues it helps to think about the relationship between the structure of a tissue and its function. The study of tissues is known as histology. People who study histology spend a lot of time looking in microscopes at the various body tissues. Let's look at how tissues are categorized. There are 4 main categories of tissues in the human body.

A. Epithelium
B. Connective
C. Muscle
D. Nervous

Epithelial tissue

It is a tissue that covers other structures. Therefore one side is always exposed to the outside (which could still be inside the body). You will see epithelial tissue covering the inside of body cavities and organs. The outer or superficial portion of your skin is an epithelial tissue. Epithelial tissue does not have a blood supply. Therefore nutrients must enter the tissue by diffusion. Epithelial tissue anchors to other structures via a basement membrane. We can categorize epithelial tissue according to the shape of the cells and number of layers.

There are 3 basic shapes of epithelial cells

- Squamous cells are flattened.
- Cuboidal cells look like cubes.
- Columnar cells are rectangular.

Connective tissue

There is also a category called "special" connective tissue that includes blood, bone, and cartilage. Loose connective tissue is not very well organized tissue. It contains fibroblasts, matrix, and some fibers scattered about. It is found in the dermis and subcutaneous layers of the skin as well as surrounding muscles. Sometimes it is called fascia.

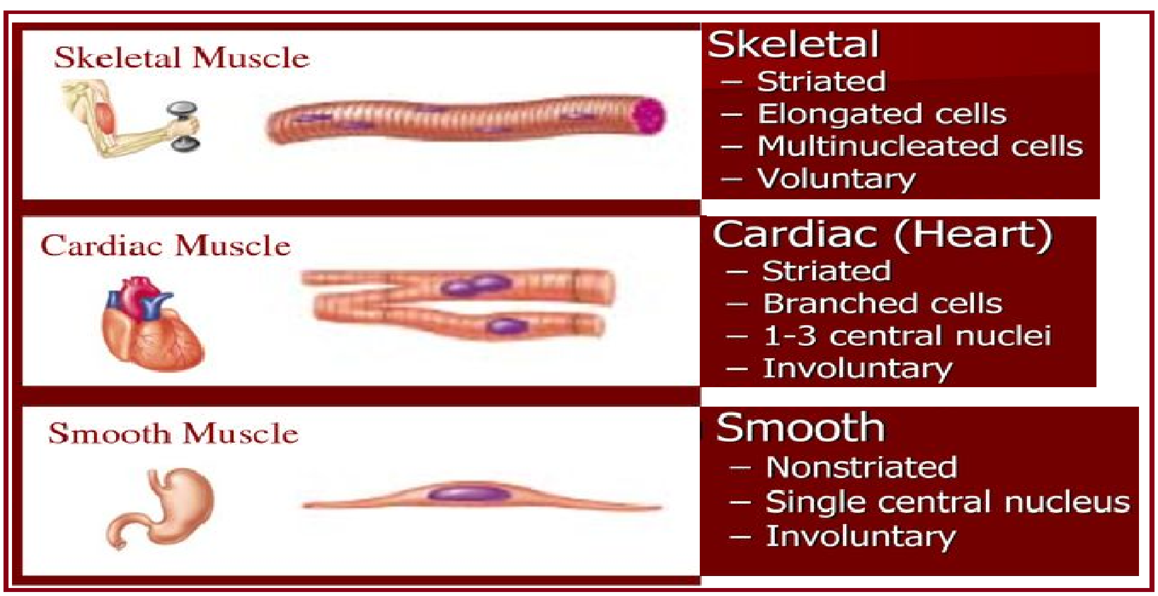
There are 5 basic types of connective tissue:

1. Loose
2. Dense
3. Adipose
4. Reticular
5. Elastic

Muscle Tissue

There are 3 types of muscular tissue.

• Skeletal • Cardiac • Smooth



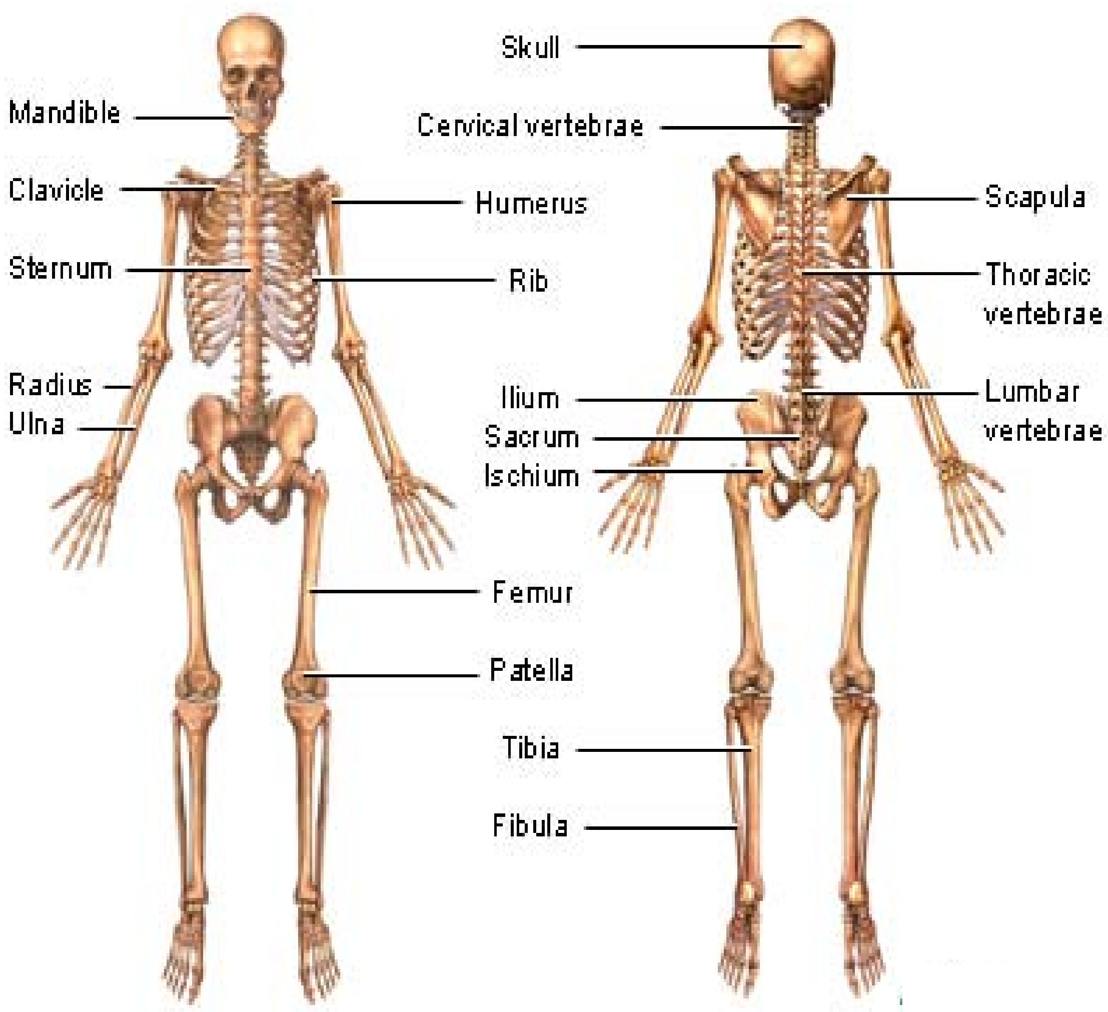
Skeletal muscle is striated. The striations are caused by the density of overlapping protein filaments called actin and myosin. The high concentration of protein filaments creates an optical illusion when light is shown on the muscle tissue. The filaments break up the light into light and dark areas causing the striated appearance

Nervous Tissue

Nervous tissue consists of nervous system cells called neurons and supportive cells called glia.

THE SKELETAL SYSTEM

The word skeleton comes from the Greek word skeleton meaning "dried up". It is strong yet light adapted for its function of body protection

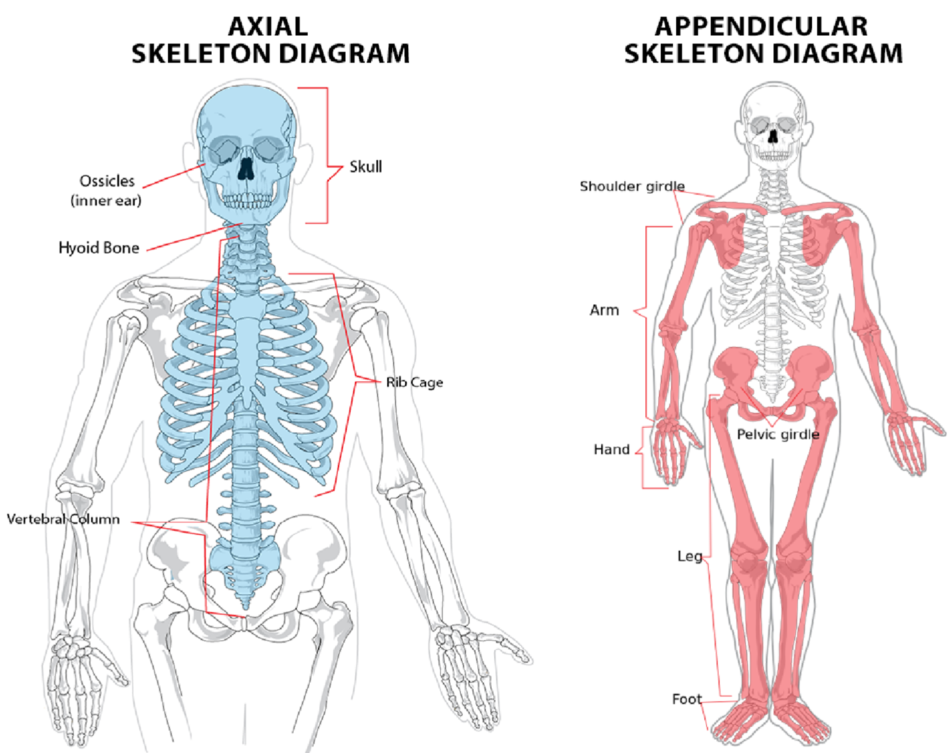


and motion. The skeletal system includes bones, joints, cartilages and ligaments. The joint give the body flexibility and allow movements to occur. But from structural point of view, the human skeletal system consists of two main types of supportive connective tissue, *bone and cartilage.*

Division of the skeletal system

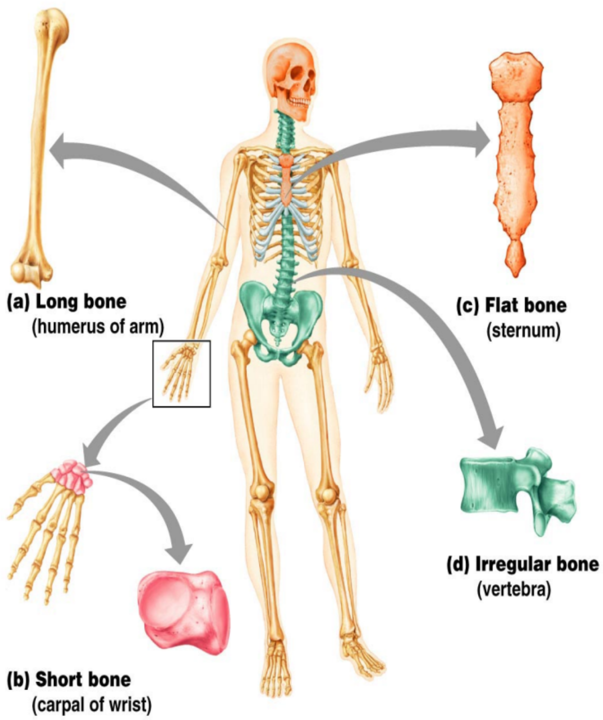
The Adult human skeleton have 206 named bones that are grouped in to two principal parts. These are the axial and appendicular skeleton.

- ***The Axial skeleton*** consist bones that lie around the axis. The axial skeleton includes the skull, spine, ribcage, and sacrum
- ***The Appendicular skeleton*** consist bones of the body out of the axial group. These are appendages. Upper & lower extremities and bones of girdles are grouped under appendicular skeleton. Total axial bones 80 Total Appendicular bones 126. The skeletal system not only helps to provide movement and support but also serves as a storage area for calcium and inorganic salts and a source of blood cells. The adult human body has 206 bones in a variety of shapes and sizes. Basically there are 4 types of bones categorized according to shape.



Types of Bone

- ***Long bones*** are called long as its length is greater than its width. The most obvious long bones are in the arm and leg. They act as levers that pulled by contraction of muscles.
- ***Short bones*** are about equal in length, width and thickness, which are shaped with regular orientation. They occur in the wrist and ankle.



- ***Flat bones*** are thin or curved more often they are flat. This includes ribs, scapulae, sternum and bone of cranium.
- ***Irregular bones***, they do not fit neatly into any other category. Examples are the vertebral, facial, and hipbone.
- ***Sesamoid bones*** are small bones embedded within certain tendons, the fibrous cord that connects muscle to bones.

Typical sesamoid bones are patella and pisiform carpal bone, which are in the tendon of quadriceps femurs and flexor carp ulnaris muscle respectively.

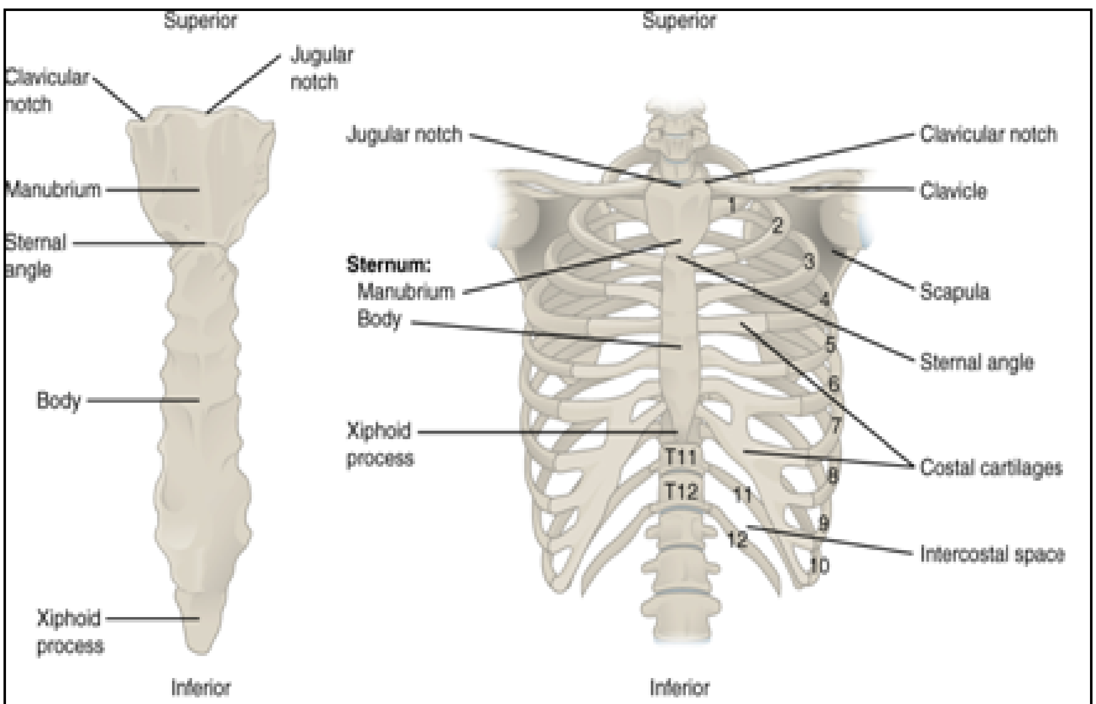
Functions of the skeletal system

1. ***Support:*** it forms the internal framework that supports and anchors all soft organs.
2. ***Protection:*** bones protect soft body organs.
3. ***Movement:*** skeletal muscles attached to the skeletal system use the bone to levers to move the body and its part.

4. ***Storage:*** fat is stored in the internal cavities of bones. Bone it self-serves as a storehouse of minerals. The most important being calcium and phosphors.
5. ***Blood cell production:*** The production of blood cells, or hematopoiesis, occurs in the red marrow found within the cavities of certain bones.
6. ***Mineral storage:*** Bones serve as a reservoir for calcium and phosphorus, essential minerals for various cellular activities throughout the body.
7. ***Energy storage:*** Lipids, such as fats, stored in adipose cells of the yellow marrow serve as an energy reservoir.

Ribs

Human being contains 12 Pair of ribs that make up the side of thoracic cavity. Ribs increase in length from 1st through 7th and they decrease in length through 12th. Each ribs posterior articulates with the body of its corresponding thoracic vertebra.



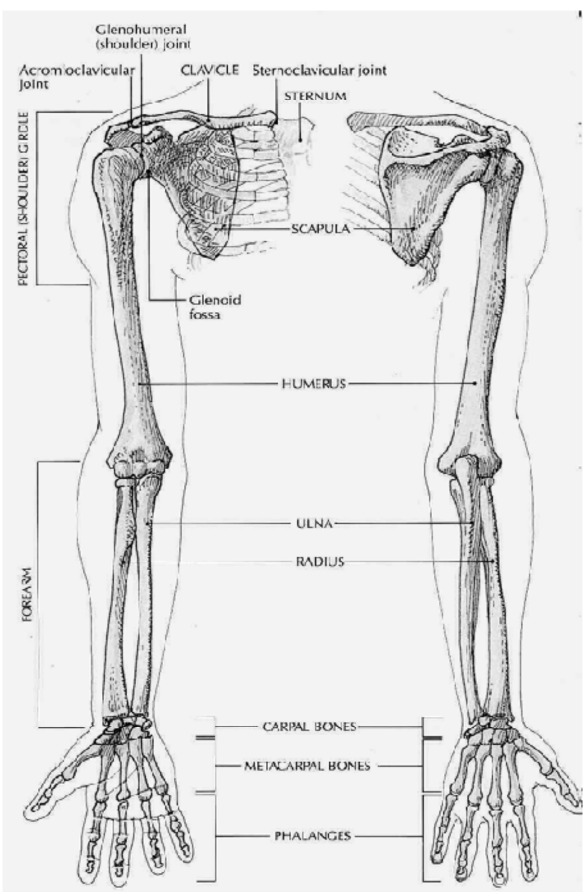
(a) Anterior view of sternum (b) Anterior view of skeleton of thorax

Anterior the 1st seven ribs have direct attachment to sternum by costal cartilage hence they are called *true (vertebro – sternal) ribs.* The remaining 5 ribs are called *false ribs.* The 8^{th} – 10^{th} ribs, which are groups of the false ribs are called *vertebro chondrial ribs* because their cartilage attach one another and then attaches to the cartilage of the 7^{th} rib. The 11^{th} & 12^{th} ribs are designated as floating ribs because their anterior part even doesn't attach indirectly to sternum. Although there is variation when we examine a typical rib (3^{rd} to 9^{th}) contains a head, neck and body parts.

The vertebral column

The vertebral column together with the sternum & ribs constitutes the skeleton of the trunk of the body. It composes 2/5th of the height of the body and has average length in male of 71c.m. and in female 61 c.m. The adult vertebral column contains 26 vertebras. Prior to fusion of sacral & coccygeal vertebrae the total number is 33. It is a strong and flexible to either direction & rotated on itself. Encloses & protect spinal cord, supports the head and serves as a point of attachment for the ribs & muscles of the back.

THE UPPER EXTREMITIES (LIMBS)



The upper extremities consists of 64 bones. Connected and supported by the axial skeleton with only shoulder joint and many muscle from a complex of suspension bands from the vertebral column, ribs and sternum to the shoulder girdle.

Bone Description and function

- **Shoulder (Pectoral) Girdle**

Clavicle (2) Collarbone; double-curved, long bone with rounded medial end and flattened lateral end; held in place by ligaments. Holds shoulder joint and arm away from thorax so upper limb can swing freely.

Scapula (2) Shoulder blade; flat, triangular bone with horizontal spine separating fossae. Site of attachment for muscles of arm and chest.

- **Arm**

Humerus (2) Longest, largest bone of upper limb; forms ball of balland socket joint with glenoid fossa of scapula. Site of attachment for muscles of shoulder and arm, permitting arm to flex and extend at elbow.

- **Forearm**

Radius (2) Larger of two bones in forearm; large proximal end consists of olecranon process (prominence of elbow). Forms hinge joint at elbow.

- **Wrist**

Carpals (16) Small short bones; in each wrist, 8 carpals in 2 transverse rows of 4. With attached ligaments, allow slight gliding movement.

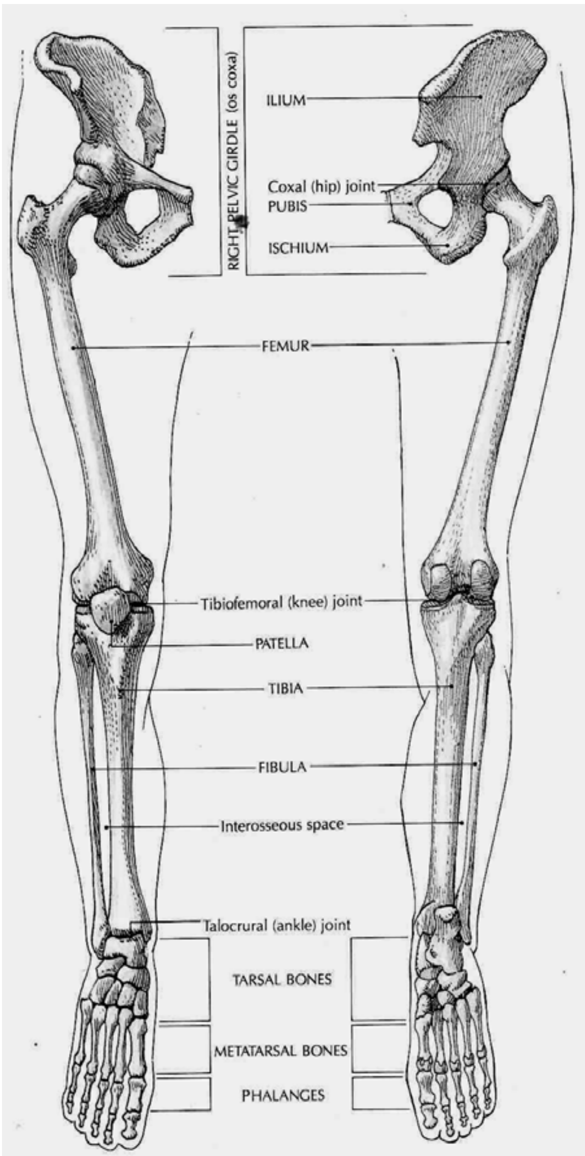
- **Hands and Fingers**

Metacarpals (10) Five miniature long bones in each hand in fanlike arrangement; articulate with fingers at metacarpophalangeal joint (the Knuckle). Aid opposition movement of thumb; enable cupping of hand. *Phalanges* (28) Miniature long bones, 2 in each thumb, 3 in each finger; articulate with each other at interphalangeal joint. Allow fingers to participate in stable grips.

THE LOWER EXTREMITY

It consist 62 bones. The lower extremity is connected to the axial skeleton with the hip girdle.

Bone Description and function



- **Pelvic Girdle**

Hipbone Irregular bone formed by fusion of ilium, ischium, pubis; with (Coxal) (2) sacrum and coccyx forms pelvis; forms socket of ball-and- socket joint with femur. Site of attachment for trunk and lower limb muscles; transmits body weight to femur.

- **Thigh**

Femur (2) Thighbone; typical long bone; longest, strongest, heaviest bone; forms ball of ball-and-socket joint with pelvic bones; provides articular surface for knee. Supports body.

Patella (2) Kneecap; sesamoid bone within quadriceps femuris tendon. Increases leverage for quadriceps muscle by keeping tendon Away from axis of rotation.

- **Leg**

Fibula (2) Smaller long bone of lower leg; articulates proximally with tibia and distally with talus. Bears little body weight, but gives strength to ankle joint. *Tibia* (2) Larger long bone of lower leg; articulates with femur fibula, talus. Supports body weight, transmitting it from femur to talus.

- **Ankle**

  Tarsals (14) Ankle, heel bones; short bones; 7 in each ankle including talus, calcaneus, cuboid, navicular, 3 cuneiforms; with metatarsals, form arches of foot. Bear body weight; raise body and transmit thrust during running and walking.

- **Foot and Toes**

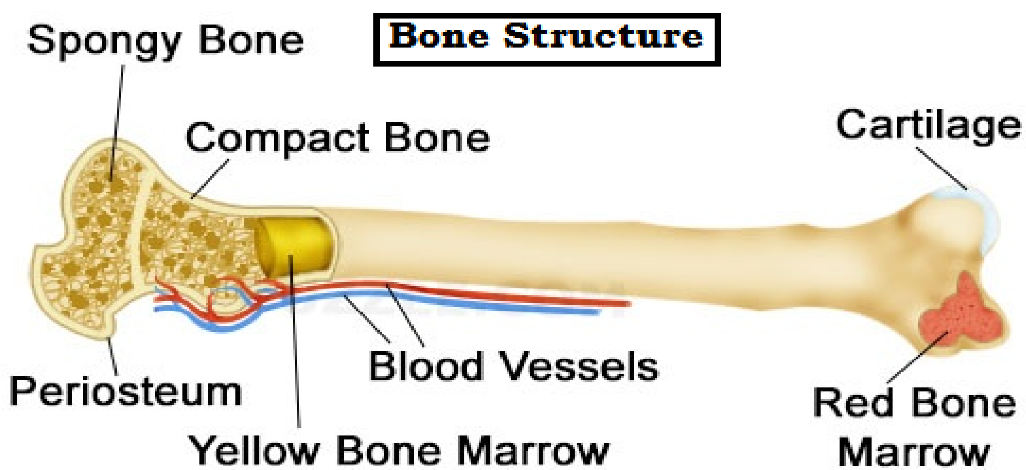
  Metatarsals (10) Miniature long bones; 5 in each foot; form sole; with tarsal, form arches of feet. Improve stability while standing; absorb shocks; bear weight; aid in locomotion.

Bone

Bone (osseous) is specialized connective tissue that has the strength of cast iron and lightness of pinewood. Living bone is not dry, brittle or dead. It is a moist changing, productive tissue that is continually resorbed, reformed and remodelled.

Bone Structure

Compact bone is organized according to structural units called Haversian systems or osteons. These are located along the lines of force and line up along the long axis of the bone. The Haversian systems are connected together and form an interconnected structure that provides support and strength to bones.



Haversian systems contain a central canal (Haversian canal) that serves as a pathway for blood vessels and nerves. The bone is deposited along concentric rings called lamellae. Along the lamellae are small openings called lacunae. The lacunae contain fluid and bone cells called osteocytes. Radiating out in all directions from lacunae are small canals called canaliculi. Haversian systems are interconnected by a series of larger canals called Volksmann's canals (perforating canals).

Bone Cells

There are 3 basic types of cells in bone. Osteoblasts undergo mitosis and secrete a substance that acts as the framework for bone. Once this substance (called osteoid) is secreted minerals can deposit and form hardened bone. Osteoblasts respond to certain bone forming hormones as well as from physical stress. Osteocytes are mature osteoblasts that cannot divide by mitosis. Osteocytes reside in lacunae. Osteoclasts are capable of demineralizing bone. They free up calcium from bone to make it available to the body depending on the body's needs.

Bone Marrow

Bone marrow is located in the medullary (marrow) cavity of long bones and in some spongy bones. There are 2 kinds of marrow. Red marrow exists in the bones of infants and children. It is called red because it contains a large number of red blood cells. In adults the red marrow is replaced by yellow marrow. It is called yellow because it contains a large proportion of fat cells. Yellow marrow decreases its ability to form new red blood cells. However, not all adult bones contain yellow marrow. The following bones continue to contain red marrow and produce red blood cells:

- Proximal end of humours
- Ribs
- Bodies of vertebrae
- Pelvis
- Femur

JOINTS

A joint is defined as the point at which two or more bones articulate. Not all joints move, and different classes of joint contain different tissues. The structure and tissue makeup of a joint will define its properties, including the mobility, strength and stability. A joint, also called an articulation, is any place where adjacent bones or bone and cartilage come together (articulate with each other) to form a connection. Joints are classified both structurally and functionally.

