The body tissues

Our body is an incredible machine composed by a number of tissues and systems with different functions working together, that allow us to be born, grow, reproduce and stay alive.

The body tissues are:

Epithelium tissue: skin, mucous membranes.
Gives protection and insulation. Epithelia lines all internal surfaces such as the digestive system, lungs and inside of blood vessels.

Connective tissue: bones, cartilage, tendons, membranes, blood.
In general everything that gives the body form, binds it together or protects it from mechanical damage. Blood is pheraps the most unusual connective tissue, as it exists in a liquid state and contains neither ground substance or fibre.
Transport of nutrients, hormones, oxygen, CO2 etc.
It is a major influence in certain sport performances. Anaerobic activities are highly dependent upon the ability of the blood to carry oxygen to the working tissues, remove waste products, supply adequate energy and maintain fluid levels.

Adipose tissue: fat
Apart from storing energy it also acts as shock absorber. It is wrapped around all the delicate organs of the body.

Muscle tissue: muscles
The tissue of movement. It has the ability to contract and provide force

Nerve tissue: neurons
The tissue of communication through transmission of electric impulse. Skill training is mainly about improving communications within our nervous system resulting in co-ordinated actions.

The different tissues make up the organs, which are grouped into systems with well-defined functions:

Nutritional system: **digestive, respiratory, cardiovascular**

Excretory system: **urinary**

Defensive system: **immune / lymphatic**

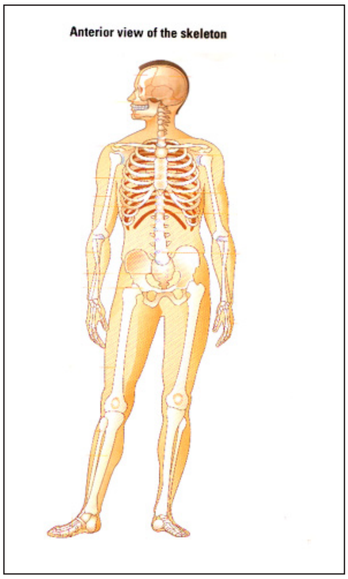
Supportive system: **muscular, skeletal (musculoskeletal), integumentary**

Regulatory system: **endocrine**

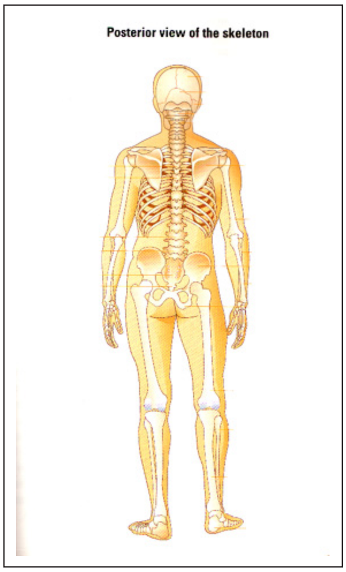
Reproductive system: **reproductive organs**

Coordination and control system: **nervous**

The skeletal system: Bones, cartilage, tendons and ligaments



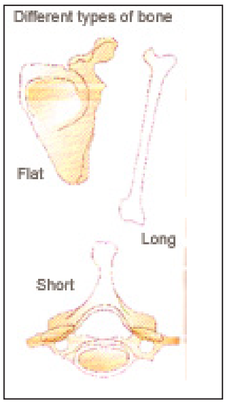
The main functions of the skeleton are to support , give shape and create the body's framework, allow movement through the joints, protect the internal organs, store minerals and produce red and white blood cells in the marrow cavity.



The bones

There are 206 bones in the body, distributed in the central area or **axial skeleton** (cranium, spinal column, sternum and ribs) and in the peripheral area or **appendicular skeleton** (bones of the limbs, scapulae, clavicles and pelvis).

Bones may be divided in three different shape types: **flat** like the scapula, **long** like the femour or **short** like the vertebrae.