Structural Classification of Joints

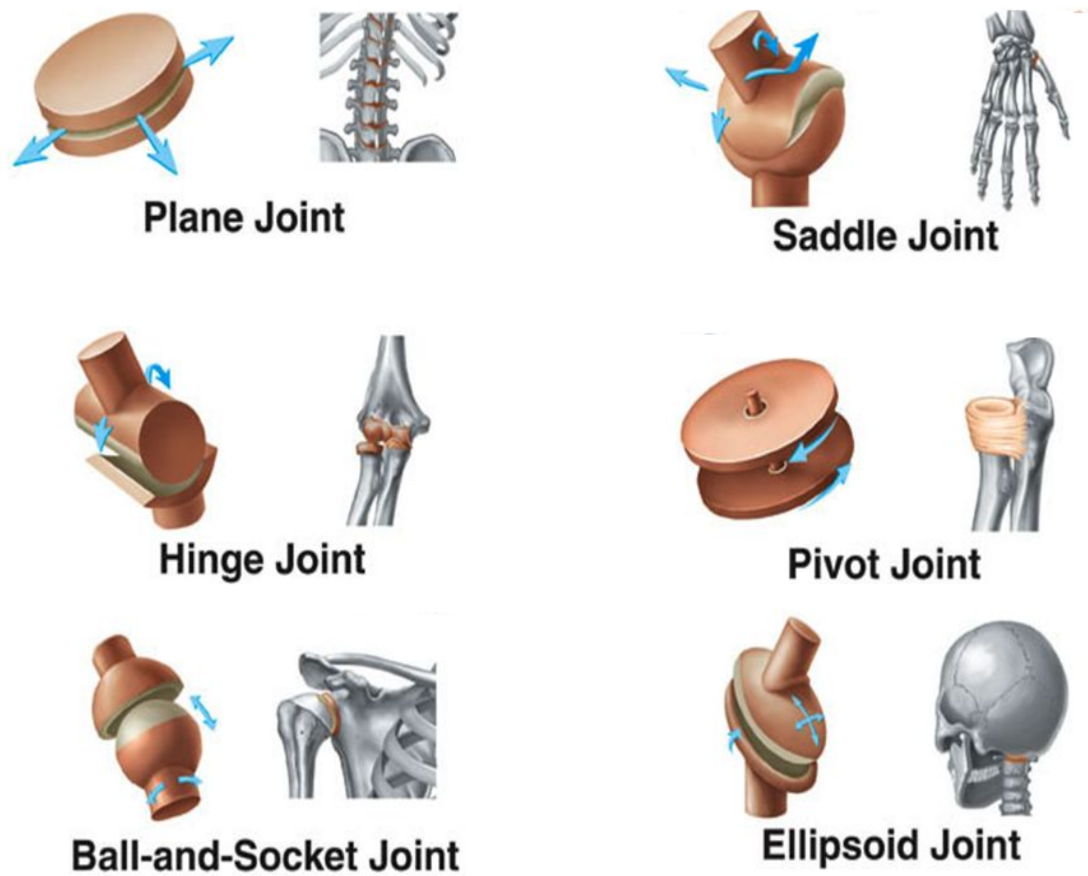
The structural classification of joints is based on whether the articulating surfaces of the adjacent bones are directly connected by fibrous connective tissue or cartilage, or whether the articulating surfaces contact each other within a fluid-filled joint cavity. These differences serve to divide the joints of the body into three structural classifications.

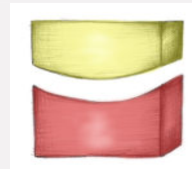
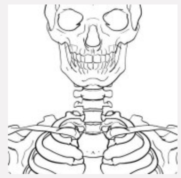
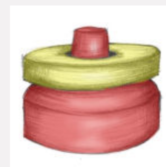
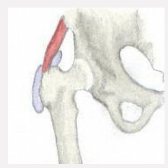
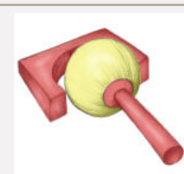
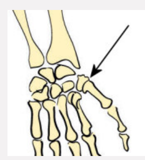
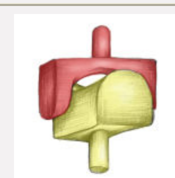
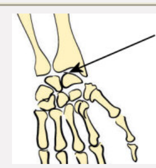
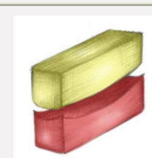
- **Fibrous joint** is where the adjacent bones are united by fibrous connective tissue.
- **Cartilaginous joint**, the bones are joined by hyaline cartilage or fibrocartilage.
- **Synovial joint**, the articulating surfaces of the bones are not directly connected, but instead come into contact with each other within a joint cavity that is filled with a lubricating fluid. Synovial joints allow for free movement between the bones and are the most common joints of the body.

Functional Classification of Joints

The functional classification of joints is determined by the amount of mobility found between the adjacent bones. Joints are thus functionally classified as a synarthrosis or immobile joint, an amphiarthrosis or slightly moveable joint, or as a diarthrosis, which is a freely moveable joint

Depending on their location, fibrous joints may be functionally classified as a synarthrosis (immobile joint) or an amphiarthrosis (slightly mobile joint). Cartilaginous joints are also functionally classified as either a synarthrosis or an amphiarthrosis joint. All synovial joints are functionally classified as a diarthrosis joint.



Joint Type	Movement at joint	Examples	Structure
Hinge	Flexion/Extension	 **Elbow/Knee**	 **Hinge joint**
Pivot	Rotation of one bone around another	 **Top of the neck** (atlas and axis bones)	 **Pivot Joint**
Ball and Socket	Flexion/Extension/Adduction/ Abduction/Internal & External Rotation	 **Shoulder/Hip**	 **Ball and socket joint**
Saddle	Flexion/Extension/Adduction/ Abduction/Circumduction	 **CMC joint of the thumb**	 **Saddle joint**
Condyloid	Flexion/Extension/Adduction/ Abduction/Circumduction	 **Wrist/MCP & MTP joints**	 **Condyloid joint**
Gliding	Gliding movements	 **Intercarpal joints**	 **Gliding joint**

UNIT – II

BLOOD AND CIRCULATORY SYSTEM

The cardiovascular system is the transport system of the body by which food, oxygen, water and all other essentials are carried to the tissue cells and their waste products are carried away. It consists of three parts:

- **The blood**, Which is the fluid in which materials are carried to and from the tissue
- **The heart**, which is the driving force which propels the blood
- **The blood vessels**, the routes by which the blood travels to and through the tissues and back to the heart.

The Blood

Blood is classified as a connective tissue, since nearly half of it is made up of cells. However, it differ from other connective tissues in that its cells are not fixed in position, instead they move freely in the liquid portion of the blood, the *plasma.*

Blood is a viscous (thick) fluid that varies in colour from bright to dark red, depending on how much oxygen it is carrying. Its quantity differs with the size of the person; the average adult male, weighing 70 kg has about 5-6 litres of blood. This volume accounts for about 8% of the total body weight. It is carried through a closed system of vessels pumped by the heart. The circulating blood is of fundamental importance in maintaining the internal environment in a constant state (homeaostasis).

Composition of Blood

The blood is composed of two prime elements: the liquid element is called plasma; the cells and fragments of cells are called formed elements or corpuscles. The formed elements are classified as follows:

- **Erythrocytes,** from erythro, meaning "red," are the *red blood cells*, which transport oxygen.
- **Leukocytes,** from leuko, meaning "white," are the several types of white *blood cells*, which protect against infection.
- **Platelets,** also called thrombocytes, are cell fragments that participate in blood clotting.

Erythrocytes (RBC):

Erythrocytes, the red cells, are tiny, disk-shaped bodies with acentral area that is thinner than the edges. They are different from other cells in that the mature form found in the circulating blood does not have a nucleus. These cells, like almost all the blood cells, live a much shorter time (120 days) than most other cells in the body, some of which last a lifetime. One purpose of the red cells is to carry oxygen from the lungs to the tissues. The oxygen is bound in the red cells to haemoglobin, a protein that contains iron. Haemoglobin combined with oxygen gives the blood its characteristic red color. The more oxygen carried by the haemoglobin, the brighter is the red color of the blood. Therefore, the blood that goes from the lungs to the tissues is a bright red because it carries a great supply of oxygen; in contrast, the blood that returns to the lings is a much darker red, since it has given up much of its oxygen to the tissues.Haemoglobin that has given up its oxygen is able to carry hydrogen ions; in this way, haemoglobin acts as a buffer and plays an important role in acid-base balance. The red cells also carry a small amount of carbon dioxide from the tissues to the lings for elimination in exhalation. Carbon monoxide is a harmful gas that combines with haemoglobin to form a stable compound. It displaces the oxygen that is normally carried by the haemoglobin and reduces the oxygen-carrying ability of the blood. Carbon monoxide may be produced by the incomplete burning of various fuels, such as gasoline, coal, wood, and other carbon containing materi als. Italso occurs in automobile exhaust fumes and in cigarette smoke. The erythrocytes are by far the most numerous of the corpuscles, averaging from 4.5 to 5 million per cubic millimetre of blood.

Leukocytes(WBC):

The leukocytes, or white blood cells, are very different from the erythrocytes in appearance, quantity, and function. They contain nuclei of varying shapes and sizes; the cells themselves are round. Leukocytes are outnumbered by red cells by 700 to 1, numbering 5,000 to 10,000 per cubic millimetre of blood. Whereas the red cells have a definite color, the leukocytes tend to be colorless. The different types of white blood cells are identified by their size, the shape of the nucleus, and the appearance of granules in the cytoplasm when the cells are stained, usually with Wright's blood stain. *Granulocytes* include *neutrophils,* which show lavender granules; *eosinophils,* which have beadlike,bright pink granules; and *basophils,* which have large, dark blue granules that often obscure the nucleus. The neutrophils are the most numerous of the white cells, constituting up to 60% of all leukocytes. Because the nuclei of the nuclei of the neutrophils are of various shapes, they are also called *polymorphs* (meaning "many forms") or simply polys. The *agranulocytes*, so named because they lack easily visible granules, are the *lymphocytes* and *monocytes*. The ratio of the different types of leukocytes is often a valuable clue in arriving at a diagnosis.

The most important function of the leukocytes is to destroy pathogens. Whenever pathogens enter the tissues, as through a wound, certain white blood cells (neutrophils and monocytes) are attracted to that area. They leave the blood vessels and proceed by *ameboid* or ameba-like motion to the area ofinfection. There they engulf the invaders by a process called *phagocytosis*. If the pathogens are extremely strong or numerous, they may destroy the leukocytes. A collection of dead and living leukocytes, forms *pus*. A collection of pus localized in one area is known as *abscess*. The Lymphocytes destroy foreign invaders by attacking the cells directly or by producing antibodies that circulate in the blood and help destroy the cells.

Platelets:

The blood platelets (thrombocytes) are the smallest. These tiny structures are not cells in themselves, but fragments of cells. The number of platelets in the circulating blood has been estimated at 2,00,000 to 4,00,000 per cubic millimeter of blood. Platelets are essential to blood coagulation (clotting). When, as a result of injury, blood comes in contact with any tissue other than the lining of the blood vessels, the platelets stick together and form a plug that seals the wound. They then release chemicals that take part in a series of reactions that eventually results in the formation of a clot. The last step in these reactions is the conversion of a plasma protein called fibrinogen into solid threads of fibrin, which form the clot.

Functions of the Blood

1. Transportation

- Oxygen- from inhaled air diffuses into the blood through the thin lung membranes and is carried to all the tissue of the body. Carbon dioxide, a waste product of cell metabolism, is carried from the tissues to the lungs, where it is breathed out.
- The blood transports foods and other needed substances such as minerals and vitamins, to the cells. These materials may inter the blood from the digestive system or may be released into the blood from body stores.
- The blood transports waste products from the cells to the sites from which they are released. The kidney removes excess water, minerals, and urea from protein metabolism and maintains the acid-base balance of the blood. The liver removes bile pigments and drugs.
- The blood carries hormones from their sites of origin to the organs they affect.

2. Regulation

- Buffers in the blood help keep the PH of body fluids at about 7.4
- The blood serves to regulate the amount of fluid in the tissues by means of substances (mainly proteins) that maintain the proper osmotic pressure
- The blood transports heat that is generated in the musclesto other parts of the body thus aiding in the regulation of body temperature by the blood, thus aiding in the regulation of body temperature.

3. Protection

- The blood carries the cells that are among the body's defenders against pathogens. It also contains substances (antibodies) that are concerned with immunity to disease.
- The blood contains factors that protect against blood loss.

Blood Typing and Transfusions

Blood Groups

If for some reason the amount of blood in the body is severely reduced, through haemorrhage or disease, the body cells suffer from lack of oxygen and food. The obvious measure to take in such an emergency is to inject blood from another person into the veins of the patient, a procedure called transfusion.

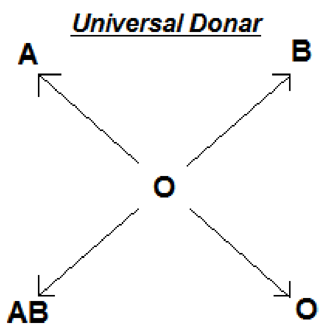
The patient's plasma may contain substances called antibodies that can cause the red cells of the donor's blood to become clumped, a process called agglutination. Alternatively, the donor's red blood cells may rupture and release their haemoglobin; such cells are said to be haemolysed, and the resulting condition can be very dangerous. These reactions are determined largely by certain proteins, called antigens, on the surface membrane of the red blood cells. There are many types of these proteins but only two groups are particularly likely to cause a transfusion reaction, the so-called A and B antigens and the Rh factor. Four blood types involving the A and B antigens have been recognized: A, B, AB, and O. These letters indicate the types of antigen present on the red cells, with O indicating that neither A nor B antigen is present. It is these antigens ton the donor's red fells that react with the antibodies in the patient's plasma and cause a transfusion reaction. Blood serum containing antibodies that can agglutinate and destroy red cells that have A antigens on the surface is called anti-A serum; blood serum containing antibodies that can destroy red cells with B antigen on the surface is called anti-B serum. These sera are used to test for blood type. Persons with type O blood are said to be universal donors because they lack the AB red cell antigens and in an emergency their blood can be given to anyone. Type AB individuals are called universal recipients, since their blood contains no antibodies to agglutinate red cells and they can therefore receive blood from most donors. Usually a person can safely give blood to any person with the same blood type. However, because of other factors that may be present in the blood, determination of blood type must be accompanied by additional tests (cross matching) for compatibility before a transfusion is given.

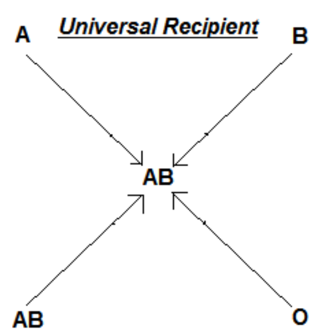
The Rh factor

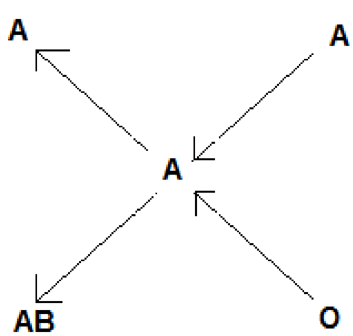
Rh factor is another red cell antigen that determines the blood group. Those individuals who possess this antigen in their red cell surface are said to be Rh positive. Those who lack this antigen are said to be Rh negative. If Rh positive blood is given to an Rh negative person, he or she may become sensitized to the protein in the Rh positive blood. The sensitized person's blood cells may then produce antibodies to the "foreign" Rh antigens and destroy the transfused red cells.

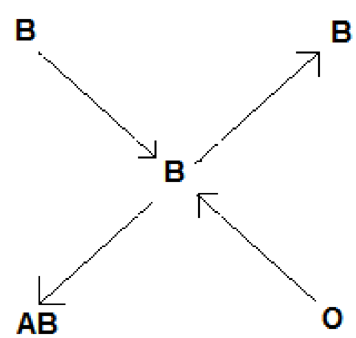
THE ABO BLOOD GROUP SYSTEM

Blood Type	RBC Antigen	Plasma Antibodies	Can take from	Can donate to
A	A	Anti-B	A, O	A, AB
B	B	Anti-A	B,O	B, AB
AB (Universal Recipient)	AB	None	AB, A, B, O	AB
O (Universal Donar)	None	Anti-A, Anti-B	O	O, A, B, AB







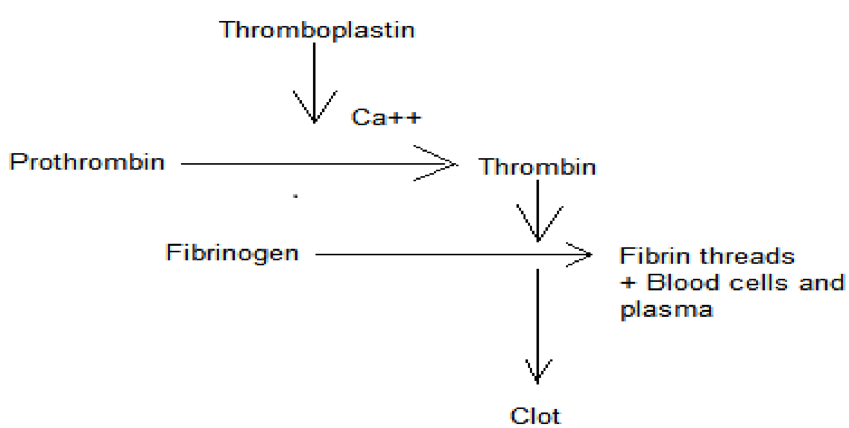


Blood Clotting

Blood clotting, or coagulation, is a protective mechanism that prevents blood loss when a blood vessel is ruptured by an injury. Many substances are necessary for clotting are normally inactive in the blood stream. A balance is maintained between compounds that promote clotting, known as procoagulants, and those that prevent clotting known as anticoagulants. In addition, there are also chemicals in the circulation that act to dissolve clots. Under normal conditions the substances that prevent clotting prevail. However, when an injury occurs, the procoagulants are activated and a clot is formed. Basically, the clotting process consists of the following essential steps.

- The injured tissues release thromboplastin, a substance that triggers the clotting mechanism.
- Thromboplastin reacts with certain protein factors and calcium ions to form prothrombin activator, which in turn reacts with calcium ions to convert the prothrombin to thrombin.
- Thrombin, in turn, converts soluble fibrinogen into insoluble fibrin. Fibrin forms a network of threads that entraps red blood cells and platelets to form clot.

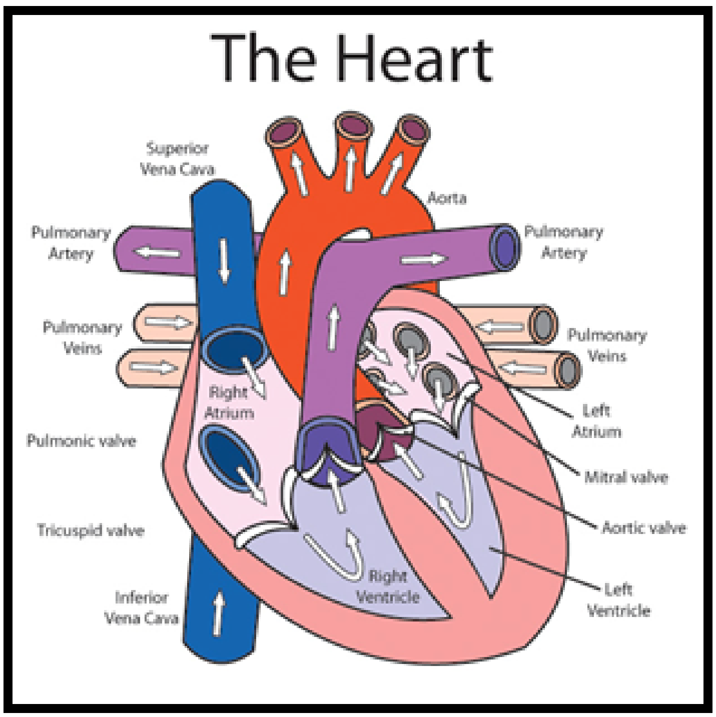
Formation of a clot.



THE HEART

The heart is a muscular pump that drives the blood through the blood vessels. Slightly bigger than a fist, this organ is located between the lungs in the center and a bit to the left on the midline of the body.

The heart is a muscular organ about the size of a closed fist that functions as the body's circulatory pump. It takes in deoxygenated blood through the veins and delivers it to the lungs for oxygenation before pumping it into the various arteries (which provide oxygen and nutrients to body tissues by transporting the blood throughout the body). The heart is located in the thoracic cavity medial to the lungs and posterior to the sternum.



On its superior end, the base of the heart is attached to the aorta.

pulmonary arteries and veins, and the vena cava. The inferior tip of the heart, known as the apex, rests just superior to the diaphragm. The base of the heart is located along the body's midline with the apex pointing toward the left side. Because the heart points to the left, about 2/3 of the heart's mass is found on the left side of the body and the other 1/3 is on the right.

Pericardium

The heart sits within a fluid-filled cavity called the pericardial cavity. The walls and lining of the pericardial cavity are a special membrane known as the pericardium. Pericardium is a type of serous membrane that produces serous fluid to lubricate the heart and prevent friction between the ever beating heart and its surrounding organs. Besides lubrication, the pericardium serves to hold the heart in position and maintain a hollow space for the heart to expand into when it is full. The pericardium has 2 layers a visceral layer that covers the outside of the heart and a parietal layer that forms a sac around the outside of the pericardial cavity.

Structure of the Heart Wall

The heart wall is made of 3 layers:

- ***Epicardium***
- ***Myocardium***
- ***Endocardium.***

Epicardium-

The epicardium is the outermost layer of the heart wall and is just another name for the visceral layer of the pericardium. Thus, the epicardium is a thin layer of serous membrane that helps to lubricate and protect the outside of the heart. Below the epicardium is the second, thicker layer of the heart wall: the myocardium.

Myocardium-

The myocardium is the muscular middle layer of the heart wall that contains the cardiac muscle tissue. Myocardium makes up the majority of the thickness and mass of the heart wall and is the part of the heart responsible for pumping blood. Below the myocardium is the thin endocardium layer.

Endocardium

Endocardium is the simple squamous endothelium layer that lines the inside of the heart. The endocardium is very smooth and is responsible for keeping blood from sticking to the inside of the heart and forming potentially deadly blood clots.

The thickness of the heart wall varies in different parts of the heart. The atria of the heart have a very thin myocardium because they do not need to pump blood very far only to the nearby ventricles. The ventricles, on the other hand, have a very thick myocardium to pump blood to the lungs or throughout the entire body. The right side of the heart has less myocardium in its walls than the left side because the left side has to pump blood through the entire body while the right side only has to pump to the lungs.

Four Chambers

On either side of the heart are two chambers, one a receiving chamber (atrium) and the other a pumping chamber (ventricle):

1. The right atrium is a thin-walled chamber that receives the blood retuning from the body tissues. This blood, which is low in oxygen, is carried in the veins, the blood vessels leading to the heart from the body tissues.

2. The right ventricle pumps the venous blood received from the right atrium and sends it to the lungs.

3. The left atrium receives blood high in oxygen content as it returns from the lungs.

4. The left ventricle, which has the thickest walls of all, pumps, oxygenated blood to all parts of the body. This blood goes through the arteries, the vessels that take blood from the heart to the tissues.

Four Valves

Since the ventricles are the pumping chambers, the valves, which are all one way, are located at the entrance and the exit of each ventricle. The entrances valves are the atrioventricular valves, while the exit valves are the semilunar valves.Semilunar means “resembling a half moon.” Each valve has a specific name, as follows:

1. The right atrioventricular valve also is known as the tricuspid valve, since it has three cusps, or flaps, that open and closes. When this valve is open, blood flows freely from the right atrium into the right ventricle. However, when the right ventricle begins to contract, the valve closes so that blood cannot return to the right atrium; this ensures forward flow into the pulmonary artery.

2. The left atrioventricular valve is the bicuspid valve, but it is usually referred to as the mirtal valve. It has two rather heavy cusps that permit blood to flow freely from the left atrium into the left ventricle. However, the cusps close when the left ventricle begins to contract; this prevents blood from returning to the left atrium and ensures the forward flow of blood into the aorta. Both the tricuspid and mitral valves are attached by means of thin fibrous threads to the wall of the ventricles. The function of these threads, called the chordae tendineae, is to keep the valve flaps from flipping up into the atria when the ventricles contract and thus causing a backflow of blood.

3. The pulmonary (semilunar) valve is located between the right ventricle and the pulmonary artery that leads to the lungs. As soon as the right ventricle has finished emptying itself, the valve closes in order to prevent blood on its way to the lungs from returning to the ventricle.

4. The aortic (semilunar) valve is located between the left ventricle and the aorta. Following contraction of the left ventricle, the aortic valve closes to prevent the flow of blood back from the aorta to the ventricle. The appearance of the heart valves in the closed position.

Human heart function

The heart circulates blood through two pathways: the **pulmonary circulation** and the **systemic circulation.**

In the ***pulmonary*** **circulation**, deoxygenated blood leaves the right ventricle of the heart via the pulmonary artery and travels to the lungs, then returns as oxygenated blood to the left atrium of the heart via the pulmonary vein.

In the ***systemic circuit***, oxygenated blood leaves the body via the left ventricle to the aorta, and from there enters the arteries and capillaries where it supplies the body's tissues with oxygen. Deoxygenated blood returns via veins to the venae cavae, re-entering the heart's right atrium.

The heart is also a muscle, so it needs a fresh supply of oxygen and nutrients, too."After the blood leaves the heart through the aortic valve, two sets of arteries bring oxygenated blood to feed the heart muscle". The left main coronary artery, on one side of the aorta, branches into the left anterior descending artery and the left circumflex artery. The right coronary artery branches out on the right side of the aorta.

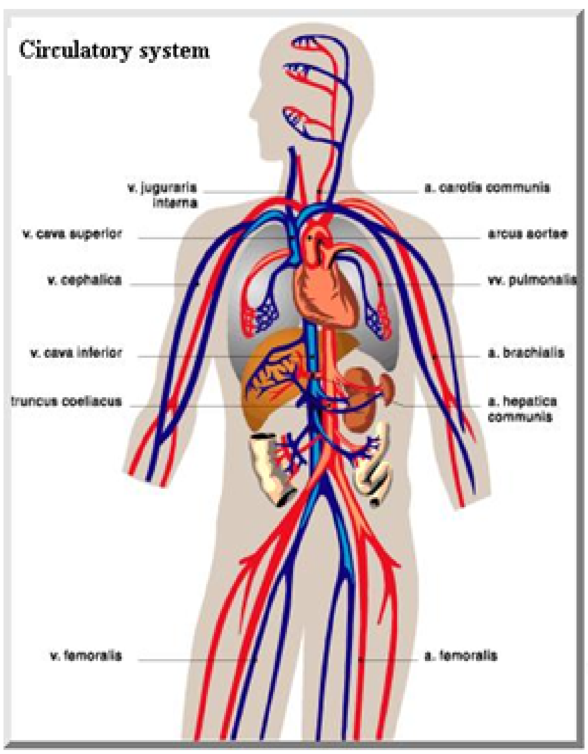
Blockage of any of these arteries can cause a heart attack, or damage to the muscle of the heart, Phillips said. A heart attack is distinct from cardiac arrest, which is a sudden loss of heart function that usually occurs as a result of electrical disturbances of the heart rhythm. A heart attack can lead to cardiac arrest, but the latter can also be caused by other problems, .

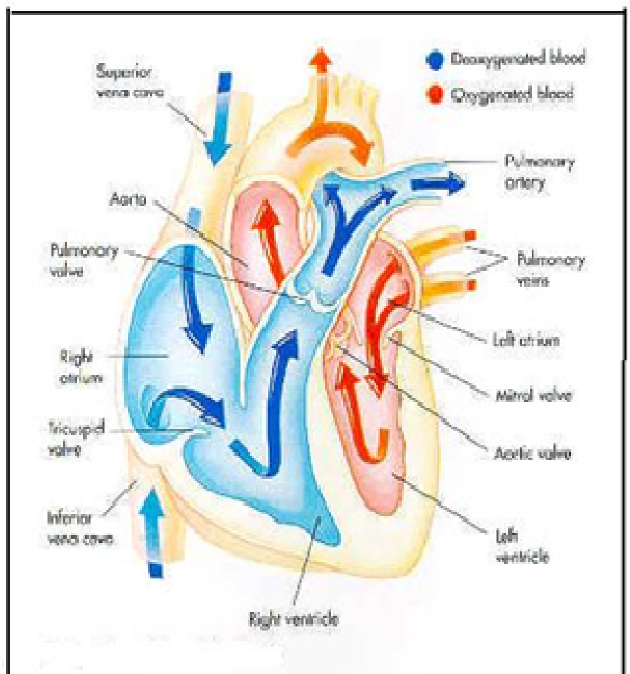
The heart contains electrical "pacemaker" cells, which cause it to contract producing a heartbeat.

"Each cell has the ability to be the 'band leader' and [to] have everyone follow," Phillips said. In people with an irregular heartbeat, or atrial fibrillation, every cell tries to be the band leader, which causes them to beat out of sync with one another.

A healthy heart contraction happens in five stages. In the first stage (early diastole), the heart is relaxed. Then the atrium contracts (atrial systole) to push blood into the ventricle. Next, the ventricles start contracting without changing volume. Then the ventricles continue contracting while empty. Finally, the ventricles stop contracting and relax. Then the cycle repeats.

Valves prevent backflow, keeping the blood flowing in one direction through the heart.





Path of blood through the heart

Pulse and Blood Pressure

Pulse

The ventricles pump blood into the arteries regularly about 70 to 80 times a minute. The force of the ventricular contraction starts a wave of increased pressure that begins at the heart and travels along the arteries. This wave, called the pulse, can be felt in any artery that is relatively close to the surface, particularly if the vessel can be pressed down against a bone. At the wrist the radial artery passes over the bone on the thumb side of the forearm, and the pulse is most commonly obtained here. Other vessels sometimes used for obtaining the pulse are the carotid artery in the neck and the dorsalis pedis on the top of the foot. Normally, the pulse rate is the same as the heart rate. Only if a heart beat is abnormally weak , or if the artery is obstructed, may the beat not be detected as a pule. In checking the pulse of another person, it is important to use your second or third finger. If you use your thumb, you may find that you are getting your own pulse. When taking a pulse, it is important to gauge the strength as well as the regularity and the rate. Various factors may influence the pulse rate, we will enumerate just a few:

1. The pulse is some what faster in small persons than in large persons usually slightly faster in women than in men.
2. In a new born infant the rate may be from 120 to 140 beats/minute. As the child grows, the rate tends to become slower.
3. Muscular activity influences the pulse rate. During sleep the pulse may slow down to 60 a minute, while during strenuous exercise the rate may go up to well over 100 a minute. In a person in good condition, the pulse does not remain rapid despite continued exercise.
4. Emotional disturbances may increase the pulse rate.

5. In many infections, the pulse rate increases with theincrease in temperature.
6. An excessive amount of secretion from the thyroid glandmay cause a rapid pulse. The pulse rate may serve as a partial guide for persons who must take thyroid extract.

Blood Pressure

Since the pressure inside the blood vessels varies with the condition of the heart, the blood, and the vessels, as well as with other factors, the measurement and careful interpretation of blood pressure may prove a valuable guide in the care and evaluation of a person's health. Because blood pressure decreases as the blood flows from arteries into capillaries and finally into veins, measurements ordinarily are mde of arterial pressure only.

The instrument used is called a sphygmomanometer, and two variables are measured:

Systolic pressure, which occurs during heart muscle contraction, averages around 120 and is expressed in millimetres of mercury (mm Hg).

Diastolic pressure, which occurs during relaxation of the heart muscle, averages around 80 mm Hg.

PHYSIOLOGY OF THE HEART

The Work of the Heart

Although the right and left side of the heart are separated from each other, they work together. The blood is squeezed through the chambers by a contraction of heart muscle beginning in the thin-walled upper chambers, the atria, followed by a contraction of the thick muscle of the lower chambers, the ventricles. This active phase is called **systole**, and in each case it is followed by a resting period known as **diastole**. The contraction of the walls of the atria is completed at the time the contraction of the ventricles begins. Thus, the resting phase (diastole) begins in the atria at the same time as the contraction (systole) begins in the ventricles. After the ventricles have emptied, both chambers are relaxed for a short period of time as they fill with blood. Then another beat begins with contraction of the ventricles. This sequence of heart relaxation and contraction is called the **cardiac cycle**. Each cycle takes an average of 0.8 seconds. Cardiac muscle tissue has several unique properties. One of these is the interconnection of the muscle fibers. The fibers are interwoven so the stimulation that causes the contraction of onefiber results in the contraction of the whole group. This plays an important role in the process of conduction and the working ofthe heart muscle. Another property of heart muscle is its ability to adjust contraction strength to the amount of blood received. When the heart chamber is filled and the wall stretched (within limits), the contraction is strong. As less blood enters the heart, the contraction becomes weaker. As more blood enters the heart, as occurs during exercise, the muscle contracts, with greater strength so push the larger volume of blood out into the blood vessels. The volume of blood pumped by each ventricle in 1 minute is termed the **cardiac output**. It is determined by the volume of blood ejected from the ventricle with each beat−the **stroke volume**−and the number of beats of the heart per minute−the **heart rate**. The cardiac output averages 5 litres/minute for an adult at rest.

Facts about the human heart

- A human heart is roughly the size of a large fist.
- The heart weighs between about 10 to 12 ounces (280 to 340 grams) in men and 8 to 10 ounces (230 to 280 grams) in women.
- The heart beats about 100,000 times per day (about 3 billion beats in a lifetime).
- An adult heart beats about 60 to 80 times per minute.
- Newborns' hearts beat faster than adult hearts, about 70 to 190 beats per minute.

- The heart pumps about 6 quarts (5.7 liters) of blood throughout the body.
- The heart is located in the center of the chest, usually pointing slightly left.

THE LYMPHATIC SYSTEM

The lymphatic system communicates with the blood circulatory system and is closely associated with it. It consists of:

1. Lymphatic capillaries made of endothelium (simple squamous epithelium)

2. Lymphatic vessels made of three layers like veins; also they have valves

3. Lymphatic ducts are ducts that drains different parts of the body and includes:

a. Right lymphatic duct drains upper right part of the body and empties in to right subclavian vein

b. Thoracic duct drains remainder part of the body and empties into left subclavian vein.

4. Lymph

It is the fluid within the lymphatic capillaries and vessels; which is derived from tissue fluid. Tissue fluid is derived from the blood plasma. A certain amount of this fluid and waste products from the cells is returned to the venous capillaries, but with in the tissue spaces fine capillary vessels known as lymphatic capillaries begin, which help to drain the waste products and water from the interstitial spaces. Also larger sized materials or substances of the result of phagocytosis of pathogenic micro-organisms are drained away in the lymphatic capillaries and vessels.

5. Lymphoid tissues are distributed throughout the body.

These are:

a. **Lymph nodes** help for filtration of lymph

b. **Tonsils** also help for filtration of tissue fluids

c.**Thymus** for processing of T-lymphocytes and hormone (thymosin) secretion to stimulate T-lymphoid tissues.

d. **Spleen** helps for filtration of blood, and destruction of old red cells.

RESPIRATORY SYSTEM

The respiratory system supplies the body with oxygen and removes carbon dioxide. It consists of a series of structures that allow for the passage of air into the body and the exchanges of gases with the blood. There are essentially two types of respiration. External respiration is the movement of gases into the body and blood. Cellular respiration is the use of oxygen and production of carbon dioxide by the cells.

The parts of the respiratory system

The respiratory system is divided into two parts:

- ***Upper respiratory tract:***

  The upper respiratory system consists of the nose and nasal cavity, the sinus, pharynx and the portion of the larynx above the vocal cords. the section that takes air in and lets it out).

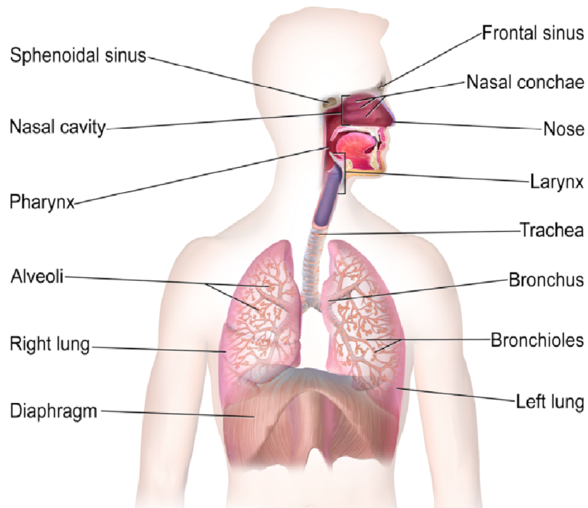
- ***Lower respiratory tract:***

  The lower respiratory system consists of the portion of the larynx including the vocal cords and below, trachea, bronchi, bronchioles, lungs and alveoli. (the act of breathing takes place in this part of the system).

The organs of the lower respiratory tract are located in the chest cavity. They are delineated and protected by the ribcage, the chest bone (sternum), and the muscles between the ribs and the diaphragm (that constitute a muscular partition between the chest and the abdominal cavity).

STRUCTURE AND FUNCTION OF RESPIRATORY PATHWAYS

The Nasal Cavity



Air makes its initial entrance into the body through the openings in the nose called the nostrils. Immediately inside the nostrils, located between the roof of the mouth and the cranium, are the two spaces known as the nasal cavities. These two spaces are separated from each other by a partition, the nasal septum. The septum and the walls of the nasal cavities are constructed of bone covered with mucous membrane. From the lateral (side) walls of each nasal cavity are three projections called the conchae. The conchae greatly increase the surface over winch air must travel on its way through the nasal cavities. The lining of the nasal cavities is a mucous membrane, which contains many blood vessels that bring heat and moisture to it. The cells of this membrane secrete a large amount of fluid. It is better to breath through the nose than through the mouthbecause of changes produced in the air as it comes in contact with the lining of the nose:

- Foreign bodies, such as dust particles and pathogens, arefiltered out by the hairs of the nostrils or caught in the surface mucus.
- Air is warned by the blood in the vascular membrane.
- Air is moistened by the liquid secretion.

- The sinuses are small cavities lined with mucous membrane in the bones of the skull. The sinuses communicate with the nasal cavities, and they are highly susceptible to infection.

The Pharynx

The muscular pharynx (throat) carries air into the respiratory tract and foods and liquids into the digestive system. The upper portion located immediately behind the nasal cavity is called the nasopharynx , the middle section located behind the mouth is called the oropharynx, and the lowest portion is called the laryngeal pharynx. This last section opens into the larynx toward the front and into the oesophagus toward the back.

The Larynx

The larynx (voice box) is located between the pharynx and the trachea. It has a framework of cartilage that protrudes in the front of the neck and some times is referred to as the Adam's apple. The larynx is considerably larger in the male than in the female; hence, the Adam's apple is much more prominent in the male. At the upper end of the larynx are the vocal cords, which serve in the production of speech. They are set into vibration by the flow of air from the lungs. A difference in the size of the larynx is what accounts for the difference between the male and female voices; because a man's larynx is larger than a woman's, his voice is lower in pitch. The nasal cavities, the sinuses, and the pharynx all serve as resonating chambers for speech, just as the cabinet does for a stereo speaker.

The space between these two vocal cords is called the glottis,and the little leaf-shaped cartilage that covers the larynx during swallowing is called the epiglottis. The epiglottis helps keep food out of the remainder of the respiratory tract. As the larynx moves upward and forward during swallowing, the epiglottis moves downward, covering the opening into the larynx. You can feel the larynx move upward toward the epiglottis during this process by placing the flat ends of your fingers on your larynx as you swallow. The larynx is lined with ciliated mucous membrane. The cilia trap dust and other particles, moving them upward to the pharynx to be expelled by coughing, sneezing, or blowing the nose.

The Trachea (Windpipe)

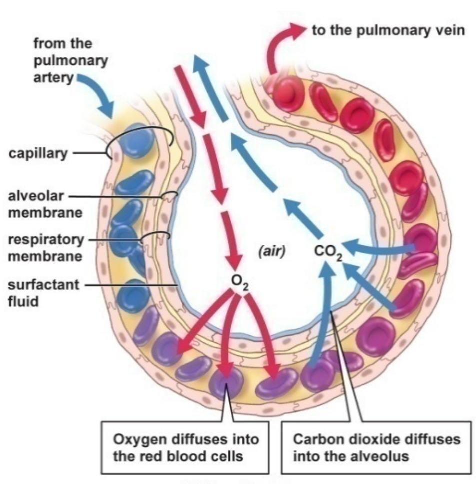
The trachea is a tube that extends from the lower edge of the larynx to the upper part of the chest above the heart. It has a framework of cartilages to keep it open. These cartilages, shaped somewhat like a tiny horseshoe or the letter C, are found along the entire length of the trachea. All the open sections of these cartilages are at the back so that the esophagus can bulge into this section during swallowing. The purpose of the trachea is to conduct air between the larynx and the lungs.

The Bronchi and Bronchioles

The trachea divides into two bronchi which enter the lungs. The right bronchus is considerably larger in diameter than the left and extends downward in a more vertical direction. Therefore, if a foreign body is inhaled, it is likely to enter the right lung. Each bronchus enters the lung at a notch or depression called the hilus or hilum. The blood vessels and nerves also connect with the lung in this region.

The Lungs

The lungs are the organs in which external respiration takesplace through the extremely thin and delicate lung tissues. The two lungs, set side by side in the thoracic cavity, are constructed in the following manner: Each bronchus enters the lung at the hilus and immediately subdivides. Because the subdivision of the bronchi resemblesthe branches of a tree, they have been given the common name bronchial tree. The bronchi subdivide again and again, forming progressively smaller divisions, the smallest of which are called bronchioles. The bronchi contain small bits of cartilage, which give firmness to the walls and serve to hold the passageways



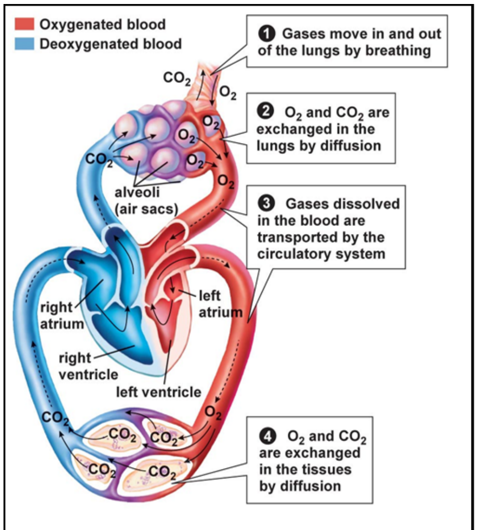
open so that air can pass in and out easily. However, as the bronchi become smaller, the cartilage decreases in amount. In the bronchioles there is no cartilageat all; what remains is mostly smoothly muscle, which is under the control of the autonomic nervous system. At the end of each of the smallest subdivisions of the bronchial tree, called terminal bronchioles, is a cluster of air sacs, resembling a bunch of grapes. These sacs are known as alveoli. Each alveolus is a single-cell layer of squamous (flat) epithelium. This very thin wall provides easy passage for the gases entering and leaving the blood as it circulates through millions of tiny capillaries of the alveoli. Certain cells in the alveolar wall produce surfactant, a substance that prevents the alveoli from collapsing by reducing the surface tension ("pull") of the fluids that line them. There are 300 millions of alveoli in the human lung. Because of the many air spaces, the lung is light in weight; normally a piece of lung tissue dropped into a glass of water will float. As mentioned the pulmonary circuit brings blood to and from the lungs. In the lungs blood passes through the capillaries around the alveoli, where the gas exchange takes place.

The Lung Cavities

The lungs occupy a considerable portion of the thorax cavity, which is separated from the abdominal cavity by the muscular partition known as the diaphragm. Each lung is enveloped in a double sac of serous membrane called the pleura. The portion of the pleura that is attached to the chest wall is called parietal pleura, while the portion that is reflected onto the surface of the lung is called visceral pleura.The pleural cavity around the lungs is an air-tight space with a partial vacuum, which causes the pressure in this space to be less than atmospheric pressure. Because the pressure inside the lungs is higher than that in the surrounding pleural cavity, the lungs tend to remain inflated. The entire thoracic cavity is flexible, capable of expanding and contracting along with the lungs. The region between the lungs, the mediastinum, contains the heart, great blood vessels, esophagus, trachea, and lymph nodes.

EXCHANGE OF GASES

Exchange of Gases



Gas Exchange

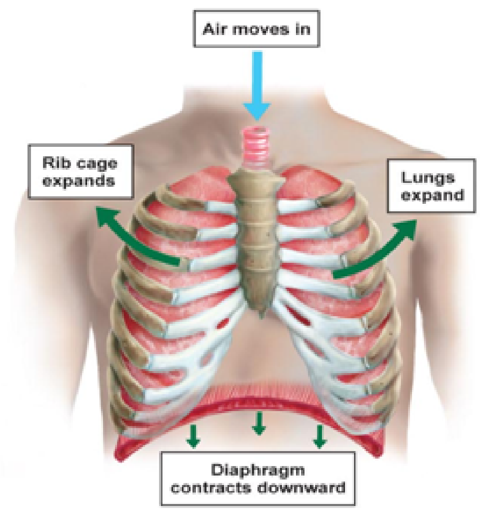
The major function of the respiratory system is gas exchange between the external environment and an organism's circulatory system. In humans and other mammals, this exchange facilitates oxygenation of the blood with a concomitant removal of carbon dioxide and other gaseous metabolic wastes from the circulation. As gas exchange occurs, the acid-base balance of the body is maintained as part of homeostasis. If proper ventilation is not maintained, two opposing conditions could occur: respiratory acidosis, a life-threatening condition, and respiratory alkalosis.

Upon inhalation, gas exchange occurs at the alveoli, the tiny sacs which are the basic functional component of the lungs. The alveolar walls are extremely thin (approx. 0.2 micrometres). These walls are composed of a single layer of epithelial cells (type I and type II epithelial cells) close to the pulmonary capillaries which are composed of a single layer of endothelial cells. The close proximity of these two cell types allows permeability to gases and, hence, gas exchange. This whole mechanism of gas exchange is carried by the simple phenomenon of pressure difference. When the air pressure is high inside the lungs, the air from lungs flow out. When the air pressure is low inside, then air flows into the lungs.

MECHANISM OF RESPIRATION

Inhalation

Inhalation is initiated by the diaphragm and supported by the external intercostal muscles. Normal resting respirations are 10 to 18 breaths per minute, with a time period of 2 seconds. During vigorous inhalation (at rates exceeding 35 breaths per minute), or in approaching respiratory failure, accessory muscles of respiration are recruited for support. These consist of sternocleidomastoid, platysma, and the scalene muscles of the neck. Pectoral muscles and latissimus dorsi are also accessory muscles.



(a) Inhalation

Under normal conditions, the diaphragm is the primary driver of inhalation. When the diaphragm contracts, the ribcage expands and the contents of the abdomen are moved downward. This results in a larger thoracic volume and negative pressure (with respect to atmospheric pressure) inside the thorax. As the pressure in the chest falls, air moves into the conducting zone. Here, the air is filtered, warmed, and humidified as it flows to the lungs.

During forced inhalation, as when taking a deep breath, the external intercostal muscles and accessory muscles aid in further expanding the thoracic cavity. During inhalation the diaphragm contracts.

During inhalation – the muscles contract:

Contraction of the diaphragm muscle – causes the diaphragm to flatten, thus enlarging the chest cavity.

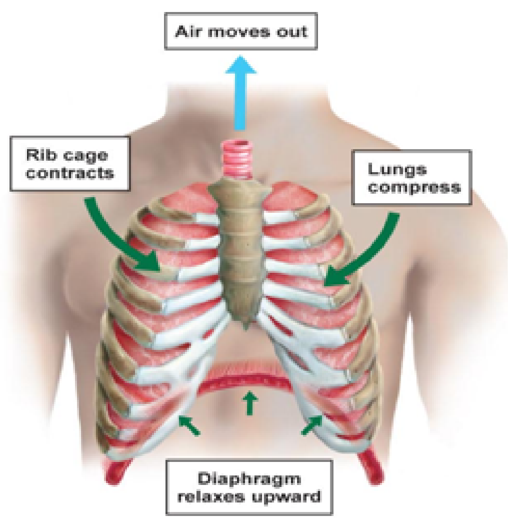
Contraction of the rib muscles – causes the ribs to rise, thus increasing the chest volume. The chest cavity expands, thus reducing air pressure and causing air to be passively drawn into the lungs. Air passes from the high pressure outside the lungs to the low pressure inside the lungs.

Exhalation

Exhalation is generally a passive process; however, active or forced exhalation is achieved by the abdominal and the internal intercostal muscles. During this process air is forced or *exhaled* out.

The lungs have a natural elasticity: as they recoil from the stretch of inhalation, air flows back out until the pressures in the chest and the atmosphere reach equilibrium.

During forced exhalation, as when blowing out a candle, expiratory muscles including the abdominal muscles and internal intercostal muscles, generate abdominal and thoracic pressure, which forces air out of the lungs.



(b) Exhalation

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.

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.

Measurements of lung function

Air volume (in liters) – lung capacity

lung volume

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

Vital capacity

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

Residual volume

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.

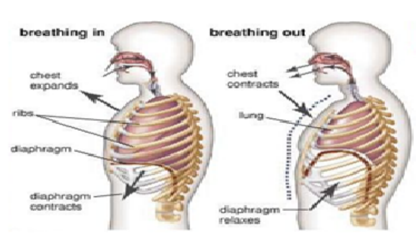
Tidal Volume

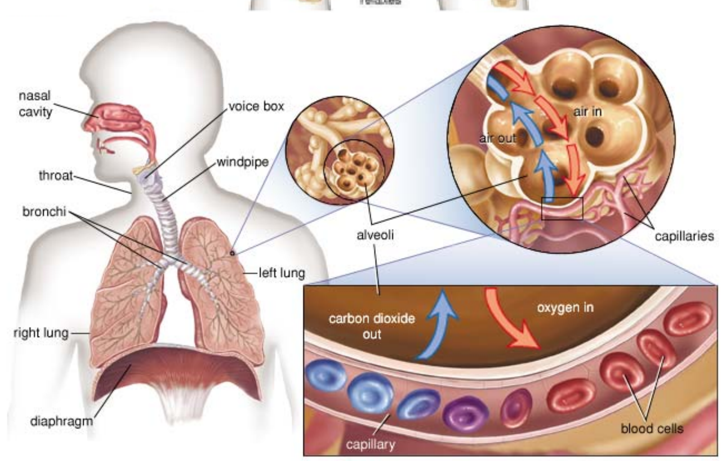
The total volume of gas entering the lungs per minute. Tidal Volume or VT is the volume of air displaced between normal inspiration and expiration. In a healthy adult the tidal volume is approximately 500 milliliters.

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.





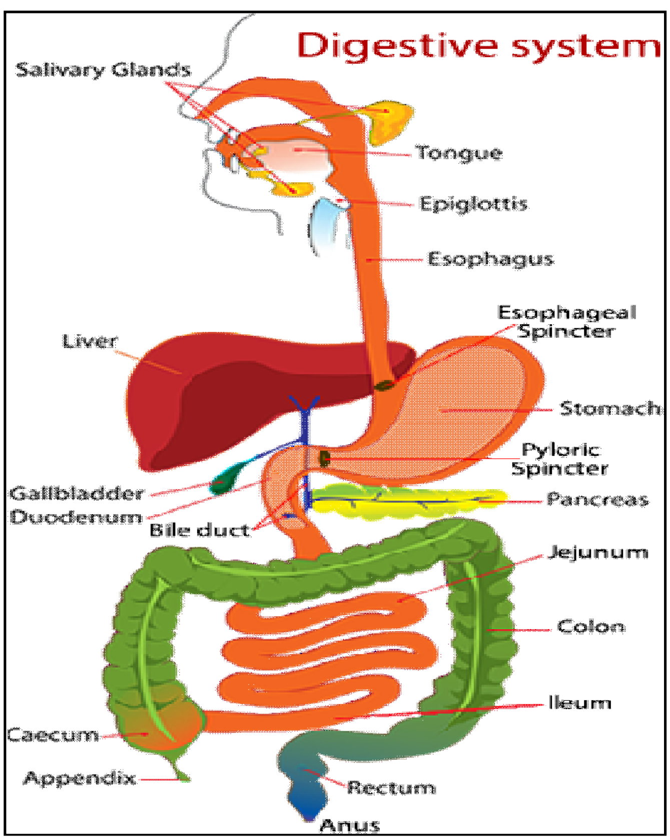
THE DIGESTIVE SYSTEM

Digestive System

The gastrointestinal system or digestive system is vital to processing the substances our bodies need for growth and maintenance. Most of the substances we take in are too big to be used by the body. The digestive system breaks these substances down and absorbs them for use by tissues and cells. Before we get into the anatomy we should learn a few terms.

Digestive System Physiology

In order to supply the body with the substances it needs the digestive system must perform a number of processes. These include breaking the substances down by mechanical and chemical digestion, absorption, assimilation and eliminating waste products. This chapter will focus on the physiology of digestion.



The Alimentary Canal

The digestive system consists of a long tube extending from the mouth to the anus with some accessory organs attached. The total length of the tube is about 15-23 feet long. Fully extended it can be as large as 30 feet. The alimentary canal consists of the mouth, esophagus, stomach, duodenum, jejunum, ileum, cecum, colon, rectum and anus. The accessory organs include the tongue, teeth, salivary glands, pancreas, liver and gallbladder.

Mouth

The mouth or oral cavity is bordered by the lips anteriorly, cheeks laterally, tongue inferiorly and the hard and soft pallete superiorly. The mouth is lined with a mucous membrane. The lips have an outer membrane consisting of skin and an inner mucous membrane. The upper lip contains a groove at the midline known as the philtrum.

The cheeks also contain an outer skin and inner mucous membrane. The buccinator muscle lies between the membranes. The hard palete consists of the two palatine bones and the palatine processes of the maxilla. The soft palate is a muscular structure that forms two arches with the uvula in the midline. The arches form openings to the oropharynx called the fauces.

The tongue consists of skeletal muscles covered by a mucous membrane. The tongue is connected externally by a series of muscles including the genioglossus and hyoglossus. Parts of the tongue include a root, tip and body. The superior surface of the tongue contains papillae. There are several types of papillae including vallate, fungiform, circumvallate and filiform. The fungiform papillae contain taste buds. A section of mucous membrane connecting the tongue to the floor of the mouth is known as the lingual frenulum.

The Enteric Nervous System

The digestive system contains a complex system of nerves called the enteric nervous system. The nerves form plexi that reside in the digestive tract walls and connect with higher nervous system centers in the central and autonomic nervous systems. Many of the actions of the enteric nervous system occur within the system. However, both sympathetic and parasympathetic divisions of the autonomic nervous system also have an effect on digestion. The neurons in the enteric nervous system include sensory neurons that sense changes in chemical concentration and mechanical deformation of the tract. There are also motor neurons that help to control smooth muscle contraction and glandular secretions. Lastly, interneurons located in the enteric nervous system interconnect other neurons. The enteric nervous system provides a good deal of control over the GI tract without influence from other parts of the nervous system. It produces reflex actions, controls secretions and smooth muscle contraction as well as blood flow.

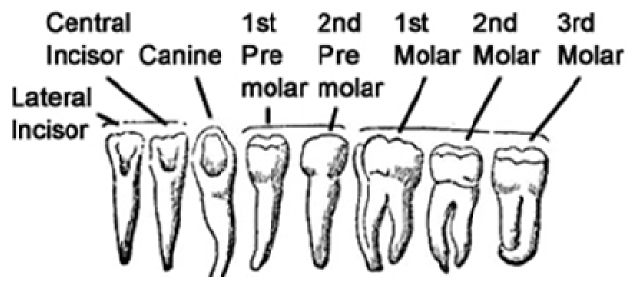
Salivary Glands

There are three pairs of salivary glands. These are the parotid, submandibular and sublingual glands. The salivary glands produce about 1L of saliva per day. In addition to the large glands, small glands on the insides of the cheeks called buccal glands also secrete saliva (about 5% of the total volume per day) which helps to keep the mouth moist. The salivary glands are considered exocrine glands which secrete their substances into tubes. The parotid glands are the largest salivary glands. They are also somewhat superficial and lie between the skin and masseter muscles just anterior and inferior to the ear. These glands secrete a serous fluid containing enzymes. The secretions travel by way of ducts (parotid or Stensen ducts) that pierce the buccinators muscles and empty into the oral cavity.