A long bone consists in a diaphasys with an **ephisys** at each end which helps to form the joint. Between them lie the **apiphyseal** plates where growth in length occurs. During childwood, these areas are made of cartilage; with maturity, the cartilage is replaced by bone. There are two types of bone tissue:

- **Compact bone** in the shaft and around the edges of the epiphysis. This is made of dense tubular construction, which combines great strength and rigidity with lightness.
- **Cancellous tissue** in the epiphyses. This is spongy bone tissue designed to cope with compression forces resulting from weight bearing or muscle compression, In the spaces, red bone marrow can be found.

The whole of the bone is covered by a though skin called the **periosteum**. This has a rich supply of nerves and blood vessels and is vitally important in the growth, repair and remodelling of the bone.

Ossification is the replacement of cartilage by bone

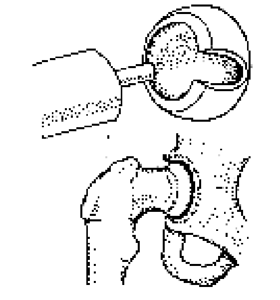
Osteoporosys is bone loss which occurs with aging.

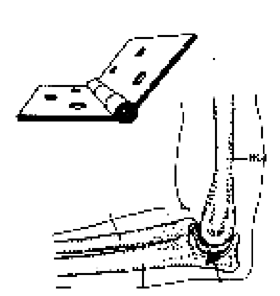
Cartilage is the pre-bone formation. Forms a cover at the end of the bones
Tendons attach muscles to the bones. Fibrous ends of skeletal muscles
Ligaments attach bone to bone. Bind bones together to stabilise joints.

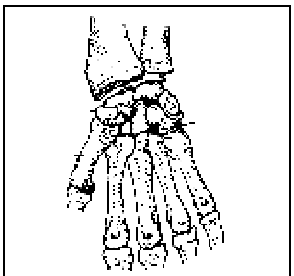
Joints of the body

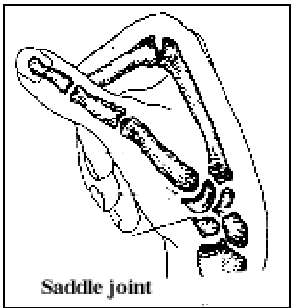
There are three types of joints:
- Fixed (i.e. skull)
- Slightly movable (i.e. vertebrae)
- Freely movable (i.e. shoulder)

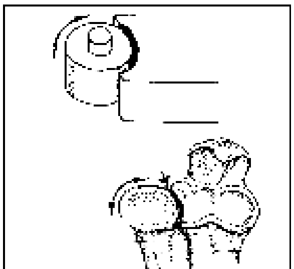
The majority of joint in the body are freely movable. These are known as **synovial joints** and can be classified according to the way they move:

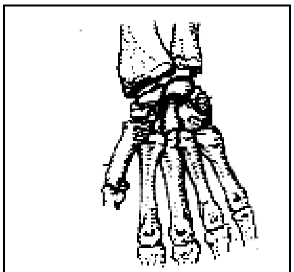

Ball and socket joint


Hinge joint


Gliding joint


Saddle joint


Pivot joint


Condyloid joint

1. Ball and socket
These give the widest range of movement; extension, flexion, rotation, abduction and adduction
- hip
- shoulder

2. Hinge
These allow movement in one direction only: extension, flexion
- elbow
- ankle

3. Gliding
These are joints where movement is limited to small gliding movements
- joints with carpus
- joints with tarsus