The submandibular glands are located just inferior to the angle of the mandible. They generate both serous and mucous secretions and are known as compound glands. The ducts of these glands (known as Wharton ducts) open into the floor of the mouth near the frenulum. The sublingual glands are located just under the mucous membrane of the floor of the mouth. The sublingual glands are the smallest salivary glands. They contain a series of up to 20 ducts (Rivinus ducts) that drain into floor of the mouth. These glands only secrete mucous.

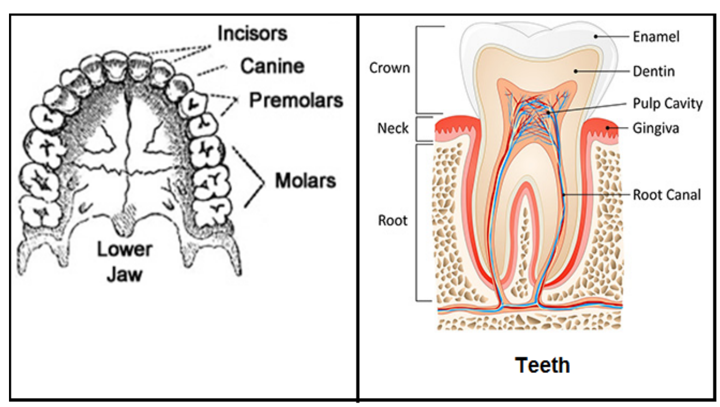
The Teeth

A typical tooth consists of a crown, neck and a root. The crown is the visible portion. The root is a cone shaped process that lies below the gum line and forms a joint with the alveolar process of the mandible or maxilla. The neck is the portion surrounded by the gums. The crown is covered by enamel which is a hard substance that protects the teeth. Deep to the enamel is the dentin. In the crown dentin is covered by enamel. In the root the dentin is covered by cementum. The deepest portion of the tooth consists of a pulp cavity and root canal that contain blood vessels and nerves. The baby teeth are also known as deciduous teeth. There are 20 of these which are gradually replaced by the permanent teeth which number 32. The deciduous teeth include:



4 central incisors
4 lateral incisors
4 canines
4 first molars
4 second molars

The secondary teeth include:



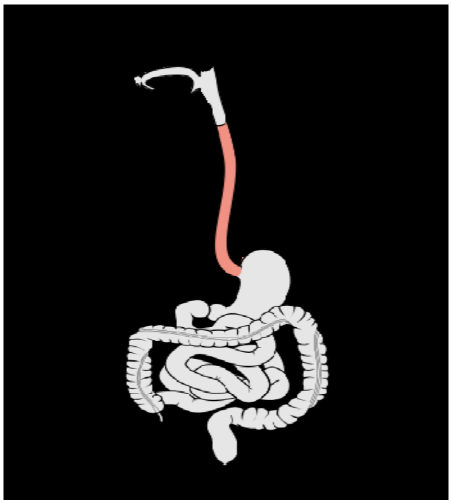
4 central incisors
4 lateral incisors
4 canines
4 first premolars (bicuspids)
4 second premolars (bicuspids)
4 first molars
4 second molars
4 wisdom teeth

The Pharynx

The pharynx is a shared passageway for the respiratory and digestive systems. Food is chewed up and rolled in what is known as a bolus and pushed to the back of the mouth where it enters the pharynx for swallowing

The Esophagus

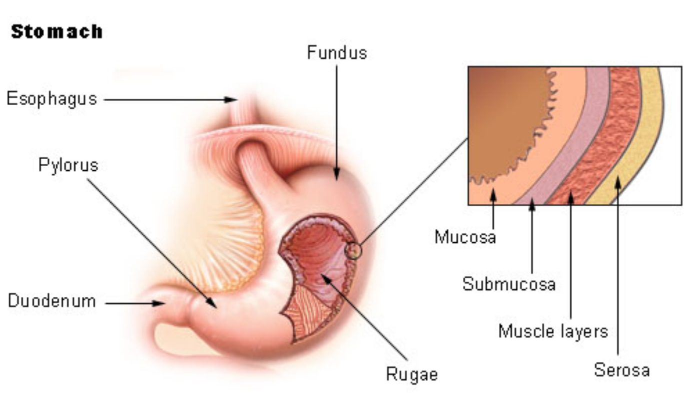
The esophagus is a muscular tube extending from the pharynx to the stomach. It lies posterior to the trachea. The upper portion of the esophagus contains voluntary skeletal muscle. The middle and lower sections contain involuntary smooth muscle.



The esophagus has two circular sphincter muscles. The upper esophageal sphincter keeps the esophagus closed during breathing to keep air from moving into the digestive tract. The lower esophageal sphincter (cardiac sphincter) is located at the inferior end of the esophagus where it pierces the diaphragm at the esophageal hiatus. The lower esophageal sphincter remains closed until swallowing occurs. In some cases the diaphragm is weakened near the hiatus and the sphincter enlarges. This is known as a hiatl hernia and can allow contents of the stomach to enter the esophagus and cause gastric reflux.

The Stomach

The esophagus empties into the stomach which is a curved pouchlike organ. There are four major divisions of the stomach. These include the cardiac region, body, fundus and pylorus. The cardiac region is the superior portion just after the esophagus. The fundus is an upward bulge that is located on the left side. The body is the central portion and the pylorus the inferior portion. The outer portion of the



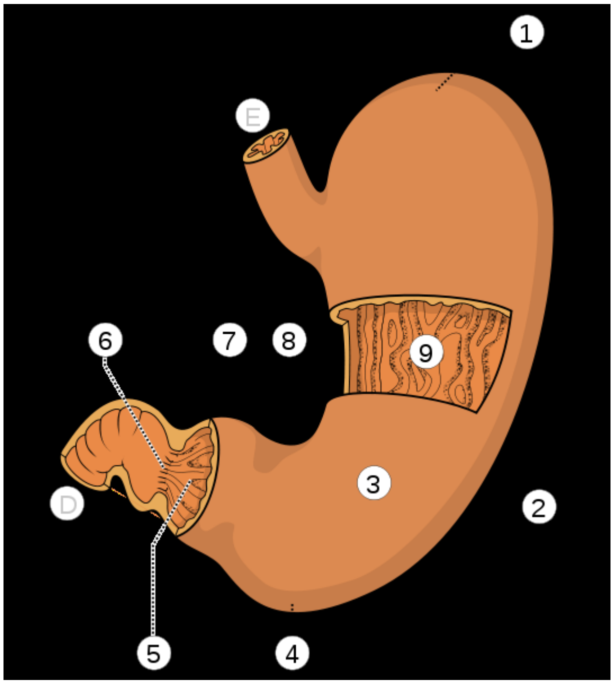
stomach contains a concave and convex curve. The concave curve is called the lesser curvature while the convex curve is the greater curvature.
The stomach contains two sphincters at each opening. The lower esophageal (cardiac) sphincter allows substances to enter while the pyloric sphincter allows substances to exit. The stomach has three smooth muscle layers. The outer layer runs longitudinally across the stomach. The middle layer is a circular layer that produces constriction of the stomach. The internal layer is an oblique muscle layer.

Stomach

1. Fundus
2. Greater curvature
3. Body
4. Inferior aspect
5. Pyloric antrum
6. Pyloric canal
7. Angular notch
8. Lesser curvature
9. Rugal folds

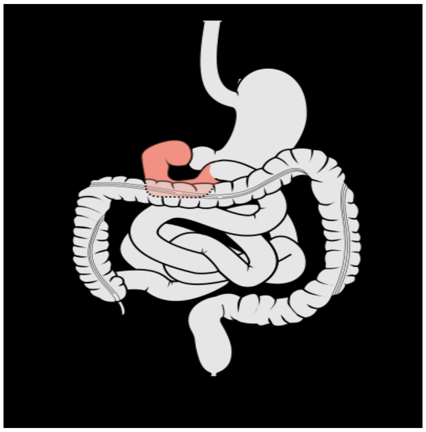
E. Esophagus

D. Duodenum



The Small Intestine

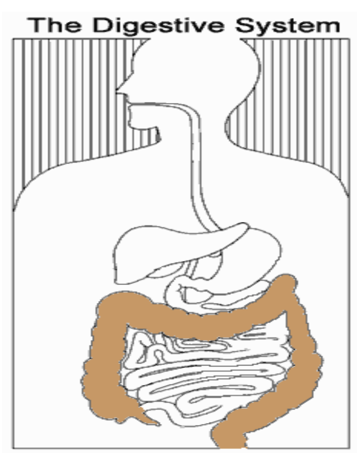
The small intestine consists of three parts. The proximal section is the duodenum which is followed by the jejunum and ileum. The duodenum begins at the pylorus and extends about 10 inches. It becomes the jejunum at its distal curve. The jejunum extends for about 8 feet before gradually becoming the ileum. There is no anatomical separation between jejunum and ileum.



The small intestine is built for absorption with a large surface area. The inside of the small intestine consists of circular folds called plica circulares. The plicae also contain numerous finger-like projections known as villi. The villi contain blood vessels and a lymphatic system tubule called a lacteal. The intestine is lined with cilia containing epithelium. The epithelial membrane resembles a brush and is sometimes referred to as a brush border.The cells lining the intestine secrete eEnzymes and mucous. The membrane also contains intestinal crypts (crypts of Lieberkuhn) that are areas of rapid mitosis. The crypts help the intestinal membrane to renew itself as old cells are pushed out of the villi as they are replaced by new cells.

The Large Intestine

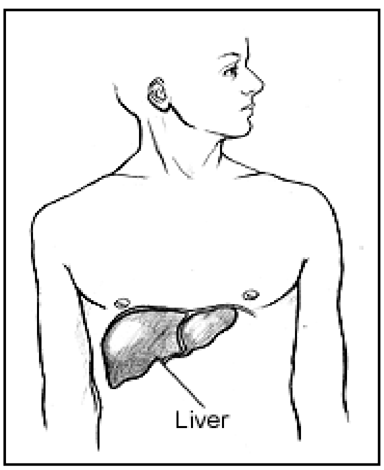
The large intestine begins at a pouch called the cecum. The junction between the ileum and cecum occurs at a smooth muscle sphincter in the cecum known as the ileocecal valve or sphincter. The diameter of the large intestine (2.5 inches) is much larger than the small intestine (1 inch). The cecum contains a fingerlike projection (8-10cm) called the vermiform appendix. The function of the appendix is not known but it may be an area for breeding intestinal bacteria (intestinal flora). Extending vertically from the cecum is the first segment of the colon known as the ascending colon. The ascending colon takes a left turn at the liver (hepatic flexure) and continues horizontally as the transverse colon. The transverse colon takes a downward turn at the spleen (splenic flexure) and continues as the descending colon. As the descending colon extends beyond the iliac crest it becomes the sigmoid colon which is S-shaped. The sigmoid colon becomes the rectum which runs about 7-8 inches long. The last inch



or so of the rectum is known as the anal canal. The anal canal contains vertical folds called anal columns. The anal columns contain blood vessels. The rectum contains two sphincter muscles including an internal and external sphincter. The internal sphincter consists of smooth muscle while the external sphincter is striated muscle. The opening of the anal canal is called the anus.The large intestine contains numerous mucous secreting glands. Along the outside of the colon are bands of smooth muscles called taeniae coli that run longitudinally. There are also rings of smooth muscle that divide the colon into pouchlike structures called haustra.

The Liver

The liver is located in the right upper quadrant of the abdominal cavity close to the diaphragm. The liver consists of four lobes including right, left, quadrate, and caudate. The falciform ligament separates the right and left lobes.



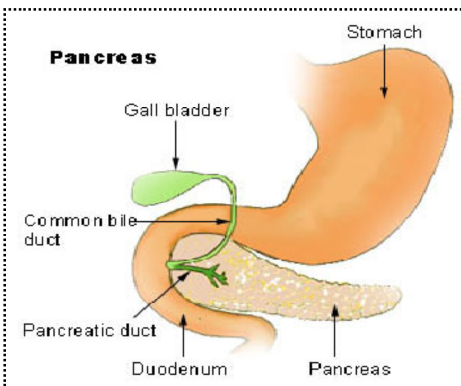
The lobes are further divided into lobules by blood vessels and connective tissue. Tributaries of the hepatic vein extend into each lobule. Hepatic plates radiate outward from the central region of the lobules. Bile ducts and interlobular arteries are located on the outer regions of the plates. Smaller bile vessels called canaliculi permeate the plates and collect bile from the hepatic cells. Sinusoids containing white blood cells called Kuppfer cells are located between the plates. These cells help phagocytize bacteria and debris.

The small bile ducts merge into one large duct known as the hepatic duct. The hepatic duct merges with the cystic duct emerging from the gallbladder to form the common bile duct. The common bile duct carries bile to the duodenum. The common bile duct merges with the pancreatic duct just before entering the duodenum. The liver performs many functions and is considered a vital organ. Its functions include detoxifying the blood, producing bile, metabolism of carbohydrates, fats and proteins, storing iron, blood and vitamins, recycling red blood cells and producing plasma proteins.

The liver secretes bile which is stored in the gallbladder. Bile contains bile salts that are formed from cholesterol. Bile works to break down fat by emulsification and eliminates products from the breakdown of red blood cells. The gallbladder contains an outer serous membrane as well as a smooth muscle layer and inner mucous membrane. The inside of the gallbladder contains rugae much like the stomach. Thegallbladder is about 3-4 inches long. In some cases bile can precipitate and form gallstones. The gallbladder can become inflamed in a condition known as cholecystitis.

The Pancreas

The pancreas has a dual endocrine and exocrine role. We investigated the endocrine role in the endocrine system chapter. The exocrine portion consists of compound acinar glands. These are branching duct structures containing clusters of cells that secrete substances into the ducts. The smaller ducts merge with the larger pancreatic duct. The pancreatic duct merges with the common bile duct at an area in the duodenum known as the hepatopancreatic ampulla. The hepatopancreatic ampulla is encircled by smooth muscle forming the hepatopancreatic sphincter. The exocrine glands secrete digestive enzymes. The endocrine cells are called alpha and beta cells. The alpha cells secrete glucagon and the beta cells secrete insulin. The pancreas consists of a body, head and a tail. It is located in the curve of the duodenum.



UNIT - III

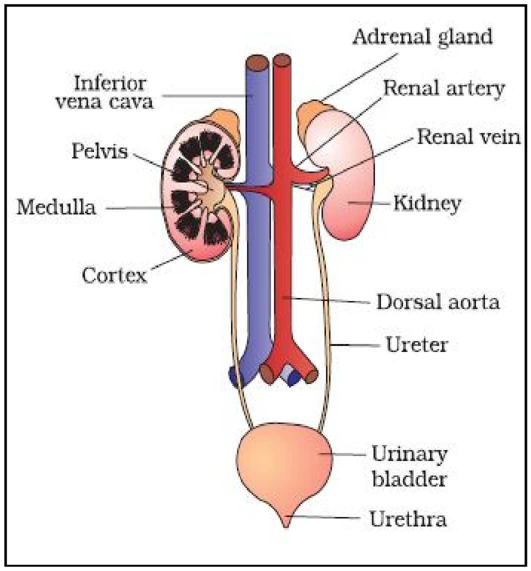
THE EXCRETORY SYSTEM

Urinary System

It would be difficult to deduce the function of the kidneys by performing a gross dissection. Their appearance is deceivingly simple and yet they perform some extremely complex physiology. In this chapter we will begin our study of the urinary system. The urinary system consists of the kidneys, ureters, urinary bladder and urethra. The urinary system can be thought of as a kind of purification system for the blood. The system functions to maintain fluid, electrolyte and pH balance and remove toxins from the blood.

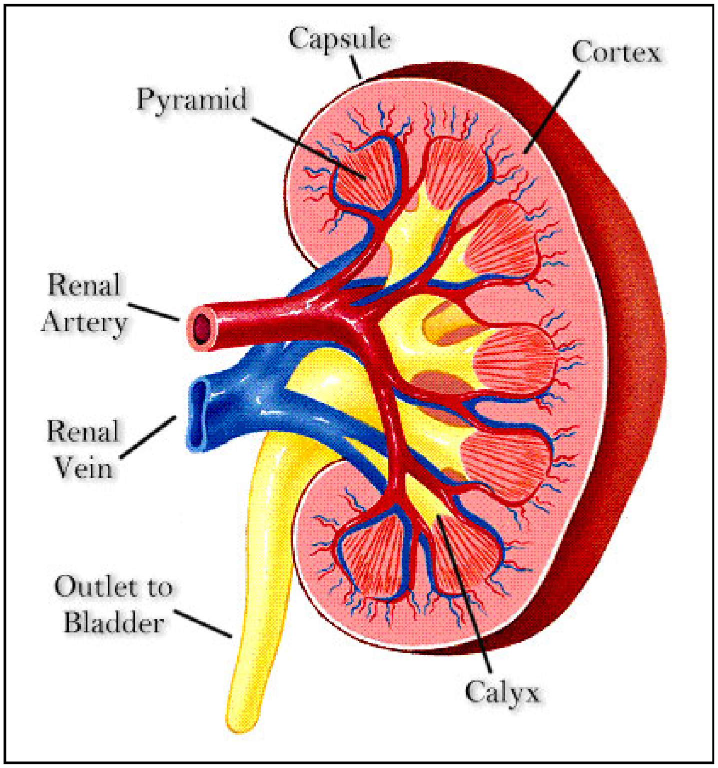
Urinary System Functions

Besides maintaining fluid, electrolyte and pH balance the kidneys also monitor blood oxygen levels. They secrete the hormone erythropoietin in response to low oxygen levels. The hormone travels to the bone marrow to stimulate the production of red blood cells. The kidneys also work to control vitamin D synthesis.



The Kidneys

The kidneys are paired organs located behind the peritoneal membrane (retroperitoneal). They are bean shaped and about the size of an adult fist. They are located laterally in the flank area about the level of the twelfth thoracic vertebra to the third lumbar vertebra. A layer of adipose tissue called perirenal fat surrounds each kidney. The outer layer of the kidneys consists of a layer of fibrous connective tissue called the renal capsule. The kidneys are partially held in place by connective tissue connections called renal fascia that connect to the outer portion of the peritoneum. Each kidney has an indentation called a hilum that opens to a renal sinus where the renal artery, vein and ureters enter and exit the kidney.



FUNCTIONS OF KIDNEY

When it comes to components of the urinary system, the kidneys are multi-functional powerhouses of activity. Some of the core actions of the kidneys include:

- **Waste excretion**: There are many things your body doesn't want inside of it. The kidneys filter out toxins, excess salts, and **urea**, a nitrogen-based waste created by cell metabolism. Urea is synthesized in the liver and transported through the blood to the kidneys for removal.
- **Water level balancing**: As the kidneys are key in the chemical breakdown of urine, they react to changes in the body's water level throughout the day. As water intake decreases, the kidneys adjust accordingly and leave water in the body instead of helping excrete it.
- **Blood pressure regulation**: The kidneys need constant pressure to filter the blood. When it drops too low, the kidneys increase the pressure. One

way is by producing a blood vessel-constricting protein (**angiotensin**) that also signals the body to retain sodium and water. Both the constriction and retention help restore normal blood pressure.

- **Red blood cell regulation**: When the kidneys don't get enough oxygen, they send out a distress call in the form of **erythropoietin**, a hormone that stimulates the bone marrow to produce more oxygen-carrying red blood cells.
- **Acid regulation**: As cells metabolize, they produce acids. Foods we eat can either increase the acid in our body or neutralize it. If the body is to function properly, it needs to keep a healthy balance of these chemicals. The kidneys do that, too.

THE SKIN

The skin is a cutaneous membrane. The skin is the largest organ of the body and has a variety of functions. It provides a protective covering to the body that inhibits the loss of water, it helps to regulate temperature, houses sensory receptors that send information to the nervous system and synthesizes chemicals and excretes wastes. The skin also contains a good deal of immune system cells that help to protect the body against pathogens. Skin is the largest organ in the body occupying almost $2m^2$ of surface area thickens of 2mm. Skin has 3 main parts. These are the epidermis, dermis and hypodermis.

The epidermis

It is the outer layer of the skin that is made of stratified squamous epithelium. It has no blood supply. Epidermis contains 4-5 strata. These are stratum cornium, lucidium, granulosum, spinosum and basale, Stratum cornium is the outer, dead, flat, Keratinized and thicker layer. Stratum lucidium is next to stratum cornium. It consists of flat, translucent layers of cells. This stratum found in thick skin only. Stratum granulosum lies just below stratum lucidium. The cells in this layer are in the process of keratinization. Stratum spinosum: next down to stratum granulosum. The cells in this stratum have a poly-hydral shape and they are in the process of protein synthesis. Stratum basale rests on the basement membrane, and it is the last layer of epidermis next to stratum spinosum. Stratum basale together with stratum spinosum constitute stratum germinativum.

The Dermis (True skin*)*

A strong, flexible, connective tissue meshes work of collagen, reticular and elastic fibers. Most part of the skin is composed of dermis. Dermis contains papillary and reticular layers.

Papillary layer is next to stratum basale of the epidermis. It contains loose connective tissue within the bundles of collagenous fibers. It also contains loose capillaries that nourish the epidermis. In some areas papillary layer have special nerve endings that serve as touch receptors (meissner's corpuscles). Indentations of papillary layer in the palms and soles reflected over the epidermis to create *ridges*.

Reticular layer: next to papillary layer. It is made of dense connective tissue with course of collagenous fiber bundles that crisscross to form a storma of elastic network. In the reticular layer many blood and lymphatic vessels, nerves, fat cell, sebaceous (oil) glands and hair roots are embedded. Receptors of deep pressure (pacinian corpuscles) are distributed through out the dermis.

Structures of the Dermis

The dermis contains a variety of accessory structures of the integument. These include:

- Hair follicles
- Arrector pili muscles
- Sweat glands
- Sebaceous glands
- Sensory receptors
- Blood vessels

Hypoderms:

It is found beneath the dermis. It is a subcutaneous layer (under the skin). Hypodermis is composed of loose, fibrous connective tissue, which is richly supplied with lymphatic and blood vessels and nerves. Hypodermis is much thicker than dermis. Within it coils of ducts of sudoriferous (sweat) glands, and the base of hair follicles.

Functions of Skin

- ***Protection:*** against harmful microorganisms, foreign material and it prevents excessive loss of body fluid.
- ***Temperature regulation:*** with the sweat, heat leaves the body
- ***Excretion*:** Small amount of waste products from the body such as urea
- ***Synthesis*:** By the action of UV. Vitamin D is synthesized in the skin. Vitamin D is necessary for absorption calcium from intestine.
- ***Sensory reception*:** it contains sensory receptors of heat, cold, touch, pressure, and pain.

Colour of the skin

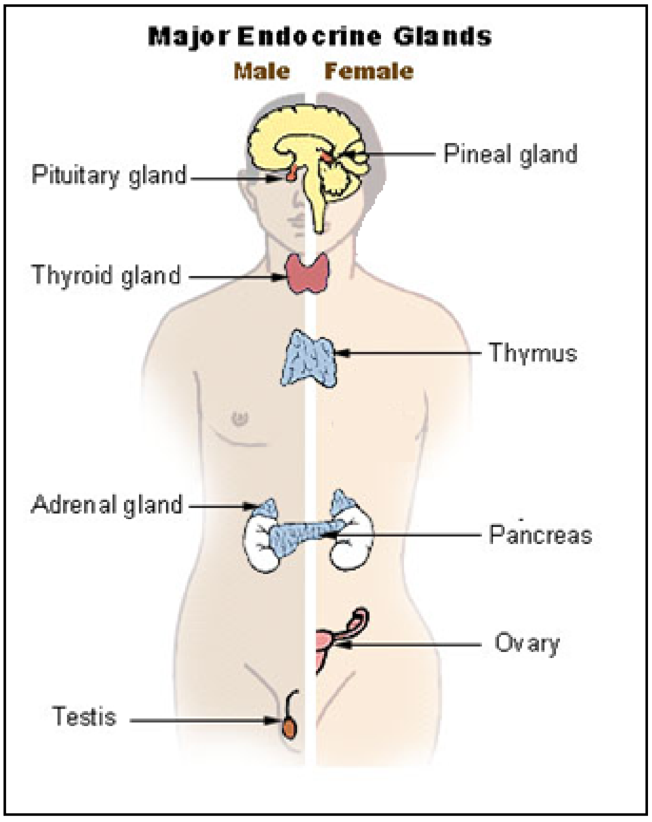
Skin's colour is determined by 3 factors

- The presence of *melanin* a dark pigment produced by
- specialized cell called melanocyte
- The accumulation of yellow pigment *carotene.*
- The *colour of blood* reflected through the epidermis

** The main function of melanin is to screen out excessive ultraviolet rays.*

** All races have some melanin in their skins although the darker races have slightly more melanocyte. The person who is genetically unable to produce any melanin is an albino.*

ENDOCRINE SYSTEM



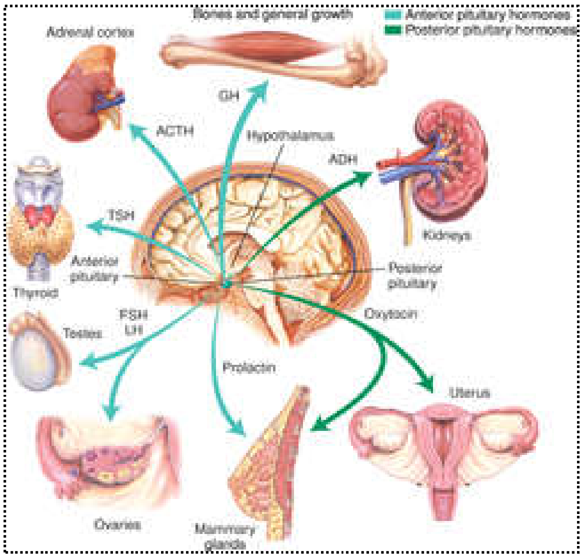
The endocrine system controls many functions of the human body much like the nervous system. The endocrine system can be considered a "link" between organs and cells. In past sections we saw other similar links between systems. For example, in the nervous system, we examined a number of chemicals called neurotransmitters that were released by neurons that affected other neurons. In the muscular section we saw neurotransmitters affecting muscular contraction. These and other links exist largely to support homeostasis. In homeostasis, changes in the internal or external environment of the body are sensed invoking some sort of correcting mechanism to keep the system in "balance."

Hormones

The glands of the endocrine system secrete hormones. Hormones are largely proteins. There are a number of classifications of hormones. Amines are derived from amino acids and are synthesized in the adrenal medulla. Peptides are short-chained amino acids found in the posterior pituitary gland and hypothalamus. Steroids are derived from cholesterol and are lipid soluble. Proteins are very long chains of amino acids found in the parathyroid glands and anterior pituitary gland. Prostaglandins have a local effect and only affect nearby cells. Hormones are very powerful in that they can invoke major changes in the body in very small amounts. Hormones travel via three major routes. Hormones can travel through the bloodstream, to nearby cells or even to other locations within the same cell.

1. Pituitary Gland

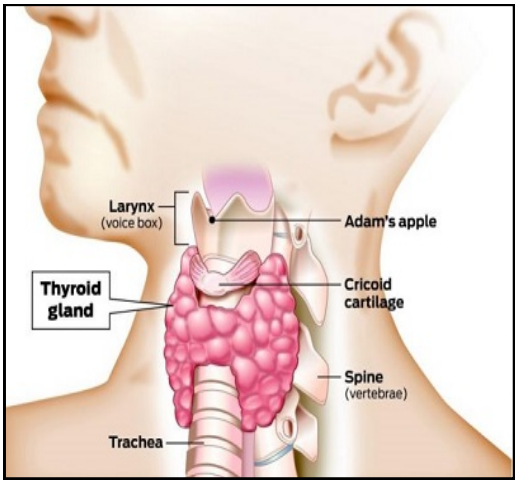
The pituitary gland sits in the sella turcica of the sphenoid bone. It is positioned in close proximity to the hypothalamus and is connected to the hypothalamus by a stalk-like structure called the infundibulum. The pituitary gland is divided into 2 sections. The anterior pituitary (aka adenohypophysis) and the posterior pituitary (aka neurohypophysis) each secrete different hormones. Other chemicals secreted by the hypothalamus known as



"releasing factors" influence hormones secreted by the anterior pituitary. Thus the nervous system exhibits some control over secretions of the anterior pituitary. The hypothalamus communicates with the anterior pituitary gland via a capillary network that interconnects the two structures. Blood levels of hormones are monitored by the hypothalamus causing the secretion of releasing factors that control release of anterior pituitary hormones. The communication between the hypothalamus and posterior pituitary is somewhat different than in the case of the anterior pituitary. The hypothalamus and posterior pituitary connect through a series of specialized nerve cells called neurosecretory cells. The hypothalamus produces the hormones secreted by the posterior pituitary.

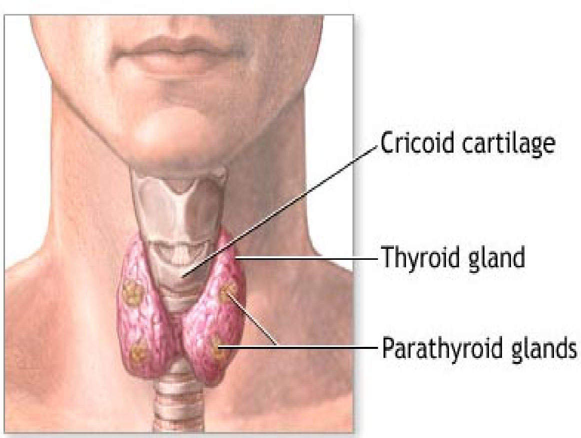
2. The Thyroid Gland

The thyroid gland is located in the anterior portion of the throat just inferior to the thyroid cartilage (Adam's apple). It contains distinct regions of tissues known as follicles. The structure of thyroid tissue produces two main cell types: those located within the follicle structure known as follicular cells, and those not located in the follicle known as extrafollicular or parafollicular cells. Both cell types secrete hormones. The follicular cells secrete triiodothyronine (T3) and tetraiodothyronine (T4). These hormones are secreted in response to the secretion of thyroid stimulating hormone from the anterior pituitary gland. Both of these hormones affect overall metabolism by increasing the cellular metabolism of carbohydrates, proteins and lipids. Both T3 and T4 require the presence of iodine in order to be produced. Iodine and thyronine (an amino acid) are joined in the follicular cells. Triodothryronine has 3 iodines and Tetraiodothyronine has 4 iodines. Thyroxine (T4) is the most abundant thyroid hormone. It works to increase metabolism and stimulates the cardiovascular system. It also works to differentiate cells. T3 (Triodothyronine) is secreted in smaller amounts but is the more active form. Most of the T4 converts to T3.



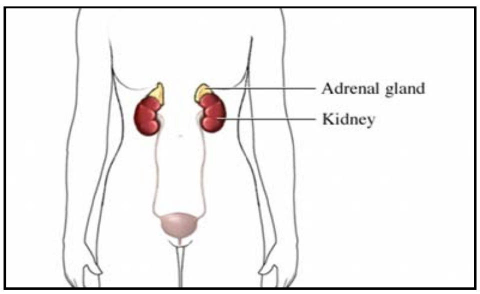
3. Parathyroid Glands

The parathyroid glands are four small masses of glandular tissue located on the posterior surface of the thyroid gland. These small glands contain secretory cells as well as capillaries. The parathyroid glands secrete one hormone aptly called parathyroid hormone (PTH). Parathyroid hormone works to increase blood calcium levels and decreases blood phosphate levels. PTH does this by stimulating osteoclastic activity to release calcium and other bone minerals into the bloodstream and inhibiting



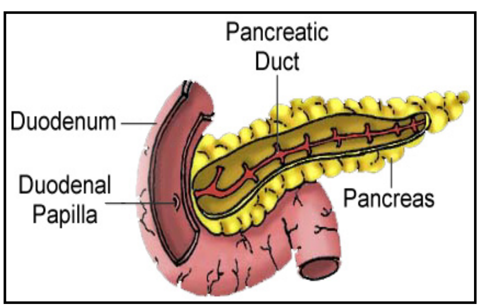
osteoblastic activity. Remember osteoblasts work to store minerals in bone. PTH also stimulates the production of vitamin D which in turn facilitates the absorption of calcium in the intestine. Vitamin D (aka cholecalciferol) is produced by converting provitamin D stored in the skin to vitamin D. This is done with the help of ultraviolet radiation from the sun. Vitamin D is also stored in tissues after it is converted to a storage form known as dihydroxycholecalciferol by the liver. PTH changes dihydroxycholecalciferol to the active form of vitamin D (cholecalciferol) which facilitates calcium absorption in the intestines. PTH also stimulates the release of the phosphate ion in the kidneys. All of these actions work to increase calcium concentration in the blood. Thus calcium levels are controlled by both calcitonin from the thyroid and parathyroid hormone.

4. The Adrenal Glands



The adrenal glands are two small pyramid shaped glands located on top of the kidneys (superior aspect). They consist of 2 functional areas: an outer cortex and an inner medulla. The cortex consists of 3 layers: zona glomerulosa, zona fasciculate and zona reticularis. The adrenal cortex produces a number of steroids as well as some other hormones. The hormones of the adrenal cortex and medulla are required by the body to sustain life.

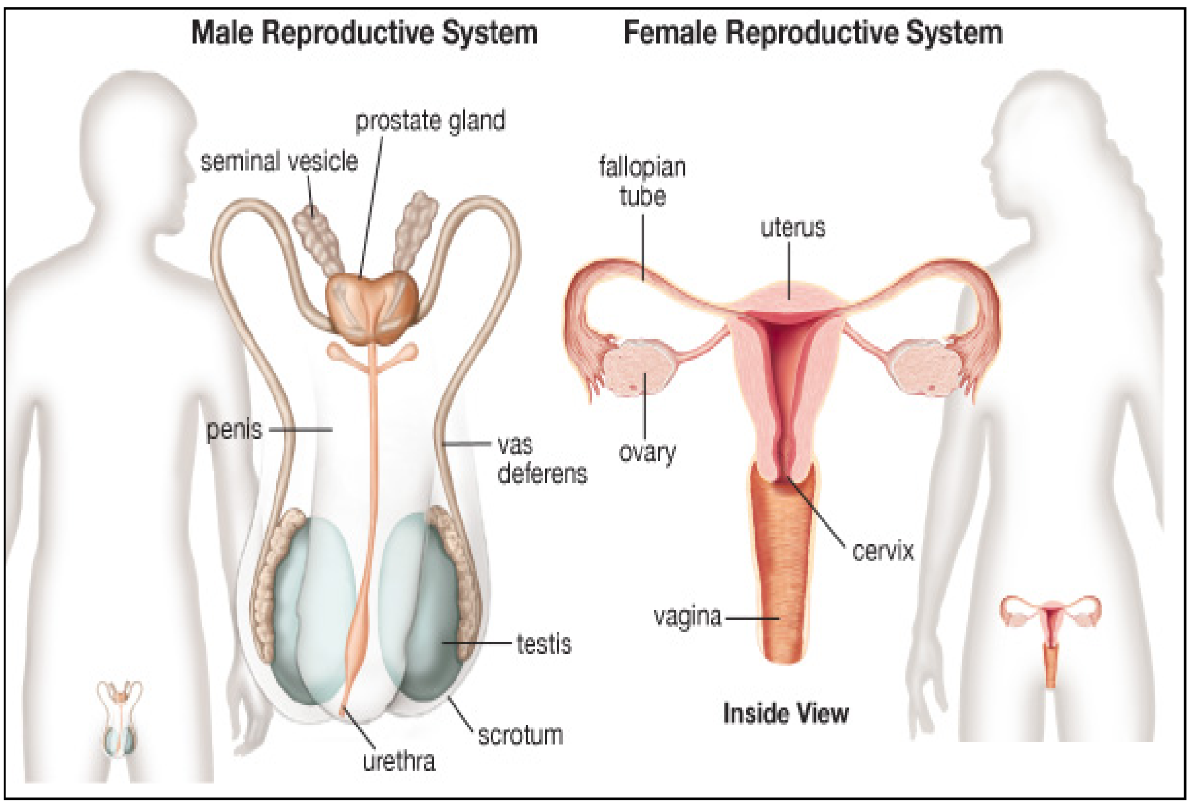
5. The Pancreas



The pancreas is located in the abdominal cavity at the flexure of the proximal portion of the small intestine called the duodenum. It is connected to the duodenum by ducts. It produces both digestive and hormonal secretions and performs a dual role in these systems. The internal structure of the pancreas consists of groupings of cells around capillary beds. The groupings of cells are called Islets of Langerhans and consist of 3 distinct types of cells: alpha, beta and delta cells. Each cell type produces a different secretion. Alpha cells secrete glucagons, beta cells secrete insulin and delta cells secrete somatostatin. Somatostatin (secreted by the delta cells) inhibits both glucagon and insulin secretion. Thus it also works to control glucose levels in the blood.

6. The Reproductive Glands

The ovaries and placenta in the female as well as the testes in the male secrete hormones that have a role in the endocrine system. The ovaries and placenta secrete estrogen and progesterone. The placenta also secretes a gonadotropin. The testes secrete testosterone.



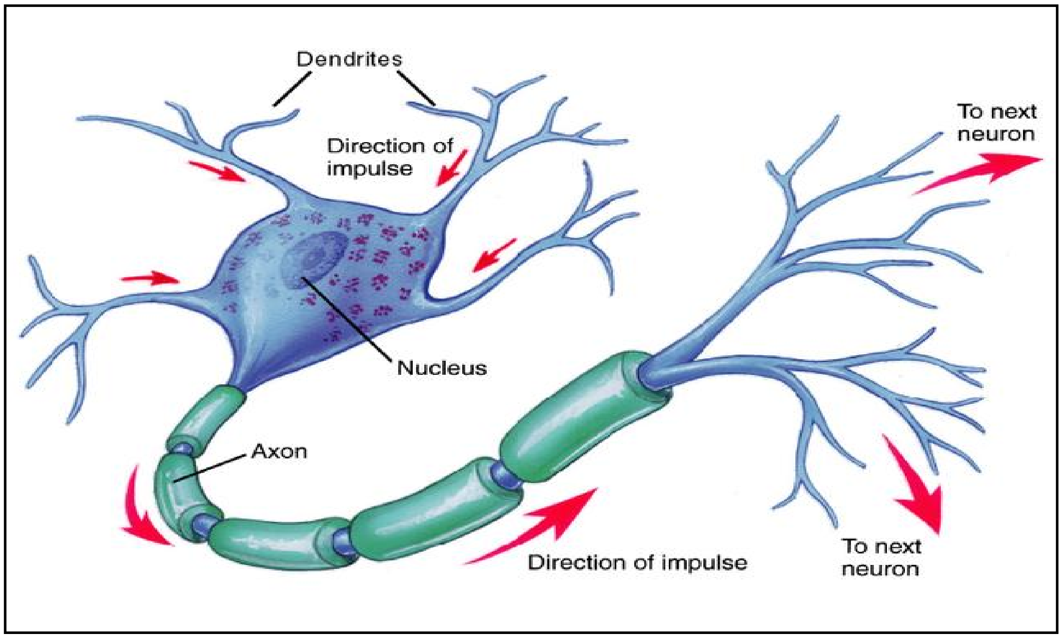
THE NERVOUS SYSTEM

The two types of cells found in the nervous system are called **neurons** or nerve cells and **neuroglia**, which are specialized connective tissue cells. Neurons conduct impulses, whereas neuroglia supports neurons.

Neurons

Each neuron consists of three parts: a main part called the neuron cell body, one or more branching projections called dendrites, and one elongated projection known as an axon. Identify each part on the neuron. Dendrites are the processes or projections that transmit impulses to the neuron cell bodies, and axons are the processes that transmit impulses away from the neuron cell bodies. Neurons can be classified structurally and functionally. The three types of functional classification of neurons are according to the direction in which they transmit impulses. These are: sensory neurons- Sensory neurons transmit impulses to the spinal cord and brain from all parts of the body. Sensory neurons are also called afferent neurons. Motor neurons- Motor neurons transmit impulses in the opposite direction-away from the brain and spinal cord. They do not conduct impulses to all parts of the body but only to two kinds of tissue-muscle and glandular epithelial tissue. motor neurons are called efferent neurons Interneurons- Interneurons conduct impulses from sensory neurons to motor neurons. interneurons are called central or connecting neurons.

The axon shown in is surrounded by a segmented wrapping of a material called myelin sheath. Myelin sheath is a white, fatty substance formed by Schwann cells that wrap around some axons outside the central nervous system. Such fibers are called Myelinated fibers. In one such axon has been enlarged to show additional detail. Nodes of Ranvier are indentions between adjacent Schwann cells. The outer cell membrane of a Schwann cell is called the neurilemma. The fact that axons in the brain and cord have noneurilemma is clinically significant because it plays an essential part in the regeneration of cut and injured axons. Therefore the potential for



regeneration in the brain and spinal cord is far less than it is in the peripheral nervous system.

Neuroglia

Neuroglia does not specialize in transmitting impulses. Instead, they are special types of connective tissue cells. Their name is appropriate because it is derived from Greek word glia meaning "glue." One function of neuroglia cells is to hold the functioning neurons together and protect them.

Impulse Generation and Conduction

The Nerve Impulse

The cell membrane of an unstimulated (resting) neuron carries an electric charge. Because of positive and negative ions concentrated on either side of the membrane, the inside of the membrane at rest is negative as compared with the outside. A nerve impulse is a local reversal in the charge on the nerve cell membrane that then spreads along the membrane like an electric current. This sudden electrical change in the membrane is called an action potential. A stimulus, then, is any force that can start an action potential. This electric change results from rapid shifts in sodium and potassium ions

across the cell membrane. The reversal occurs very rapidly (in less than one thousandth of a second) and is followed by a rapid return of the membrane to its original state so that it can be stimulated again. A myelinated nerve fiber conducts impulses more rapidly than an unmyelinated fiber of the same size because the electrical impulse "jumps" from node (space) to node in the myelin
sheath instead of traveling continuously along the fiber.

The Synapse

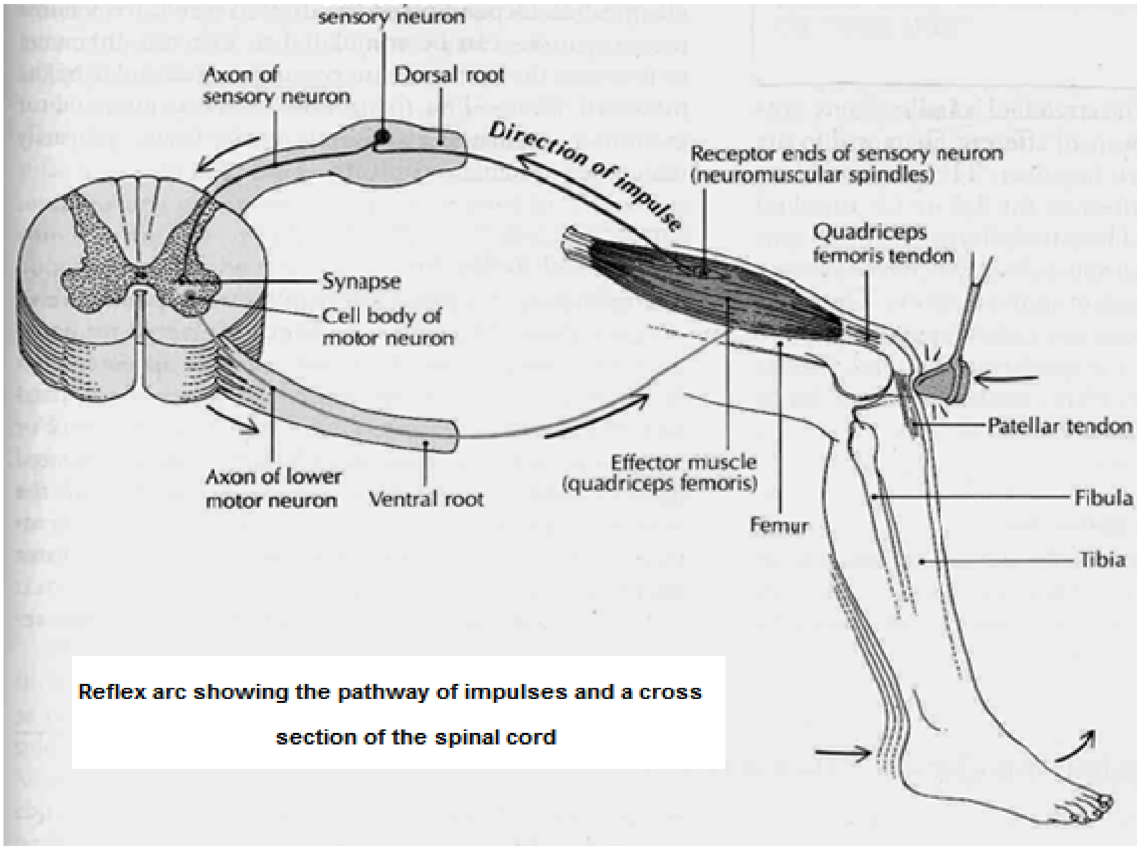
Each neuron is a separate unit, and there is no anatomic connection between neurons. How then is it possible for neurons to communicate? In other words, how does the axon of one neuron make functional contact with the membrane of another neuron? This is accomplished by the synapse, from a Greek word meaning "to clasp." Synapses are points of junction for the transmission of nerve impulses. Within the branching endings of the axon are small bubbles (vesicles) containing a type of chemical known as a neurotransmitter. When stimulated, the axon releases its neurotransmitter in to the narrow gap, the synaptic cleft, between the cells. The neurotransmitter then acts as a chemical signal to stimulate the next cell, described as the postsynaptic cell. On the receiving membrane, usually that of a dendrite, sometimes another part of the cell, there are special sites, or receptors, ready to pick up and respond to specific neurotransmitters. Receptors in the cell membrane influence how or if that cell will respond to a given neurotransmitter.

The Reflex Arc

As the nervous system functions, both external and internal stimuli are received, interpreted, and acted on. A complete pathway through the nervous system from stimulus to response is termed a reflex arc . This is the basic functional pathway of the nervous system. The parts of a typical reflex arc are:

- Receptor-the end of a dendrite or some specialized receptor cell, as in a special sense organ, that detects a stimuli.
- Sensory neuron, or afferent neuron-a cell that transmits impulses toward the CNS.
- Central neuron-a cell or cells within the CNS. These neurons may carry impulses to and from the brain, may function within the brain, or may distribute impulses to different regions of the spinal cord.
- Motor neuron, or efferent neuron-a cell that carries impulses away from the CNS.
- Effector-a muscle or a gland outside the CNS that carries out a response.

At its simplest, a reflex arc can involve just two neurons, one sensory and one motor, with a synapse in the CNS. There are very few reflex arcs that require only this minimal number of neurons. The knee jerk reflex is one of the few examples in humans. Most reflex arcs involve many more, even hundreds, of connecting neurons within the central nervous system.

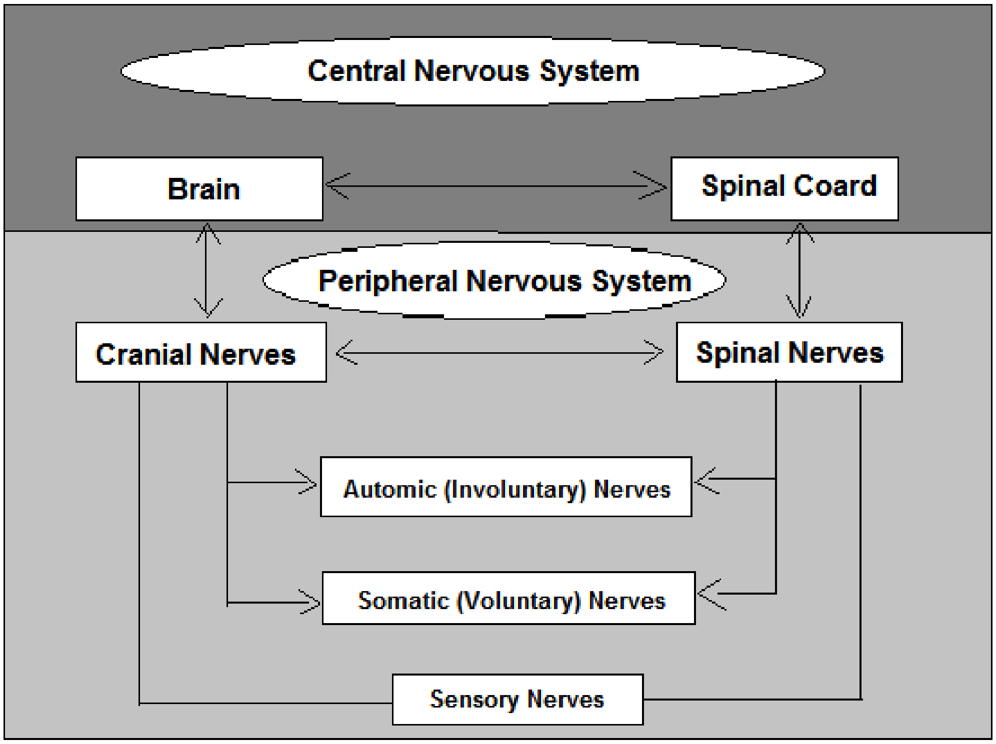


Reflex arc showing the pathway of impulses and a cross section of the spinal cord

Division of the Nervous System

The nervous system as a whole consists of two principal divisions called the central nervous system and peripheral nervous system. Because the brain and spmaI cord occupy a midline or central location in the body, they are together called the central nervous system or CNS. Similarly, the usual designation for the nerves of the body is the peripheral nervous system or PNS. Use of the term peripheral is appropriate because nerves extend to outlying or peripheral parts of the body. A subdivision of the peripheral nervous system called the autonomic nervous system (ANS) consists

of structures that regulate the body's autonomic or involuntary functions (for example, the heart rate, the contractions of the stomach, and intestines, and the secretion of chemical compounds by glands) .



Central Nervous System

The CNS as its name implies, is centrally located. Its two major structures, the brain and spinal cord, are found along the midsagittal plane of the body. The brain is protected in the cranial cavity of the skull, and the spinal cord is surrounded in the spinal column. In addition, protective membranes called **meninges** cover the brain and spinal cord.

CNS

The central nervous system (CNS) develops from a flat tissue structure called the neural plate. The neural plate forms neural folds on the lateral sides. The neural folds contain elevated portions called neural crests. At the center of the neural plate lies the neural groove. During fetal development the neural folds move toward each other and meet in the midline forming a neural tube. The superior portion of the neural tube becomes the brain and the inferior portion becomes the spinal cord. The neural crest contains neural crest cells that eventually separate from the neural crest and develop into the autonomic and sensory neurons of the peripheral nervous system. A series of pouch-like structures also develop from the anterior portion of the neural tube. The walls of these structures become parts of the brain while the hollow areas become the ventricles.

The developing brain can be divided into three main regions. These are the forebrain (prosencephalon), midbrain (mesencephalon) and hindbrain (rhombencephalon). The forebrain divides into the telencephalon and diencephalon. The midbrain remains as one structure and the hindbrain divides into the myelencephalon which eventually becomes the medulla oblongata and the pons and cerebellum.

The Brain

Divisions of the Brain

The brain, one of our largest organs, consists of the following major divisions, named in ascending order beginning with most inferior part:

I. Brain stem

A. Medulla oblongata

B. Pons

C. Midbrain

II. Cerebellum

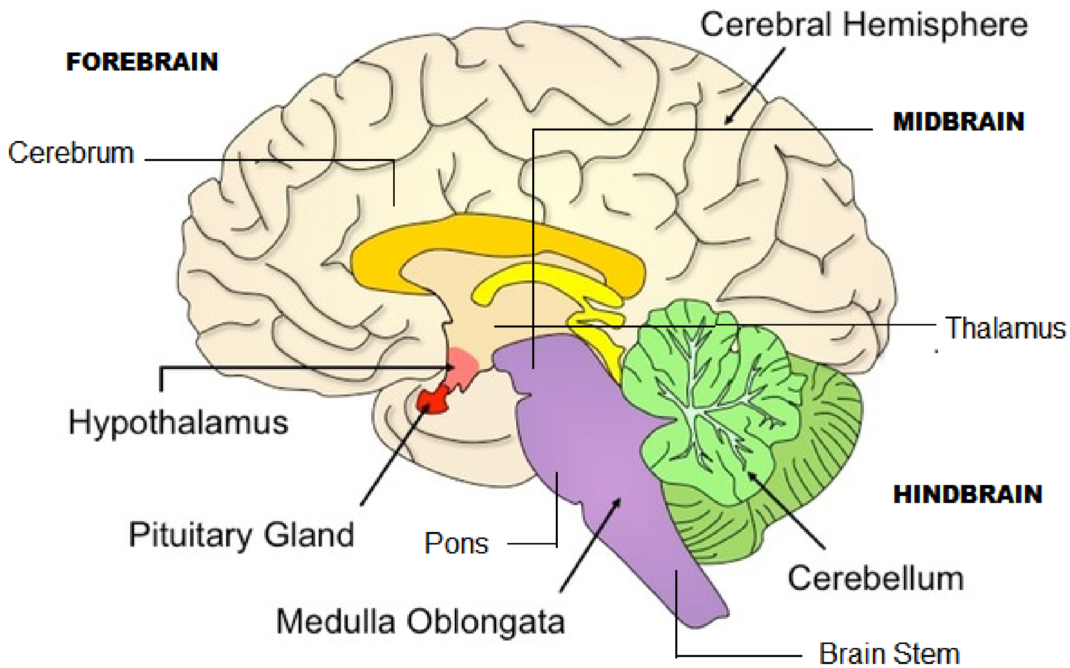
Ill. Diencephalon

A. Hypothalamus

B. Thalamus

IV. Cerebrum

Observe in Figure the location and relative sizes of the medulla, pons, cerebellum, and cerebrum. Also identify the midbrain.



Brain Stem

The lowest part of the brain stem is the medulla oblongata. The brainstem lies between the cerebral cortex and the spinal cord. It consists of the midbrain, pons and medulla oblongata.

The medulla oblongata is the most inferior portion of the brainstem and contains a number of centers for controlling heart rate, respiration, swallowing, vomiting and blood vessel diameter. These centers consist of nuclei which are clusters of neuron cell bodies. The spinal tracts also continue through the medulla connecting the spinal cord with the brain. The medulla contains two rounded structures called olives which consist of nuclei that help to control balance, coordination and sound information. Sensory fibers conduct impulses up from the cord to other parts of the brain, and motor fibers conductimpulses down from the brain to the cord. The cardiac,respiratory, and vasomotor centers (collectively called the vital centers) are located in the medulla. Impulses from these centers control heartbeat, respirations, and blood vessel diameter (which is important in regulating blood pressure). In addition, many important reflex centers lie in the brain stem.

The pons also contains spinal cord tracts as well as nuclei that help to control respiration and sleep. A number of cranial nerve nuclei are located in the pons (CN V, VI, VII, VIII, IX).

The midbrain is the most superior portion of the brainstem. It contains the nuclei of cranial nerves III, IV, and V. The roof or tectum of the midbrain contains the corpora quadrigemina which consist of four nuclei. The two superior nuclei are called the superior colliculli while the inferior are called the inferior colliculli. The superior colliculli help to control the movement of the head toward stimuli including visual, auditory, or touch. *The superior colliculli receive input from the eyes. The inferior colliculli help to process hearing and also receive input from the skin and cerebrum.* The floor of the midbrain is called the tegmentum. It contains two reddish colored structures called the red nuclei that process information for unconscious motor movements. The midbrain also contains the cerebral peduncles that carry motor information from the cerebrum to the spinal cord. The substantia nigra resides in the midbrain and processes information relating to tone and coordination of muscles.

Cerebellum

The cerebellum is the second largest part of the human brain. It is located posterior and inferior to the cerebrum. It lies under the occipital lobe of the cerebrum. The cerebellum contains both gray and white matter. In the cerebellum, gray matter composes the outer layer, and white matter composes the bulk of the interior. It is connected to the brainstem via three cerebellar peduncles (superior, middle and inferior peduncles). The cerebellum contains a number of different types of neurons but one in particular; the Purkinjie cell is the largest cell in the brain. These cells have very intricate dentritic networks that can synapse with as many as 200,000 other fibers. Purkinjie cells are inhibitory cells and function in processing motor information. The cerebellum can be divided into three parts. The flocculonodular lobe is the inferior portion. The vermis constitutes the middle portion and the two lateral hemispheres make up the remaining portion.

Function.

- The general functions of the cerebellum, then, are to produce smooth coordinated movements, and unconscious proprioception
- It is maintain equilibrium, and sustain normal postures.
- From such observations, we know that the cerebellum plays an essential part in the production of normal movements.

Diencephalon

The diencephalon lies between the brainstem and cerebrum. It consists of the thalamus, hypothalamus, subthalamus and epithalamus. The diencephalon is a small but important part of the brain located between the midbrain inferiorly and the cerebrum superiorly. It consists of two major structures: the hypothalamus and the thalamus. The ventricles of the diencephalons is the 3rd ventricle.

Thalamus

The thalamus is the largest part of the diencephalon. It consists of two lateral portions connected by a stalk called the interthalamic adhesion sometimes referred to as the intermediate mass. The thalamus carries all sensory information to the cerebral cortex with the exception of the sense of smell which is carried directly to the frontal lobe of the cerebral cortex by the olfactory nerves. The thalamus is sometimes referred to as a relay station for sensory information. Examples of sensory information include auditory information that synapses in the medial geniculate nucleus, visual information that synapses in the lateral geniculate nucleus, and motor information from the basal nuclei, motor cortex and cerebellum synapsing in the ventral anterior and lateral nuclei. The thalamus is also intimately involved in emotions due to its connections to the limbic system.

It performs the following functions:

- It helps produce sensations. Its neurons relay impulses to the cerebral cortex from the sense organ of the body.
- It associates sensations with emotions. Almost all sensations are accompanied by a feeling of some degree of pleasantness or unpleasantness. The way that these pleasant and unpleasant feelings are produced is unknown except that they seem to be associated with the arrival of sensory impulses in thalamus.
- It plays a part in the so -called arousal or alerting mechanism.
- It contains important nuclei such as medial geniculate which is responsible for auditory sense and lateral geniculate which is responsible for vision.

Hypothalamus

The hypothalamus, as its name suggests, is located inferior to the thalamus. The posterior pituitary gland, the stalk that attaches it to the undersurface of the brain, and areas of gray matter located in the sidewalls of a fluid-filled space called the third ventricle are extensions of the hypothalamus. Identify the pituitary gland and the hypothalamus.

- The hypothalamus is intimately connected with the endocrine system and helps to regulate hormones.
- The hypothalamus also regulates body temperature, thirst, hunger and sexual drive and is involved in processing emotions, mood, sleep cycles and pain along with the reticular activating system.
- Important center is involved in functions such as the regulation of water balance;

Cerebrum

The cerebrum is the largest and uppermost part of the brain and nervous system . The cerebrum consists of two hemispheres (right and left) connected by a white matter bridge called the corpus callosum. On the surface of the cerebrum are folds called *gyri* and grooves called *sulci*. Deep grooves are known as fissures. Each hemisphere is divided into lobes. The lobes are the frontal, parietal, temporal and occipital.

The frontal lobe processes information involving motor movements, concentration, planning and problem solving as well as the sense of smell and emotions. The parietal lobes process sensory information with the exception of hearing, smell and vision. The temporal lobes process information related to hearing, smell and memory as well as abstract thought and making judgments. The occipital lobe processes visual information. The nerve fibres of the white matter of the cerebral hemispheres are of three groups: ***commissural***, ***association*** and ***projection.***

Structure of the Spinal Cord

The spinal cord has a small, irregular shaped internal section. The spinal cord lies within the vertebral canal and extends from the foramen magnum to the level of the second lumbar vertebrae after which a fibrous remnant, the filum terminal, descends to be attached to the back of the coccyx. The cord is about 45 cm long. It is cylindrical in shape, flattened slightly anteroposteriorly, and has cervical and lumbar enlargements where the nerves supplying the upper and lower limb originatethe enlargements lie opposite the lower cervical and lower thoracic vertebrae. Since the spinal cord is shorter than the vertebral canal, the nerves descend with increasing obliquity before leaving the canal through the intervertebral foramina. The collection of lower lumbar, sacral and coccygeal nerves below the spinal cord, with the filum terminale, is known as the **cauda equina**.

Functions of the Spinal Cord

The spinal cord is the link between the spinal nerves and the brain. It is also a place where simple responses, known as reflexes can be coordinated even without involving the brain. The functions of the spinal cord may be divided into three categories:

- Conduction of sensory impulses upward through ascending tracts to the brain

- Conduction of motor impulses from the brain down through descending tracts to the efferent neurons that supply muscles or glands
- Reflex activities. A reflex is a simple, rapid, and automatic response involving very few neurons.

When you fling out an arm or leg to catch your balance, withdraw from a painful stimulus, or blink to avoid an object approaching your eyes, you are experiencing reflex behaviour. A reflex pathway that passes through the spinal cord alone and does not involve the brain is termed a spinal reflex. The stretch reflex, in which a muscle is stretched and responds by contracting, is one example. If you tap the tendon below the kneecap (the patellar tendon), the muscles of the anterior thigh (quadriceps femoris) contracts, eliciting the knee jerk. Such stretch reflexes may be evoked by appropriate tapping of most large muscles (such as the triceps brachii in the arm and the gastrocnemius in the calf of the leg). Because reflexes occur automatically, they are used in physical examinations to test the condition of the nervous system.

FUNCTIONS OF MAJOR DIVISIONS OF THE BRAIN

S.NO	Brain Area	Function
I	**Brain stem**	Two-way conduction pathway between the spinal cord and higher brain centers; cardiac, respiratory, and vasomotor control center.
1	Medulla oblongata	
2	Pons	Two-way conduction pathway between areas of the brain and other regions of the body; Influences respiration.
3	Midbrain	Two-way conduction pathway; relay for visual and auditory Impulses.

II	Diencephalon	Regulation of body temperature,water balance, sleep cycle control appetite, and sexual arousal.
1	Hypothalamus	
2	• Thalamus	Sensory relay station from various body areas to cerebral cortex; emotions and alerting or arousal mechanisms.
III	Cerebellum	Muscle coordination; maintenance of equilibrium and posture.
IV	Cerebrum	Sensory perception, emotions willed movements, consciousness, and Memory.

SENSE ORGANS

Classification of sense organs

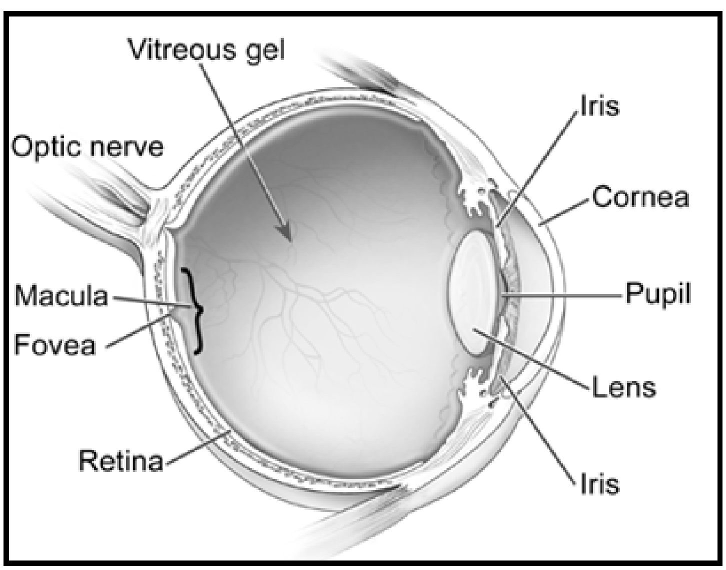
The sense organs are often classified as special sense organs and general sense organs. Special sense organs, such as the eye, are characterized by large and complex organs or by localized groupings of specialized receptors in areas such as the nasal mucosa or tongue. The general sense organs for detecting stimuli such as pain and touch are microscopic receptors widely distributed throughout the body.

Other general sense organs include receptors that indicate the tension on our muscles and tendons so that we can maintain balance and muscle tone and are aware of the positions of our body parts. Following table classifies the special sense organs.

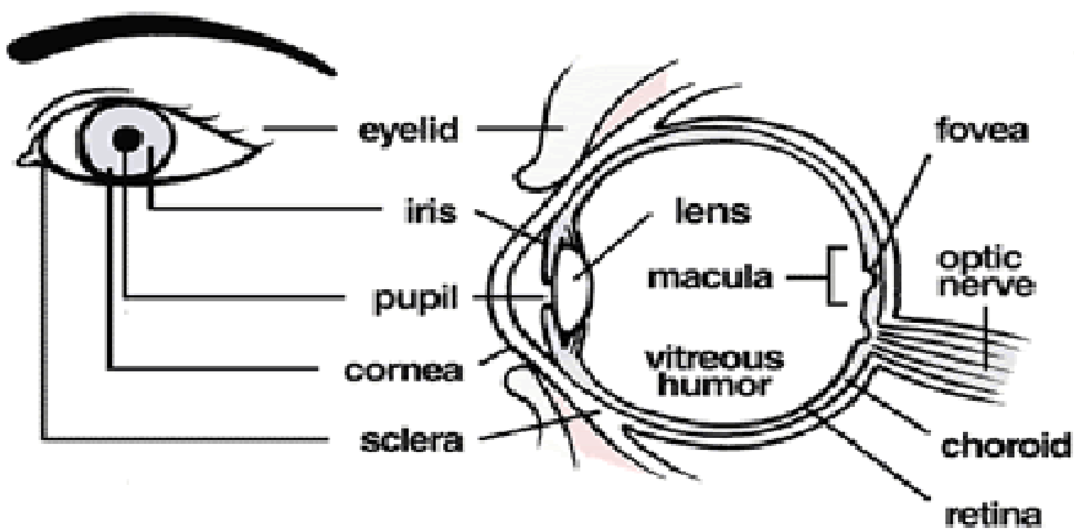
SENSE ORGAN	SPECIFIC RECEPTOR	TYPE OF RECEPTOR	SENSE
Eye	Rods and Cons	Photoreceptor	Vision
Ear	Organ of Corti Cristae ampularis	Mechanoreceptor Mechanoreceptor	Hearing Balance
Nose	Olfactory cells	Chemoreceptor	Smell
Taste buds	Gustatory cells	Chemoreceptor	Taste

The Eye

When you look at a person's eye you see only a small part of the whole eye. Three layers of tissue from the eye ball: the sclera, the choroids, and the retina. The outer layer of sclera consists of though fibrous tissue. The white of the eye is part of the front surface of the sclera. The other part of the front surface of the sclera is called the cornea and is sometimes spoken of as the window of the eye because of its transparency. At a casual glance, however, it does not look transparent but appears blue, brown, gray, or green because it lies over the iris, the coloured part of the eye. A mucous membrane known as the conjunctiva lines the eyelids and covers the sclera in front. The conjunctiva is kept moist by tears formed in the lacrimal gland located in the upper lateral portion of the orbit.



The middle layer of the eyeball, the choroid, contains a dark pigment to prevent the scattering of incoming light rays. Two involuntary muscles make up the front part of the choroids. One is the iris, the colored structure seen through the cornea, and the other is the ciliary muscle. The black center of the iris is really a hole in this doughnut-shaped muscle; it is pupil of the eye. Some of the fibers of the iris are arranged like spokes in a wheel. When they contract the pupils dilate, letting in more light rays. Other fibers are circular. When they contract, the pupils constrict, letting fewer light rays. Normally, the pupils constrict in bright light and dilate in dim light. When we look at distant objects, the ciliary muscle is relaxed, and the lens has only a slightly curved shape.



Although we may take it for granted, seeing is one of the most complex functions our bodies perform and it requires the cooperation of many small and intricate parts. The human eye functions much like a digital camera. Both devices gather, focus, and transmit light through a lens to create an image of the surrounding environment. In order to see, we must have light.

Functions of the Eye

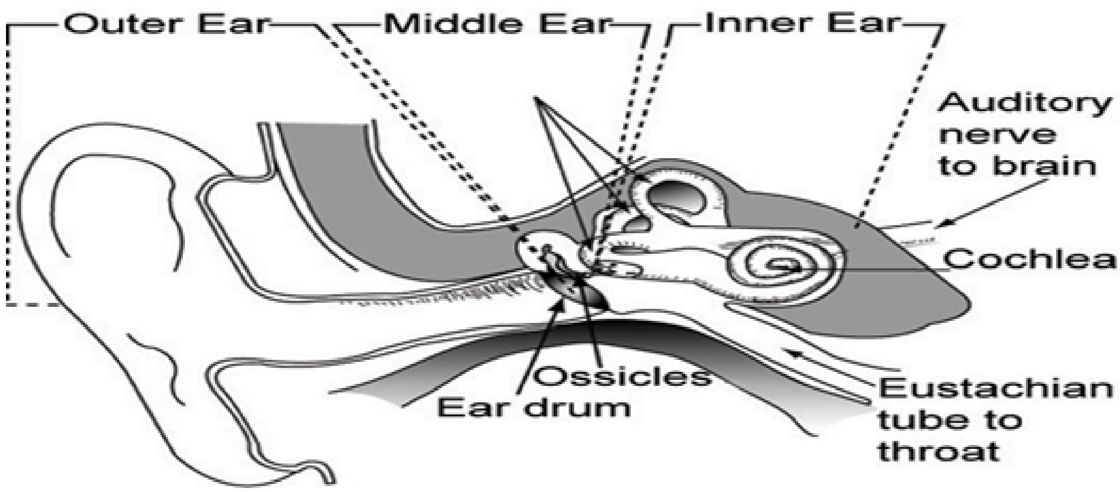
1. Light enters the eye through the **cornea**, the clear front surface of the eye, which acts like a camera lens.

2. The **iris** of the eye functions like the diaphragm of a camera, controlling the amount of light reaching the back of the eye by automatically adjusting the size of the **pupil**, which acts like an aperture. In dark conditions, the pupil widens. In bright conditions, the pupil constricts.
3. The eye's **crystalline lens**, located directly behind the pupil, helps the eye automatically focus on near and approaching objects, like an autofocus camera lens.
4. The light then travels through the **vitreous humor**, a clear gel-like substance that fills the middle of the eye.
5. Light then reaches the **retina**, a sensitive inner lining of the back of the eye. The retina acts like camera film, converting optical images into electronic signals.
6. The image reflected on the retina is upside down. The **optic nerve** transmits signals to the **visual cortex** in the brain, which flips the image right side up and creates one composite image

The Ear

In addition to its role in hearing, the ear also functions as the sense organ of equilibrium and balance. As we shall later see, the stimulation or "trigger" that activates receptors involved with hearing and equilibrium is mechanical, and the receptors themselves are called mechanoreceptors. Physical forces that involve sound vibrations and fluid movements are responsible for initiating nervous impulses eventually perceived as sound and balance. The ear is much more than a mere appendage on the side of the head. A large part of the ear, and by far its most important part, lies hidden from view deep inside the temporal bone. It is divided into the following anatomical areas.

1. External ear (Outer ear)
2. Middle ear
3. Internal ear (Inner ear)



External ear

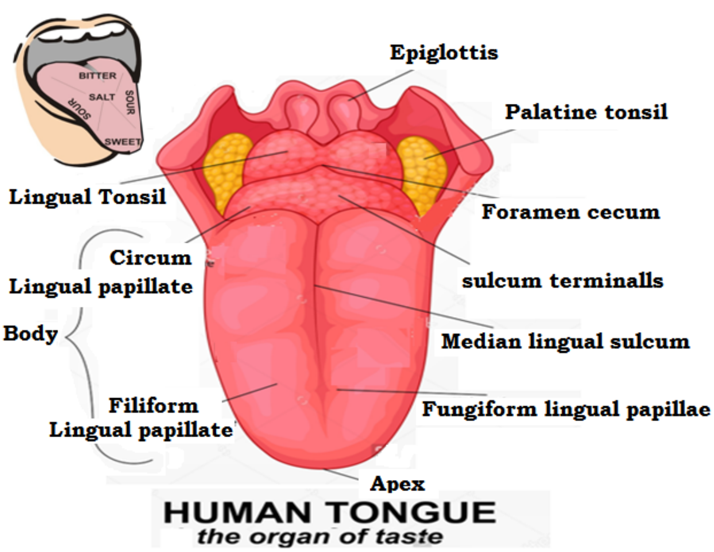
The external ear has two parts: the auricle or pinna and the external auditory canal. The auricle is the appendage on the side of the head surrounding the opening of the external auditory canal. The canal itself is a curve about 2.5 cm (1 inch) in length. It extends into the temporal bone and ends at the tympanic membrane or eardrum, which is a partition between the external and middle ear. The skin of the auditory canal, especially in its outer one third, contains many short hairs and ceruminous glands that produce a waxy substance called cerumen that may collect in the canal and impair hearing by absorbing or blocking the passage of sound waves. Sound waves travelling through the external auditory canal strike the tympanic membrane and cause it to vibrate.

Middle Ear

The middle ear is a tiny and very thin epithelium lined cavity hollowed out of the temporal bone. It houses three very small bones. The names of these ear bones, called ossicles, describe their shapes − malleus (hammer), incus (anvil), and stapes (stirrup). The "handle" of the malleus attaches to the inside of the tympanic membrane, and the "head" attaches to the incus. The incus attaches to the stapes, and the stapes presses against a membrane that covers a small opening, the oval window. The oval window separates the middle ear from the inner ear. When sound waves cause the eardrum to vibrate, that movement is transmitted and amplified by the ear ossicles as it passes through the middle ear. A point worth mentioning, because it explains the frequent spread of infection from the throat to the ear, is the fact that a tube– the auditory or eustachian tube– connects the throat with the middle ear. The epithelial lining of the middle ears, auditory tubes, and throat are extensions of one continuous membrane. Consequently a sore throat may spread to produce a middle ear infection called otitis media.

Inner Ear

The activation of specialized mechanoreceptors in the inner ear generates nervous impulses that result in hearing and equilibrium. Anatomically, the inner ear consists of three spaces in the temporal bone, assembled in a complex maze called the bony labrynth. This odd shaped bony space is filled with a watery fluid called perilymph and is divided into the following parts: vestibule, semicircular canals, and cochlea. The vestibule is adjacent to the oval window between the semicircular canals and the cochlea. The organ of hearing, which lies in the snail shaped cochlea,is the organ of corti. It is surrounded by endolymph filling themembranous cochlea or cochlear duct, which is the membranous tube within the bony cochlea. Specialized hair cells on the organ of Corti generate nerve impulses when they are bent by the movement or endolymph set in motion by sound waves.

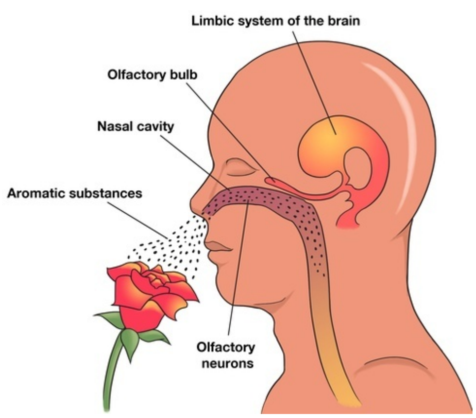


The Taste Receptors

The chemical receptors that generate nervous impulses resulting in the sense of taste are called taste buds. About 10,000 of these microscopic receptors are found on the sides of much larger structure on the tongue called papillae and also as portions of other tissues in the mouth and throat. Nervous impulses are generated by specialized cells in taste buds, called gustatory cells. They respond to dissolved chemicals in the saliva that bathe the tongue and mouth tissues Only four kinds of taste sensations−sweet, sour, bitter, and salty−result from stimulation of taste buds. All other flavours result from a combination of taste bud and olfacctory receptor stimulation. In other words, the myriads of tastes recognized are not tastes alone but tastes plus odours. For this reason a cold that interferes with the stimulation of the olfactory receptors by odours from foods in the mouth markedly dulls taste sensations. Nervous impulses generated by stimulation f taste buds travel primarily through two cranial nerves to end specialized taste area of the cerebral cortex.

The Smell Receptors

The chemical receptors responsible for the sense of smell are located in a



small area of epithelial tissue in the upper part of the nasal cavity. The location of the olfactory receptors is somewhat hidden, and we are often forced to forcefully sniff air to smell delicate odours. Each olfactory cell has a number of specialized cilia that sense different chemicals and cause the cell to respond by generating a nervous impulse. To be detected by olfactory receptors, chemicals must be dissolved in the watery mucus that lines the nasal cavity. Although the olfactory receptors are extremely sensitive (that is, stimulated by even very slight odours), they are also easily fatigued a fact that explains why odours that are at first very noticeable are not sensed at all after a short time. After the olfactory cells are stimulated by odour-causing chemicals, the resulting nerve impulse travels through the olfactory nerves in the olfactory bulb and tract and then enters the thalamic and olfactory centers of the brain, where the nervous impulses are interpreted as specific odours.

The pathways taken by olfactory nerve impulses and the area where these impulses are interpreted are closely associated with areas of the brain important in memory and emotion. For this reason, we may retain vivid and long-lasting memories of particular smells and odours. Temporary reduction of sensitivity to smells often results from colds and other nasal infections.

UNIT – IV
THE MUSCULAR SYSTEM

The term muscle tissue refers to all the contractile tissues of the body: skeletal, cardiac, and smooth muscle. The muscular system, however, refers to the skeletal muscle system: the skeletal muscle tissue and connective tissues that makeup individual muscle organs, such as the biceps brachii muscle. Cardiac muscle tissue is located in the heart and is therefore considered part of the cardiovascular system. Smooth muscle tissue of the intestines is part of the digestive system, whereas smooth muscle tissue of the urinary bladder is part of the urinary system and so on.

1. Skeletal muscles

Skeletal Muscles are those which attach to bones and have the main function of contracting to facilitate movement of our skeletons. They are also sometimes known as striated muscles due to their appearance. The cause of this 'stripy' appearance is the bands of Actin and Myosin which form the **Sarcomere,** found within the Myofibrils.

Skeletal muscles are also sometimes called voluntary muscles, because we have direct control over them through nervous impulses from our brains sending messages to the muscle. Contractions can vary to produce powerful, fast movements or small precision actions. Skeletal muscles also have the ability to stretch or contract and still return to their original shape.

Skeletal muscle fibre type

Not all fibres within Skeletal muscles are the same. Different **fibre types** contract at different speeds, are suited to different types of activity and vary in colour depending on their Myoglobin (an oxygen carrying protein) content.

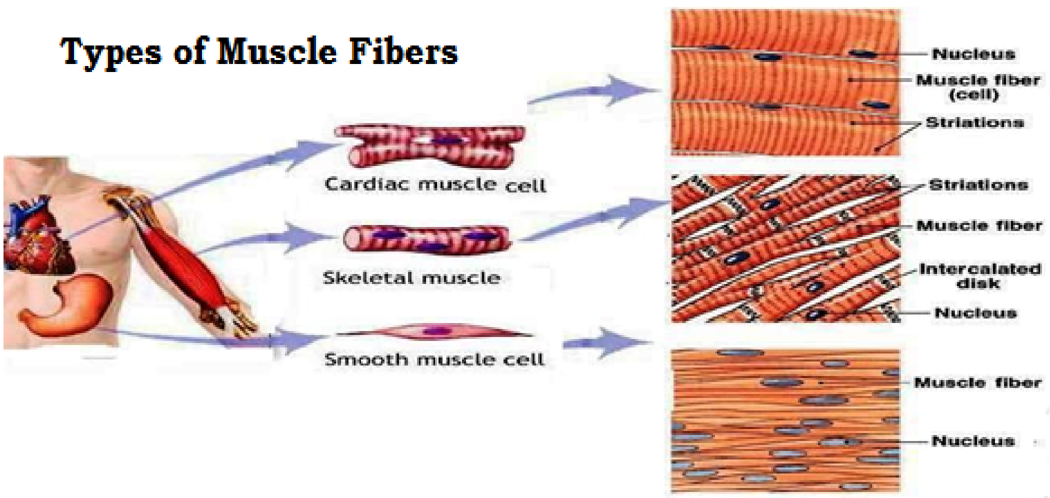
Although there are over 700 individual skeletal muscles in the human body, an appreciation and understanding of skeletal muscles can be accomplished by concentrating on the large superficial muscles and muscle groups.

2. Cardiac Muscle

Cardiac muscle is only found in the heart. Like skeletal muscle it has a high concentration of myofilaments and is striated. However, there are also a number of structural differences between skeletal and cardiac muscle. Cardiac muscles are smaller and generally contain one nucleus whereas skeletal muscles are multinucleated. They have a different arrangement of T-tubules and no triads. The sarcoplasmic reticulum does not have terminal cisternae. Cardiac muscle fibers are powered by aerobic metabolism and contain energy reserves in the form of glycogen and lipids. Cardiac muscle cells contain large numbers of mitochondria to utilize aerobic energy systems. Cardiac muscle cells also contain a specialized kind of cell junctions called intercalated discs that allow the flow of chemicals between cells and help to maintain the structure of the muscle. This allows for a greater transmission of electrical signals across large areas of cardiac muscles. The discs also allow adjacent fibers to pull together in a more coordinated contraction. Instead of motor units working separately in skeletal muscle, intercalated discs allow cardiac muscle to contract in large uniform segments. Cardiac muscle can also contract without a stimulus from the nervous system. Cardiac muscle contains self-generating action potential cells called pacemaker cells or nodes. The pacemaker cells however can respond to the nervous system by changing the rate and force of contraction of cardiac muscle cells. Cardiac muscle cannot undergo tetanic contractions due to the structure of the cell membrane.

3. Smooth Muscle

Smooth muscle cells are found throughout the body in organs, blood vessels and tube like structures. Smooth muscles contain actin and myosin and are long spindle shaped cells. Actin and myosin are not arranged in sarcomeres so smooth muscle is not striated. Instead the actin and myosin are scattered about throughout the muscle. Smooth muscle has no T-tubules and the myosin has a larger number of globular protein heads. Smooth muscle contraction differs from skeletal or cardiac contraction in that when calcium is released by the sarcoplasmic reticulum it binds with a calcium-binding protein called calmodulin that activates an enzyme called myosin light chain kinase. This enzyme allows for the formation of cross-bridges. Because of the structure of smooth muscle, length and tension are not related. When smooth muscle is stretched it adapts to its new resting length and can continue to contract. Smooth muscle cells are classified as multiunit or visceral. Multiunit smooth muscle is organized into motor units that are innvervated by the nervous system. However, each cell can be connected to more than one motor unit. Visceral cells do not connect directly with motor neurons and are arranged in layers. Gap junctions connect layers of smooth muscle so that one area can influence others when contracting. This can produce a wave-like contraction called *peristalsis*.



Functions of muscle tissue

Through sustained contraction or alternating contraction and relaxation, muscle tissue has three key functions: producing motion, providing stabilization, and generating heat.

1. Motion: Motion is obvious in movements such as walking and running, and in localized movements, such as grasping a pencil or nodding the head. These movements rely on the integrated functioning of bones, joints, and skeletal muscles.

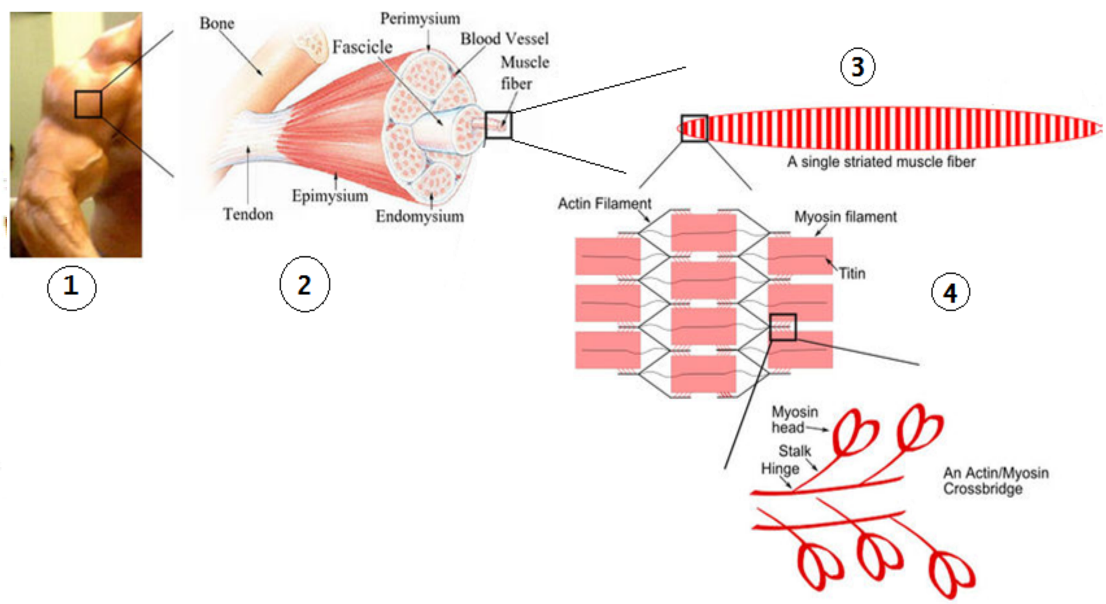
2. Stabilizing body positions and regulating the volume of cavities in the body: Besides producing movements, skeletal muscle contractions maintain the body in stable positions, such as standing or sitting. Postural muscles display sustained contractions when a person is awake, for example, partially contracted neck muscles hold the head upright. In addition, the volumes of the body cavities are regulated through the contractions of skeletal muscles. For example muscles of respiration regulate the volume of the thoracic cavity during the process of breathing.

3. Thermo genesis (generation of heat). As skeletal muscle contracts to perform work, a by-product is heat. Much of the heat released by muscle is used to maintain normal body temperature. Muscle contractions are thought to generate as much as 85% of all body heat.

Muscle structure

A skeletal muscle is an organ composed mainly of striated muscle cells and connective tissue. Each skeletal muscle has two parts; the connective tissue sheath that extend to form specialized structures that aid in attaching the muscle to bone and the fleshy part the **belly** or **gaster**. The extended specialized structure may take the form of a cord, called a **tendon**; alternatively, a broad sheet called an **aponeurosis** may attach muscles to bones or to other muscles, as in the abdomen or across the top of the skull. A connective tissue sheath called **facia** surrounds and separates muscles. Connective tissue also extends into the muscle and divides it into numerous **muscle bundles** (fascicles). There are three connective tissue components that cover a skeletal muscle tissue. These are:

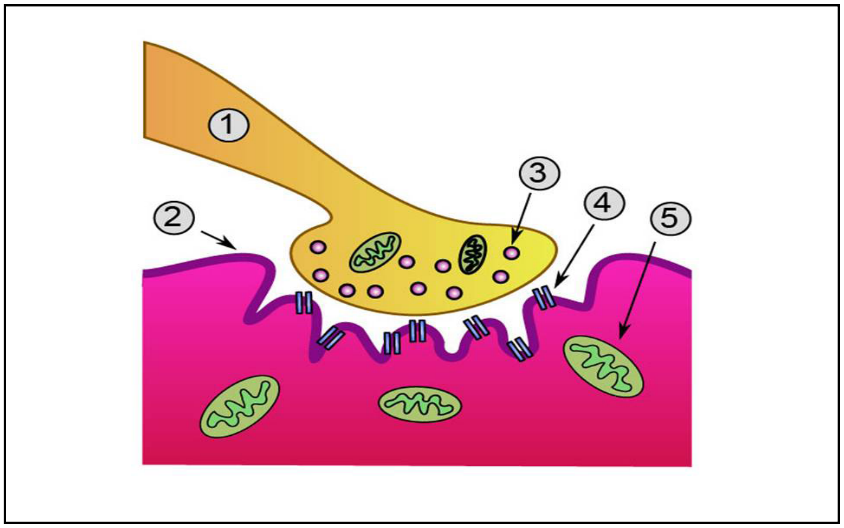
1. Epimysium a connective tissue sheath that surrounds and separates muscle.
2. Perimysium a connective tissue that surrounds and holds fascicles together.
3. Endomysium a connective tissue that surrounds each muscle fibre.



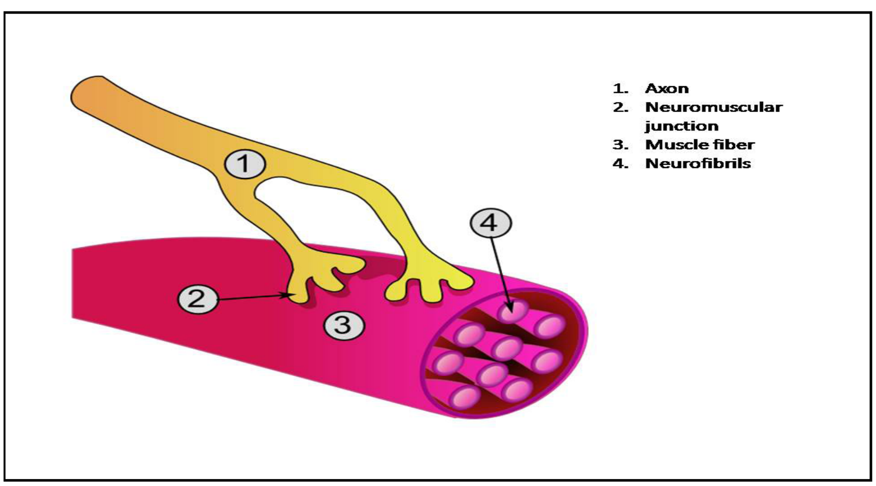
B. Microscopic structures

The muscle bundles are composed of many elongated muscle cells called muscle fibres. Each **muscle fibre** is a cylindrical cell containing several nuclei located immediately beneath the cell membrane (**sarcolemma**). The cytoplasm of each muscle fibre (**sarcoplasm**) is filled with myofibrils. Each myofibril is a thread-like structure that extends from one end of the muscle fibre to the other. Myofibrils consist of two major kinds of protein fibres: **actins** or thin **myofilaments**, and **myosin** or thick **myofilaments**. The actins and myosin myofilaments form highly ordered units called **sarcomers**, which are joined end-to-end to form the yofibrils (see Figure). Sarcomere is a structural and functional unit of muscle tissue. The ends of a sarcomere are a network of protein fibres, which form the **Z-lines** when the sarcomere is viewed from side. The Z-lines form an attachment site for actins myofilaments. The arrangement of the actin and myosin myofilaments in a sarcomere gives the myofibril a banded appearance because the myofibril appears darker where the actin and myosin myofilaments overlap. The alternating light (**I-band**) and dark (**A-band**) areas of the sarcomers are responsible for striation (banding pattern) seen in skeletal muscle cells observed through the microscope.

Neuromuscular junction
1. Presynaptic terminal
2. Sarcolemma
3. Synaptic vesicles
4. Acetylcholine receptors
5. Mitchondrion



The motor neuron releases a message in the form of a neurotransmitter to the muscle to tell it to contract. The neurotransmitter floats across an area between the neuron and muscle called the synaptic cleft. The muscle side of the synaptic cleft is called the motor end plate. The sarcolemma is enfolded at the motor end plate in order to increase the surface area. The neurotransmitter involved in skeletal muscle contraction is acetylcholine



Muscle contractions

The thick myofilaments are composed of a protein called myosin. Each myosin filament has small regular projections known as **crossbridges**. The crossbridges lie in a radial fashion around the long axis of the myofilament.

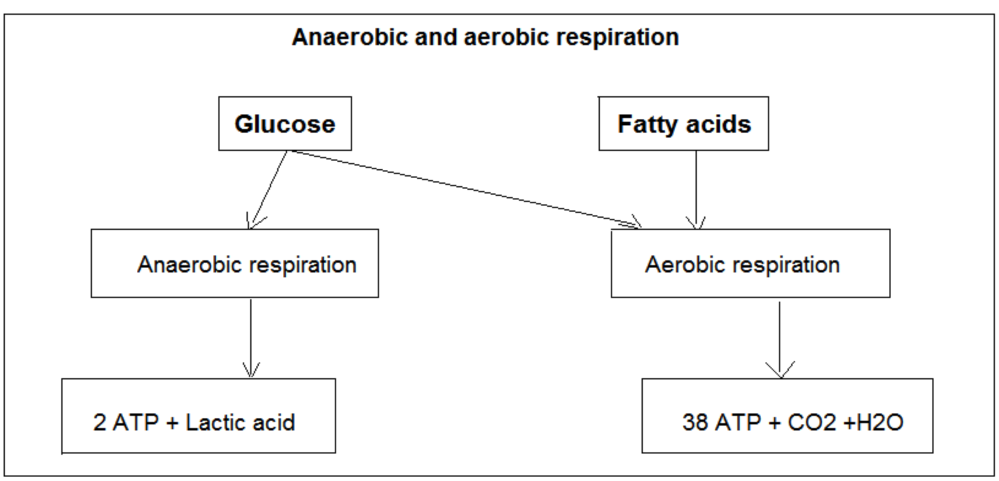
The rounded heads of the cross bridges lie in opposition to the thin myofilaments. The thin myofilaments are composed of a complex protein called actin, arranged in a double stranded coil. The actin filaments also contain two additional proteins called **troponin** and **tropomysin**. In a resting muscle fibre the myosin cross bridges are prevented from combining with the actin filaments by the presence of troponin and tropomysin. When a nerve impulse reaches a muscle fibre it is conducted over the sarcolemma and in to the T-tubules, then to the sarcoplasmic reticulum. The sarcoplasmic reticulum releases calcium ions into the sacrcoplasm. The liberated calcium ions combine with troponin causing it to push tropomysin away from the receptor sites on the actins filaments. The myosin crossbridges interactwith the actin receptor sites and pull the actins myofilaments toward the centre (H-zone) of each sarcomere. The bond between the myosin cross bridges and actin breaks down under the influence of enzymes and the cross bridges are then free to rejoin with other actin receptor sites. The actin filaments do not shorten but slide past the myosin filaments overlapping them so that the Z lines are drawn toward each other, shortening the sarcomere. As each sarcomere shortens the whole muscle fibre contracts. Relaxation of the muscle fibres occurs when the calcium ions are actively reabsorbed by the sarcoplasmic reticulum thus allowing troponin and tropomysin to again inhibit the interaction of the actins and myosin filaments.

Energy Requirements for Muscle Contraction

Contraction o skeletal muscle requires adenosine triphosphate (ATP). The ATP releases energy when it breaks down to adenosine diphosphate (ADP) and a phosphate (P), some of the energy is used to move the cross bridges and some of the energy is released as heat.

ATP→ADP + P + Energy (for cross bridge movement) + Heat

The ATP required for muscle contraction is produced primarily in numerous mitochondria located within the muscle fibres. Because ATP is a very short-lived molecule and rapidly degenerates to the more stable ADP, it is necessary for muscle cells to constantly produce ATP. ATP is produced by anaerobic or aerobic respiration. **Anaerobic respiration**, which occurs in the absence of oxygen, results in the breakdown of glucose to yield ATP and Lactic acid. **Aerobic respiration** requires oxygen and breaks down glucose to produce ATP, carbon dioxide, and water. Compared with anaerobic respiration, aerobic respiration is much more efficient. The breakdown of glucose molecule by aerobic respiration theoretically can produce 19 times as much ATP as is produced by anaerobic respiration. In addition, aerobic respiration can utilize a greater variety of nutrient molecules to produce ATP than can anaerobic respiration. For example, aerobic respiration can use fatty acids to generate ATP. Although anaerobic respiration is less efficient than aerobic respiration, it can produce ATP when lack of oxygen limits aerobic respiration. By utilizing many glucose molecules, anaerobic respiration can rapidly produce much ATP, but only for a short period. Resting muscles or muscles undergoing long-term exercise primarily on aerobic respiration for ATP synthesis. Although some glucose is used as an energy source, fatty acids are a more important energy source during sustained exercise as well as during resting conditions. On the other hand, during intense exercise such as riding a bicycle up a steep hill, anaerobic respiration provides enough ATP to support intense muscle.



Types of muscle contraction

Muscle Contractions

There are three types of muscle contractions. All three are used in treating injuries in rehabilitation and physical therapy settings.

In **Isotonic contractions** (iso = equal, tonic = tone) the force remains the same but the length of the muscle changes. An example of an isotonic contraction is the classic biceps curl with a barbell. The force exhibited by the barbell does not change. However the length of the bicep muscle can change by shortening during elbow flexion and lengthening during extension. Isotonic exercises are used in many gym settings in which participants use barbells and selectorized weight equipment.

In **Isometric contractions** (iso = equal, metric = length) the force can change but the length of the muscle remains the same. In isometric contractions there is no movement of the joint since the muscle length does not change. An example of an isometric contraction would be to push against an object that cannot be moved such as a wall. The participant can push with a little amount of force or a lot of force (force can change) but there is no movement of the joint. Isometric exercises are used in rehabilitation settings for the strengthening of damaged muscle tissue. They are relatively safe because the damaged area can be omitted during the exercises. For example let's say an athlete injured her shoulder. Upon examination she was able to abduct her arm about 30 degrees before she experienced severe pain. Isometric exercises could then be used up to about 30 degrees of abduction. She would begin with using low amounts of force and then progress to higher amounts of force until the tissue healed.

In **Isokinetic contractions** (iso = equal, kinetic = motion) both the force and length of the muscle can vary but the contraction happens at a fixed speed. Isokinetic exercises are primarily used in rehabilitation settings. Sophisticated machines are used to control the speed of the exercise while allowing varying resistance. However a simple treadmill is a good example of isokinetic exercise. The participant can exercise at a fixed speed with varying degrees of force provided by the different incline angles of the treadmill.

There are 5 different muscle shapes within the human body:

- **Circular**
- **Convergent**
- **Parallel**
- **Pennate**
- **Fusiform**

Circular Muscles

These muscles appear circular in shape and are normally sphincter muscles which surround an opening such as the mouth, surrounded by Obicularis Oris and Obicularis Oculi surrounding the eyes

Convergent Muscles

These are muscles where the origin (the attachment to a fixed bone, usually the proximal attachment) is wider than the point of insertion. This fibre arrangement allows for maximum force production. An example is Pectoralis Major. Convergent muscles are also sometimes known as triangular muscles.

Parallel Muscles

Parallel muscles have fibres which, as the name suggests, run parallel to each other and are sometimes called strap muscles.

They are normally long muscles which cause large movements, are not very strong but have good endurance. Examples include Sartorius and Sternocleidomastoid. Some textbooks include Fusiform muscles in the parallel group.

Pennate Muscles

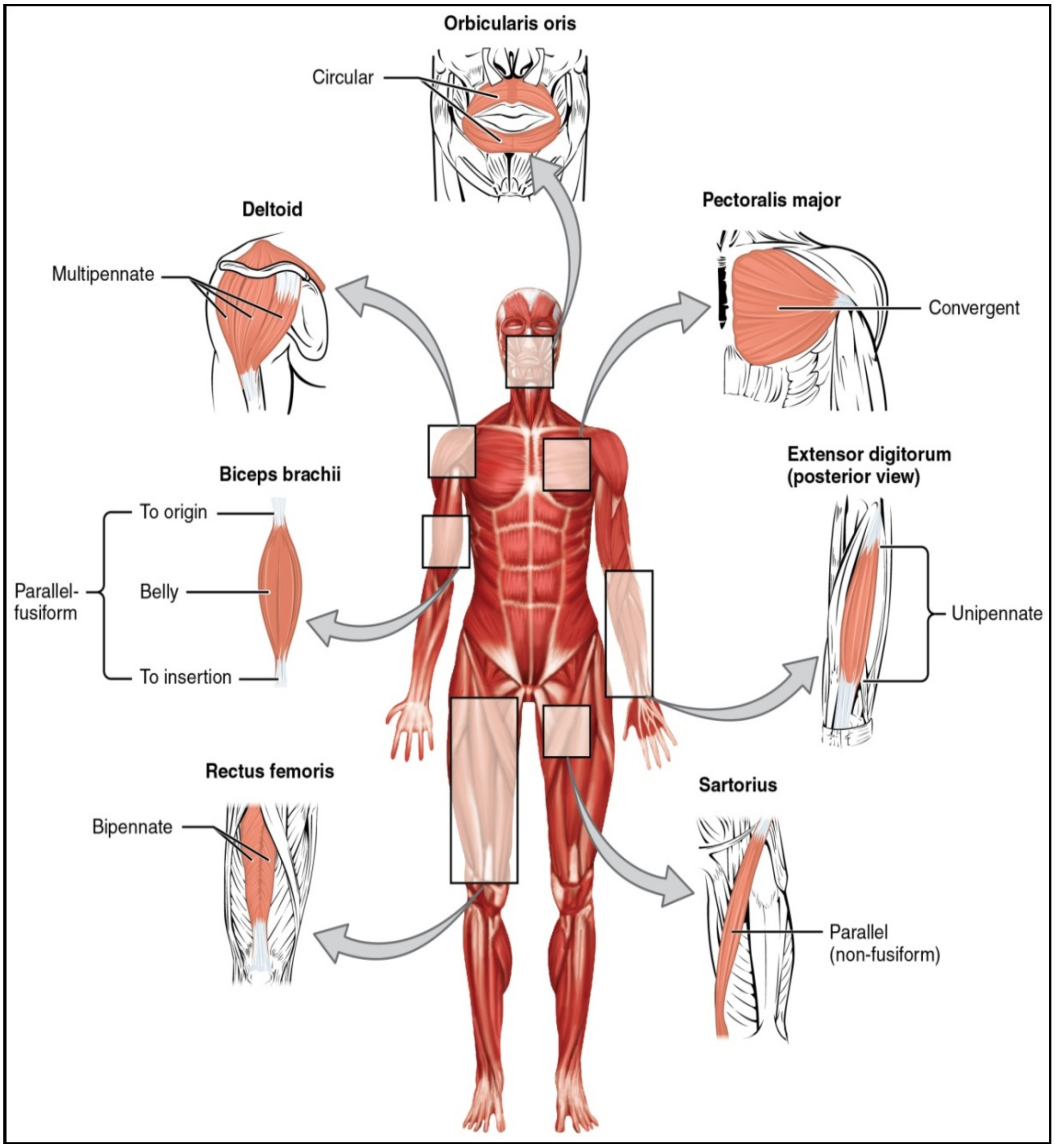
Pennate muscles have a large number of muscle fibres per unit and so are very strong, but tire easily. They can be divided into:

- **Unipennate**: These muscles have their fibres arranged to insert in a diagonal direction onto the tendon, which allows great strength. Examples include the Lumbricals (deep hand muscles) and Extensor Digitorum Longus (wrist and finger extensor)
- **Bipennate**: Bipennate muscles have two rows of muscle fibres, facing in opposite diagonal directions,with a central tendon, like a feather. This allows even greater power but less range of motion. An example is the Rectus Femoris
- **Multipennate:** As the name suggests Multipennate muscles have multiple rows of diagonal fibres, with a central tendon which branches into two or more tendons. An example is the Deltoid muscle which has three sections, anterior, posterior and middle.

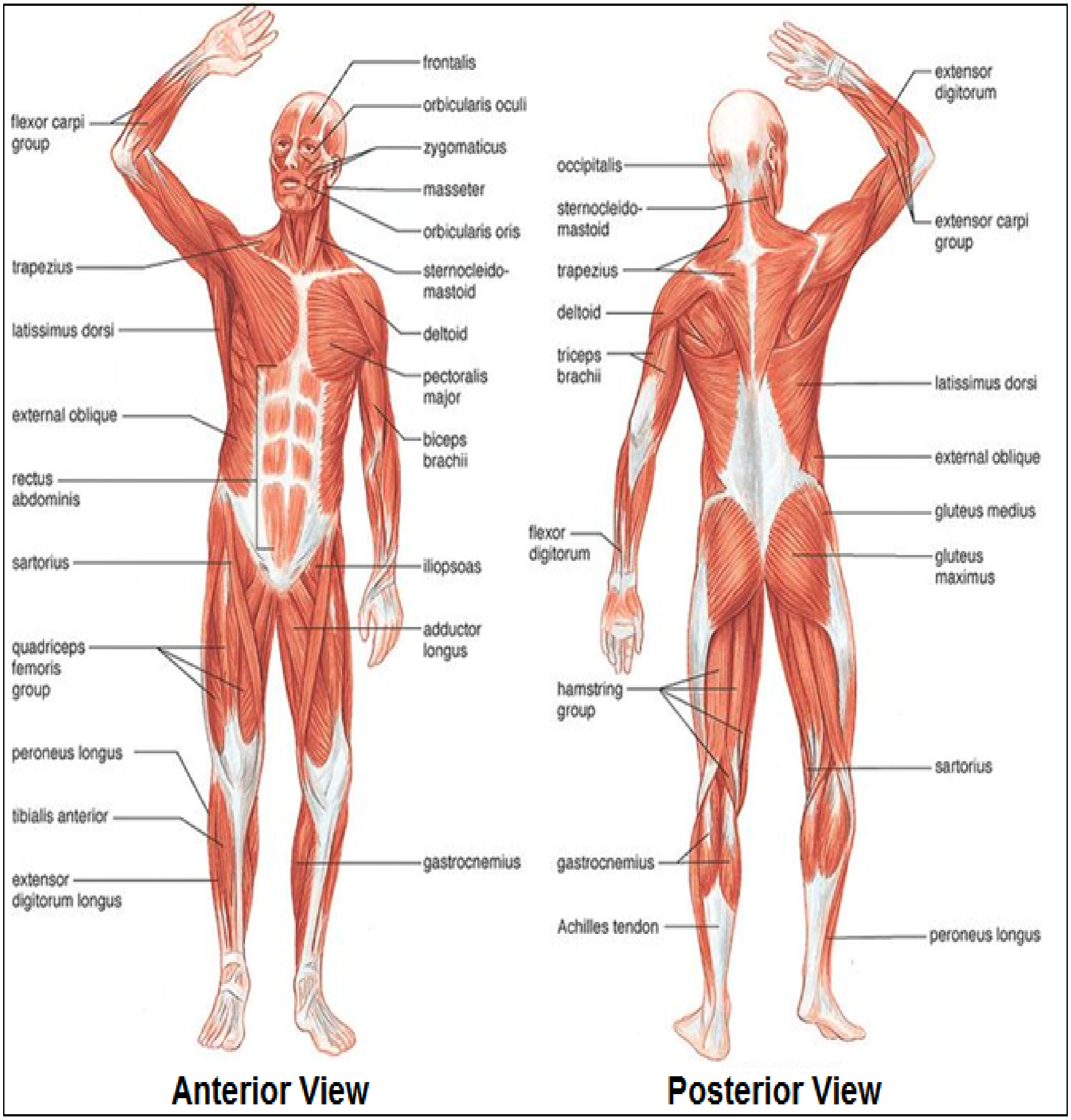
Fusiform Muscles

Sometimes included in the parallel muscle group, these muscles are more spindle shaped, with the muscle belly being wider than the origin and insertion. Examples are Biceps Brachii and Psoas major

SHAPES OF MUSCLES



MUSCLES

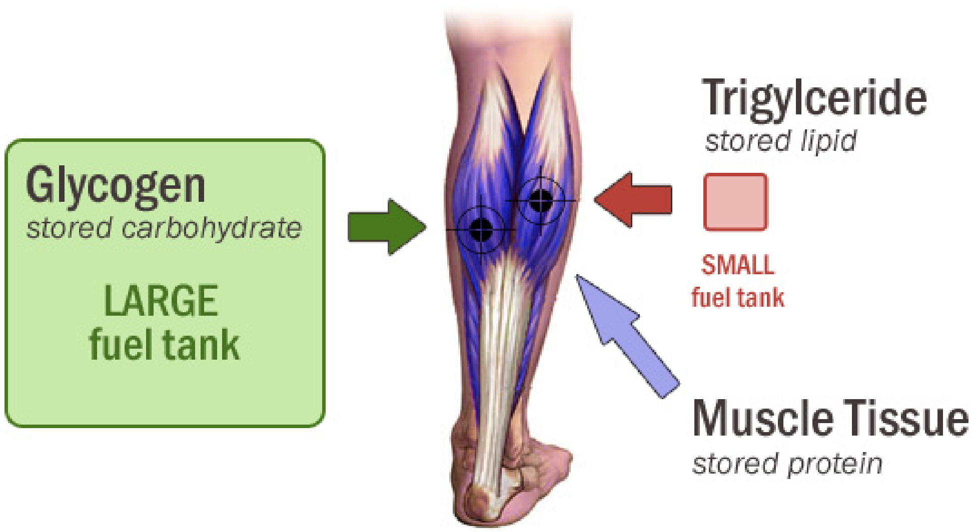

frontalis
orbicularis oculi
zygomaticus
masseter
orbicularis oris
sternocleido-mastoid
deltoid
pectoralis major
biceps brachii
iliopsoas
adductor longus
gastrocnemius
flexor carpi group
trapezius
latissimus dorsi
external oblique
rectus abdominis
sartorius
quadriceps femoris group
peroneus longus
tibialis anterior
extensor digitorum longus
Anterior View
extensor digitorum
occipitalis
sternocleido-mastoid
trapezius
deltoid
triceps brachii
flexor digitorum
hamstring group
gastrocnemius
Achilles tendon
extensor carpi group
latissimus dorsi
external oblique
gluteus medius
gluteus maximus
sartorius
peroneus longus
Posterior View

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.



Our bodies process three things: food, liquid, and oxygen. And while we might enjoy the food and the liquid more, it's the oxygen that actually provides the fuel that runs our body. Oxygen, through a process called oxidation, chemically changes food and liquid into energy. It's this "oxygen fire" that contracts our muscles, repairs our cells, feeds our brains, and even calms our nerves. Not only that, but breathing is our body's chief cleansing tool.

Every day, our body burns off some seven hundred billion old cells. These old cells are toxic and must be removed from our system. This is a normal, natural process of the body and nothing to worry about unless for some reason this toxic waste material is not eliminated at the same rate it's being produced. As long as we're breathing properly and getting plenty of oxygen, there is sufficient energy and the waste is easily eliminated. The problem comes when we don't take in enough oxygen. You see, the body can store up food and liquid, but it can't store oxygen. Every minute that we are alive, we must continually provide our cells with stream of fresh oxygen.

Role of oxygen:

Oxygen (O_2) is one of the most important elements required to sustain life. Without it, our health begins to suffer and/or we die. Unhealthy or weak cells due to improper metabolism lose their natural immunity and are thus susceptible to viruses and lead the way to all kinds of serious health problems.

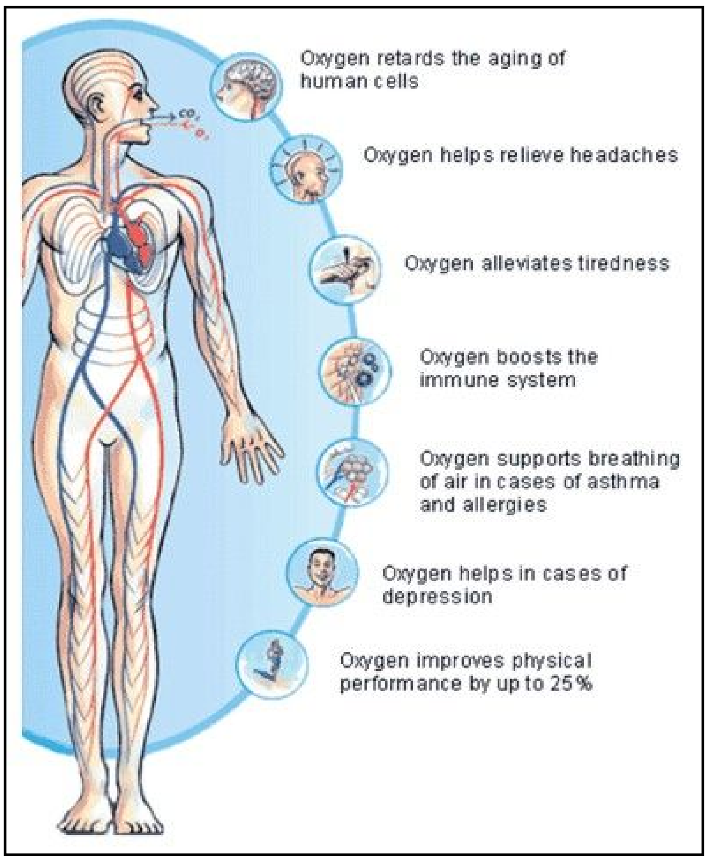
O_2 not only gives us life but destroys also the harmful bacteria in our bodies without affecting the beneficial bacteria that we need. No antibiotic or drug can make that claim. I believe that God's plan for mankind was for us to lead a physically productive life in a clean environment, following His dietary laws and not require drugs to remain healthy...our bodies would then receive the sustenance it needs.

Life styles today, in a modern world environment with depleted O_2 levels in the atmosphere, actually requires our cells to use more of this odourless/colourless gas to deal with several stresses on our body's ability to function.

The major causes of stress are:

- ***Toxic stress***: A constant need for cellular detoxification from chemical exposure.
- ***Emotional stress*** requiring the production of adrenaline and adrenal hormones
- ***Physical trauma*** that reduces circulation and O_2 supply
- ***Infections*** that use up O_2 to combat bacteria, fungi and viruses.
- ***An acidic diet*** producing an excessive number of hydrogen ions in the tissues that combine with and also use up O_2. Acidity also stresses the body to balance itself and become more alkaline by taking calcium from our bones.

ROLE OF OYGEN



Oxygen Debt

During muscular exercise, blood vessels in muscles dilate and blood flow is increased in order to increase the available oxygen supply. Up to a point, the available oxygen is sufficient to meet the energy needs of the body. However, when muscular exertion is very great, oxygen cannot be supplied to muscle fibres fast enough, and the aerobic breakdown of pyruvic acid cannot produce all the ATP required for further muscle contraction.

Lactic Acid

During such periods, additional ATP is generated by anaerobic glycolysis. In the process, most of the pyruvic acid produced is converted to lactic acid. Although about 80% of the lactic acid diffuses from the skeletal muscles and is transported to the liver for conversion back to glucose or glycogen.

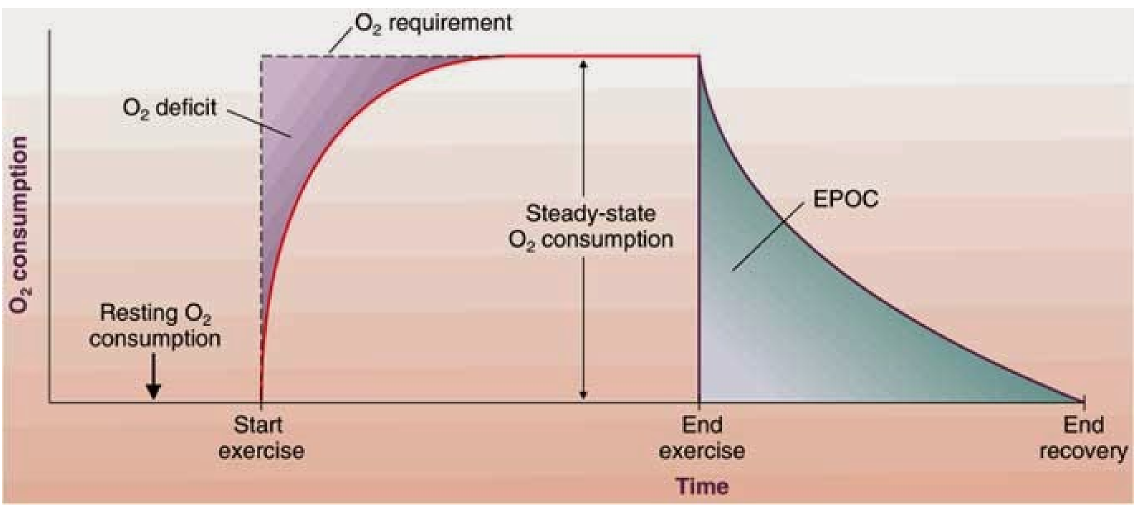
Oxygen

Ultimately, once adequate oxygen is available, lactic acid must be catabolized completely into carbon dioxide and water. After exercise has stopped, extra oxygen is required to metabolize lactic acid; to replenish ATP, phosphocreatine, and glycogen; and to pay back any oxygen that has been borrowed from hemoglobin, myoglobin (an iron-containing substance similar to hemoglobin that is found in muscle fibres), air in the lungs, and body fluids.

The additional oxygen that must be taken into the body after vigorous exercise to restore all systems to their normal states is called **oxygen debt**.

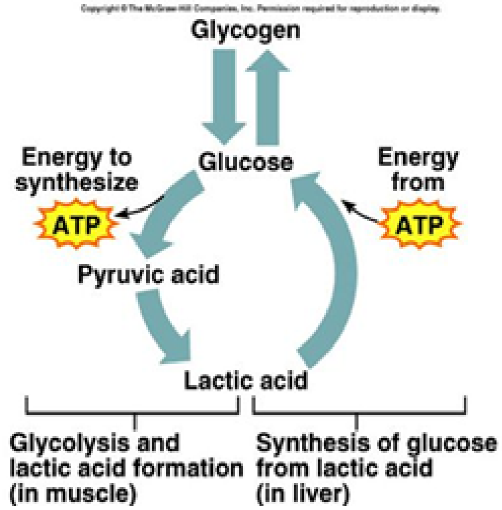
Eventually, muscle glycogen must also be restored. This is accomplished through diet and may take several days, depending on the intensity of exercise. The maximum rate of oxygen consumption during the aerobic catabolism of pyruvic acid is called "maximal oxygen uptake". It is determined by sex (higher in males), age (highest at about age 20) and size (increases with body size).

Highly trained athletes can have maximal oxygen uptakes that are twice that of average people, probably owing to a combination of genetics and training. As a result, they are capable of greater muscular activity without increasing their lactic acid production, and their oxygen debts are less. It is for these reasons that they do not become short of breath as readily as untrained individuals.



Oxygen debt – amount of oxygen needed by liver cells to use the accumulated lactic acid to produce glucose

- oxygen not available
- glycolysis continues
- pyruvic acid converted to lactic acid
- liver converts lactic acid to glucose

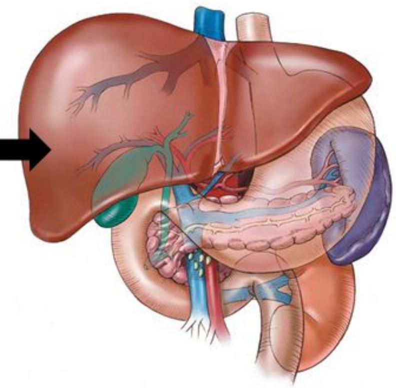


Oxygen Debt

- The **lactic acid** that has built up during anaerobic respiration needs to be **broken down**.

It gets broken down in the **liver**.

The blood carries the lactic acid there.



- Oxygen is required in the breakdown of lactic acid.
- **Heavy breathing** after exercise provides the extra oxygen required to break down lactic acid, and is known as the **oxygen debt.**
- This is followed by **panting** to allow aerobic respiration to resume.

Second wind

Second wind is a phenomenon in distance running, such as marathons or road running (as well as other sports), whereby an athlete who is too out of breath and tired to continue suddenly finds the strength to press on at top performance with less exertion. The feeling may be similar to that of a "**runner's high**", the most obvious difference being that the runner's high occurs after the race is over. Some scientists believe the second wind to be a result of the body finding the proper balance of oxygen to counteract the build-up of lactic acid in the muscles. Others claim second winds are due to endorphin production.

Vital capacity

Vital capacity is the maximum amount of air a person can expel from the lungs after a maximum inhalation. It is equal to the sum of in spiratory reserve volume, tidal volume, and expiratory reserve volume.

A person's vital capacity can be measured by a wet or regular spirometer. In combination with other physiological measurements, the vital capacity can help make a diagnosis of underlying lung disease. Furthermore, the vital capacity is used to determine the severity of respiratory muscle involvement in neuromuscular disease, and can guide treatment decisions in Guillain-Barré syndrome and myasthenia crisis.

UNIT - V

EFFECT OF EXERCISE ON DIFFERENT SYSTEMS OF THE BODY

Acute and chronic exercise programmes develops physiological adaptations ia different systems of the body., due to the stress placed on the system. Acute exercise refers to short duration exercise, such as a cycle ergometer or a treadmill maximal exercise test. Chronic refers to extended or long term exercise, such a physical training programme of four to six months duration.

Effect of Exercise on the Circulatory System

Acute and chronic exercise causes an augmented supply of oxygenated blood to the working tissues and an increased return of deoxygenated blood to the heart and the lungs. Due to chronic exercise, the following adaptive changes in the circulatory system take place:

(i) Stroke Volume

Stroke volume can be defined as the amount of blood that is ejected or pumped out from the left ventricle of the heart in one maximal contraction of the heart. At rest the stroke volume of untrained and trained athletes are about 70 ml and 100 ml, respectively. During maximal exercise the amount of blood pumped out from the heart in one forceful contraction for athletes is about 175 ml, compared to non-athletes who eject about 120 ml of blood. The endurance athletes stroke volume during rest and exercise is considerably larger than untrained individuals of the same age. The greatest increase in stroke volume during exercise occurs in the transition from rest to moderate exercise (upto about 120 beats per minute). As the intensity of exercise increases, there is negligible increase in stroke volume.

(ii) Cardiac Output

Cardiac output is a product of stroke volume and heart rate per minute and is the amount of blood pumped out from the heart in one minute. The resting cardiac output for athletes and non-athletes are approximately equal (about 5 liters per minute). The cardiac output for athletes is higher compared to non-athletes and thus more oxygen and nutrients are supplied to the working tissues every minute. In untrained individuals the cardiac output increases by about four times the resting level to an average maximum of 20 liters. However, well trained athletes achieve a maximum cardiac output of 35 to 40 liters per minute during intense maximal exercise, which is seven to eight fold increase from the normal resting level.

(iii) Blood Pressure

Systolic pressure increases in direct proportion to increase in exercise intensity. The systolic pressure may increase upto and above 200 mm Hg during maximal exercise from a normal resting value of 120 mm Hg. The increase in systolic pressure is due to increase in the cardiac output, with increase in the exercise intensity. Diastolic pressure changes are negligible and even an increase of about 10 mm Hg from the normal resting value of 80 mm Hg is considered to be an abnormal response to exercise. This is used as one of the test criteria in an exercise test to stop the test prematurely.

(iv) Coronary Circulation

Coronary circulation is the circulation within the heart muscles itself. Due to regular exercise the heart muscle receive more blood and there is increased vascularisation in the cardiac muscle for its efficient functioning. At rest the heart muscle utilises about 75 percent of the oxygen from its blood supply. A four to five times increase in cardiac output is accompanied by a similar increase in coronary circulation.

(v) Cardiac Muscles

Due to increased blood supply by the coronary circulation to the heart, the heart muscles get more quantity of oxygen as well as energy. Regular training increases the size and bulk of the cardiac muscles and specifically that of left ventricle. Well trained endurance athletes have a larger left ventricle and hypertrophied muscles compared to untrained individuals. Thus more forceful contraction of the left ventricular heart muscle fibers occurs during each heart beat, resulting in an increased stroke volume.

(vi) Arterial-Venous 0_2 Difference (a-v 0_2 diff)

Chronic exercise supplies more quantity of blood to the working muscle, and as a result more 0_2 is carried by the blood to the muscles. The amount of $C0_2$ and also waste products produced within the muscle is also removed at a faster rate by the blood returning through the veins. The arterial-venous difference (a-v diff) is the amount .of 0_2 extracted from the blood at cellular level, ie., the difference in oxygen content between the arterial and the venous blood. At rest, about 5 ml of 0_2 is utilised from the [1] 20 ml of 0_2 in each 100 ml of arterial blood that passes through the capillaries. During exercise about 15 ml of oxygen is extracted from 100 ml of blood.

(vii) Resting Heart Rate

Chronic exercise, specially aerobic exercise causes the resting heart rate of individuals to decrease below the normal resting heart rate that ranges between 70 to 80 beats per minute. Resting heart rate as low as 38 beats per min was recorded for Bjorn Borg, the five times Wimbledon champion. With decreased heart rate the athletes can eject equal or more amount of blood from the heart than the non-athletes in the same unit of time.

(viii) Heart Rate During Exercise

The relationship between heart rate and oxygen consumption is linear during submaximal exercise. In untrained individuals the heart rate accelerates rapidly as the exercise intensity increases, whereas in trained endurance athletes the heart rate accelerates as a slower pace. As result, a trained athlete would be able to exert his heart and do more work to achieve a higher maximal oxygen uptake when compared to a untrained individual. During a submaximal exercise the trained athletes heart rate will be lower than that of the untrained individuals at a given level of maximal oxygen consumption. For example, at an oxygen consumption of 2.0 liters per minute, the heart rate of athletes is generally lower by 40 to 50 beats per minute, compared to non-athletes.

(ix) Blood Flow

Blood is directed away from areas where they are not essential, to the working muscular tissues that are active during the exercise. At rest, only 15 to 20 percent of the cardiac output is directed to the muscles, whereas in exhaustive exercise, the muscles receive 80 to 85 percent of the cardiac output. This diversion of blood to the working muscular tissues is accomplished by a decrease in blood flow to the kidneys, stomach, liver and intestines. Prolonged exercise causes the internal body temperature to increase above the normal value of 37 degree centigrade. The body temperature is cooled by shifting an increasing amount of blood to the skin for dissipating the heat away from the body core. The heat is lost to the environment as sweat, by conduction and convection. When the sweat evaporates, it reduces the temperature of blood by cooling process.

(x) Availability of Nutrients

The blood is the only source by which carbohydrate (Glucose), Protein and fat can be taken to different parts of the body. Due to regular exercise the utilisation of the energy sources by the working muscles and other tissues is increased. Increased cardiac output and vascularisation of tissues enable the body to supply adequate amount of nutrients to different parts of the body to meet the required energy needs.

Effect of Exercise on the Muscular System

A regular programme of systematic strength training causes a number of anatomical and physiological changes in the muscular system. They are described in detail below:

(i) Muscle Fiber Splitting (Hyperplasia)

It is believed that heavy resistance training actually causes the muscle fibers to split. This is known as Hyperplasia. All individuals are born with a genetic make up of specific number of muscle fibers. Researchers have reported that some muscle fibers from trained animals undergo a process of longitudinal muscle splitting. Body builders who train with heavy weights, develop large limb circumference and muscle mass possibly through muscle fiber splitting. MacDougall (1984) has demonstrated the possibility of hyperplasia occurring in body builders.

(ii) Muscle Size

The muscle fiber size and composition undergo adaptive changes due to strength training. The muscle fibers increase in size because of increased vascularisation of the muscles and they develop the ability to generate more force. Increase in the size of the muscle is known as Hyper- , trophy. However, there is no evidence to suggest that, there is increase in the percentage of the slow to fast twitch muscle fibers. The degree of muscular hypertrophy varies between men and women due to strength training. Despite improvement in strength, increases in muscle girth is less for women.

(iii) Availability of metabolites to the muscle

The amount of nutrients available to the muscles is increased due to increased vascularisation. Increased circulation in the muscles provides more amount of energy yielding substances such as glucose, protein and fats. About four to five grams of glycogen is present in 100 grams of wet muscle. The quantity of glucose present in the muscle can supply immediate energy for muscular work.

(iv) Better Safety Mechanism

The muscle spindles, die Golgi tendon organs are tuned properly for a quick response in order to prevent injuries to the muscle and to give continuous feed back to the brain regarding the length and the tension generated in the muscle.

(v) Muscular Tone

Chronic exercise programme helps to maintain the normal muscular tone, facilitating the muscle to be in a state of readiness at all times.

(vi) Oxygen Supply to the Muscles

In a normal individual at rest the 0_2 supply to one kg of muscle per minute is 3.5 ml of 0_2 which is known as one MET (Metabolic Equivalent). Due to regular exercise the 0_2 supply to resting muscle is increased. During maximal exercise well trained athletes can extract about 60 to 70 ml of oxygen per Kg of muscle, which is almost 20 times the normal resting value.

(vii) Posture

Chronic exercise strengthens the postural muscles, such as soleus, gluteal and back muscles to help to maintain a proper posture. Quick, powerful and graceful movements are developed with improved efficiency in walking, jumping and running.

(viii) Body Coordination

Chronic exercise integrates the nervous system with the muscular system in a proper way which results in well co-ordinated movements of different body parts.

Effect of Exercise on the Respiratory System

The respiratory system does not limit exercise performance, since it is capable of supplying adequate oxygen and in the prompt removal of carbon di oxide. Regular training causes physiological adaptations in the respiratory system. They are as follows:

(i) Efficiency of Gaseous Exchange

Due to exercise the efficiency of the complete respiratory system is improved. The respiratory pathways and the area for exchange of gases are constantly used and increased blood flow is present in these areas. As a result there in an increase in the ability of the lungs to enhance the exchange of gases that takes place between the lungs and the blood. This improves the efficiency of the respiratory system.

(ii) Ventilation-Perfusion Ratio

At rest, about 4.2 liters of air ventilate the alveoli each minute and the quantity of blood that flows through the pulmonary capillaries is about 5.0 liters. The ratio of alveolar ventilation to pulmonary blood flow is known as ventilation-perfusion ratio and is 0.8 (4.2 - 5.0 = 0.8). This means that for each liter of blood that perfuses the lungs, 0.8 liters of ventilation is available to the alveoli of the lungs. During maximal exercise there is a disproportionate increase in alveolar ventilation and the ventilation-perfusion ratio may increase beyond 5.0 to provide adequate supply of air to the blood returning to the lungs.

(iii) Availability of 0_2 and Elimination of CO_2:

Maximal exercise increases the quantity of air that is moved in and out of the lungs by many folds. There is an increase in the tidal volume and in the frequency of breathing per minute. In well conditioned athletes, the minute volume may increase to 150*liters in response to maximal exercise. The amount of 0_2 that will reach the alveoli is greater and its diffusion across the alveoli membrane and to the arterial blood is increased. During acute exercise above 90% of the lung are ventilated compared to only 60% ventilation at rest. Hence the amount of 0_2 available for diffusion in the blood through the alveoli is more and hence the greater purification of blood takes place. The CO, from the venous blood diffuses into the lungs and are exhaled quickly so as to maintain normal acid-base balance.

(iv) Increased Area for Exchange of Gases

Important factors that are necessary for exchange of gases are (a) Increased surface area of the alveoli (b) Increased surface tension around the alveoli and (c) a reduced thickness of the membrane of the alveoli. Regular exercise causes continuous movement of air in and out of the lungs in large volumes and as a result the elasticity and surface tension of alveoli are greatly increased. This helps in faster exchange of 0_2 and CO, across the membranes of the alveoli.

(v) Respiratory Muscles

The amount of 0, consumed by the respiratory muscles at is about one to two percent of the total oxygen consumption of the body. During heavy exercise, with the increased active movement of the respiratory muscles, the oxygen consumption of the ventilatory muscles increases to about eight to ten percent of the total oxygen consumption of the body. This increase in oxygen cost of the respiratory muscles is sufficient to meet the demands of strenuous exercises.

*

(yi) Body Temperature and pH

One of the most important function of respiratory system is to maintain the body Homeostasis (normal body's internal enviromnent). By increasing or decreasing the respiratory rate, the respiratory system is able to maintain the normal body temperature and pH, so that the quantity of $C0_2$ present in the blood is maintained at normal levels. Athletes compared to nonathletes have greater ability to fluctuate above or below normal homeostasis, which is brought back to normal withjn a short span of time by increasing die respiratory frequency (hyperpnea) and expelling the excess CO_2.

(**vii) Ability to function at low 0_2, levels**

Since athletes are used to performing at 0_2, debt, their capacity to continue exercise is far greater than non-athletes. The athletes can also perform exercise anaerobically for a longer time than non-athletes. In hill stations, where the availability of 0_2, is low in the atmosphere, the athletes quickly develop physiological coping mechanisms, such as increase in concentration of hemoglobin and in glycolytic oxidative enzyme.

Effect of Exercise on the Nervous System

Acute and chronic exercise programmes produce physiological adaptations in central and peripheral nervous system. The important physiological changes and adaptations are as follows:

(i) Sympathetic and Parasympathetic Nervous System

The functions of the sympathetic and the parasympathetic nervous systems are typically opposite to each other. During exercise, the sympathetic nervous stimulation increases the heart rate thereby increasing the cardiac output. It causes the dilation of the coronary blood vessels, thereby increasing the blood supply to the heart muscles. This enables the heart to get necessary nutrients and remove waste products at a faster rate. Sympathetic stimulation increases the blood pressure to allow sufficient blood to return to tire heart in order to continue to maintain the increasing demand for blood in the working muscular tissues. The parasympathetic nervous system plays an opposing role to that of the sympathetic nervous system in controlling the systemic blood vessels.'

(ii) Recruitment of Motor Units

Acpte and chronic exercise enhances the excitability of the alpha motor neurons, which increases the recruitment of more number of motor units,and produces powerful muscular contractions. Neuromuscular activity is graded on the basis of a fixed order of recruitment of motor units. When more force is needed to perform a certain movement, more number of motor units are recruited.

(iii) Glycogen Supply

There is an increase in the blood supply to the brain as a result of acute and chronic exercise. The brain utilises glucose as the only source of energy. The brain functions efficiently with an augmented supply of glucose.

(iv) Screening and Facilitation Process

The regular exercise sends constant information to the spinal cord and brain from the sensory receptors, and when corrective action is required, signals to initiate movement are transmitted to the motor organs through efferent neurons. As a result of the screening process the movement patterns in the brain are memorised. Hence, smooth, co-ordinated and skillful execution of simple as well as complex motor movements can be performed.

(v) Decision Making Process

The decision making process in our nervous system involves in gathering of information from the sensory nerves, transmission of information to the higher centers of the brain and giving command through the motor nerves for end organs to perform the necessary function. This decision making process is greatly improved as a result of regular exercise due to constant screening and facilitation process.

(vi) Pain tolerance

The athletes are able to withstand greater pain compared to nonathletes, since their pain threshold is higher. The pain substances that accumulate at the spot of the injury are responsible for creating pain sensations. However, athletes can ignore the pain sensations upto and even beyond the pain threshold point.

(vi) Safety Mechanism

The muscle spindles are sensor}- receptors present in the muscles, which provide continuous information to the brain and the spinal cord regarding, the status of the lengthening of the muscle and its tension. The golgi tendon organs are also sensory receptors through which the muscle tendons pass, before their attachment to the muscle fibers. The golgi tendon organs are sensitive to increasing tension and when stimulated, they inhibit the agonist or the contracting muscles and excite the antagonist or the opposite group of muscles, thus reducing the strength of contraction. The muscle spindles and the golgi tendon organs act to integrate the sensory and motor information and play an important role in preventing damage to the muscle.

Basic Concept of balanced diet

A balanced diet is one that gives your body the nutrients it needs to function correctly. In order to get the proper nutrition from your diet, you should obtain the majority of your daily calories . 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.

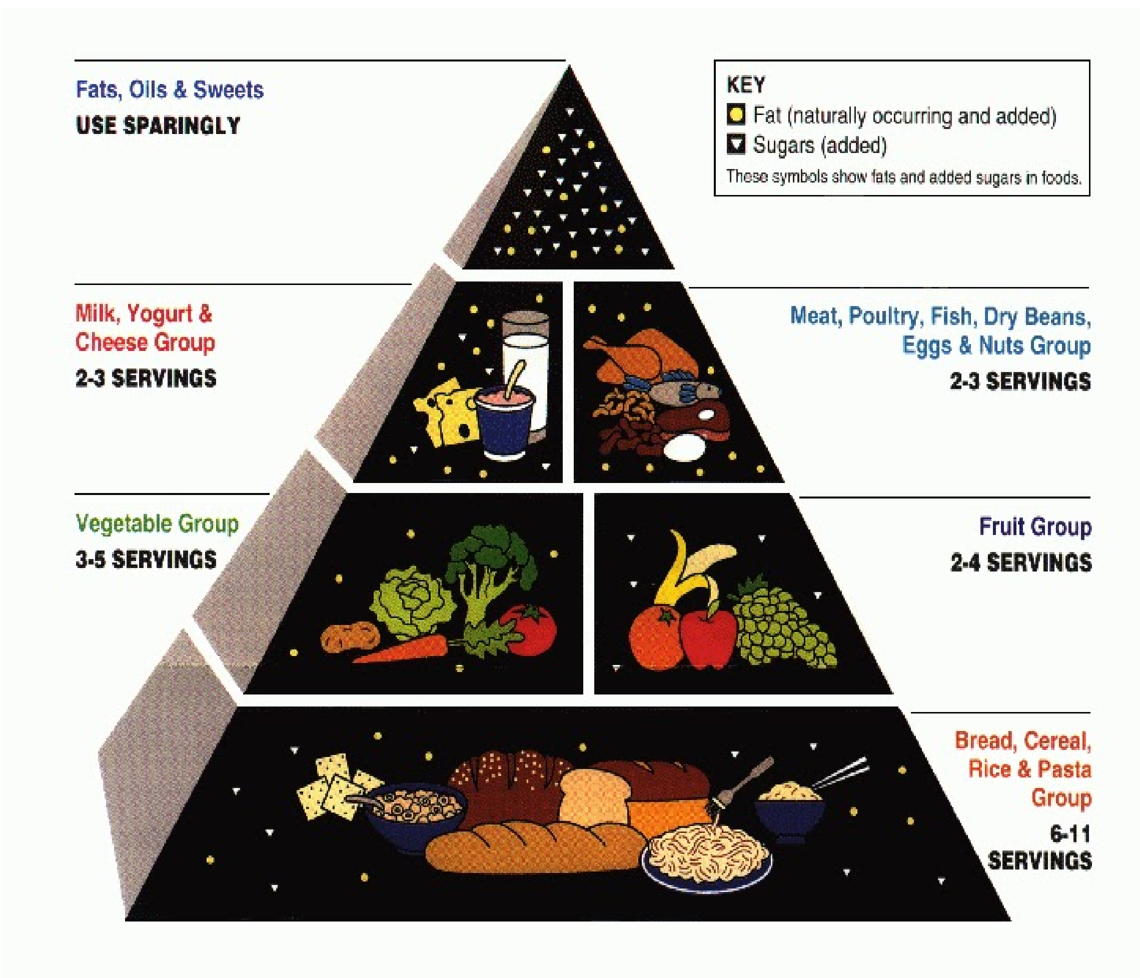
Calories

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.

A balance diet is one which contains the correct proportions of all the different food requirement of the body. A balanced diet should supply enough energy for each day activities.

A balance diet consist of the following food requirement.

1. Carbohydrates and lipids to provide energy for all the activities in the body.
2. Protein to build new tissues for growth and repair damaged tissues.
3. Vitamins to prevent diseases and for normal healthy development.
4. Mineral salts which are essential for normal healthy growth and development.
5. Fibres as roughage to stimulate peristalsis and prevent constipation.
6. Water which is needed as medium for all chemical reactions in the cells. It helps to transport substances that are needed by the cells and remove metabolic wastes. It also help to distribute and regulated body heat



Before digging into the fascinating topic of workout nutrition, let's get something straight. Food quality and food amount make the biggest impact on an athlete's body composition and performance. With that said, workout nutrition can give athletes a real competitive advantage when it comes to recovery from workouts and overall performance during competition.

The Before, During, and After of Workout Nutrition

Putting this information to use, here are some ideas for creating the perfect "peri-workout" period.

Before training/competition

Consuming a balanced meal containing carbohydrates, proteins, and fats – about 1-2 hours before training/competition – is what you're after. You certainly don't have to load up on a huge meal. In fact, that could be counterproductive. Rather, the idea here is to find meals that don't cause stomach distress, meals that make the athlete feel energetic, and meals that help maintain blood sugar.

A good example of a larger pre-workout meal would be 4 oz of lean meat, 8 oz of sweet potato, and 2 cups of veggies with olive oil dressing. If this seems like too much, a piece of fruit, a couple pieces of string cheese, and ½ cup of mixed nuts can work too.

During training/competition

What an athlete eats/drinks during competition is dependent upon length of the workout and athlete's preference. In general, we recommend a sport drink containing 30 grams of carbohydrate and 15 grams of protein (in 500 ml water) per hour of exercise. With multiple events back to back, a larger amount of this beverage should be consumed throughout the day, along with food meals interspersed between events.

This drink can be a "homemade blend" or a pre-formulated drink that contains rapidly digesting carbohydrates (e.g., maltodextrin, dextrose, glucose, etc) and proteins (e.g., protein hydrolysates or isolates).

After training/competition

Post-workout nutrition requires two things: protein to aid in protein synthesis, carbohydrate to replace muscle glycogen. A whole food meal that meets these requirements is ideal. However, whole food meals aren't always practical. Some athletes aren't hungry, some athletes might not have access to whole food, and some athletes might not want to wait for those nutrients to digest and get to cells.

That's why most of our athletes generally default to consuming a liquid form of nutrition that contains rapidly digesting carbohydrates and proteins that accelerates recovery, digests quickly, and is usually well tolerated. We generally prefer drinks (like those discussed above) to be ingested at a 2 carbohydrate: 1 protein ratio. Now, if food is an option, then choosing some of the following options within an hour or two of the training session or event would get the recovery process rolling.