4. Saddle
This give movement in two directions: extension, flexion, adduction, abduction
- base of thumb

5. Pivot
This is not a very common joint: supination and pronation
- elbow joint
- 1st and 2nd vertebrae joint

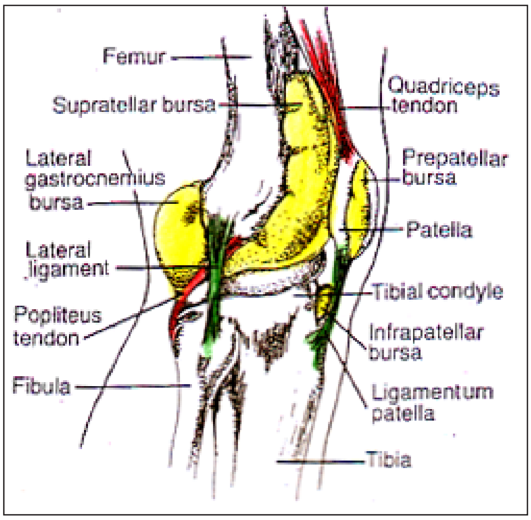
6. Condyloid
These allow movement in two directions because one surface is concave, the other is convex: flexion, extension, adduction, abduction
- Wrist between ulna and radius and carpal bones

Freely movable joints have a thin membrane found on the extremities of the bones that secretes **synovial fluid** which allows friction-free movement. If the joint is cold the synovial fluid is pumped into the cartilage as movement begins improving the cushioning between the bones. As the synovial fluid warms up it becomes less sticky and helps the mobility of the joint.

The knee

The knee is the most complex synovial joint in the body.
It is also the most vulnerable to injuries in sport.
It has little stability because of the shape of the bones and relies heavily upon the other structures for support.

As all the typical synovial joints the knee consist of the following elements:



Articular cartilage: a special type of cartilage that covers the end of the bones involved in articulation and helps the joint to move without causing too much friction.

Synovial membrane: Secretes synovial fluid, which performs the important role of lubricating the joint.

Synovial capsule: located outside the synovial membrane. It consists of a small sleeve of connective tissue, which holds the bones of the joint together

The ligaments: Strips of very strong connective tissue which are inserted into the bones of the joint. They are located outside the joint capsule and give stability to the joint, but are prone to damage. They take a long time to heal because they have poor supply of blood vessels.

In addition, to improve stability, the knee has elements like the **meniscuses** which are small cushions of connective tissue situated between the articular cartilage.

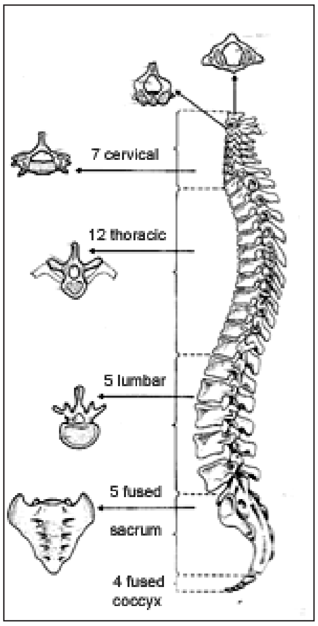
It also has **lateral ligaments** passing on both sides of the joint capsule to strengthen it and two **cruciate ligaments** which bind the femour and tibia together inside the joint capsule.

The muscles crossing the joint provide the most stabilising influence, particularly in sporting situations. Injury risk can be minimised and a damaged joint protected by a programme of training.

The muscles involved in knee stability and movement are the quadriceps and hamstrings: sartorius, rectus femoris, vastas lateralis, vasta medialis and semitendinosis, semimembranosus, bicep femoris.

The spine

The spine is composed of 26 vertebraes: 7 cervical,12 thoracic and 5 lumbar, 1 sacrum (5 fused vertebrae) and 1 coccyx (4 fused vertebrae).

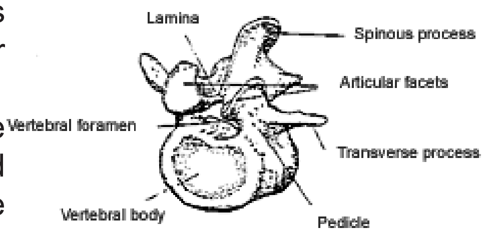


The vertebrae joints are slightly movable. The flexibility of the vertebral column comes about because of the combination of these very small movements in all 26 joints. In these slightly movable joints stability is more important than mobility.

The pivot joint between the atlas and axis (the two first cervical vertebrae) permits the head to turn to the side.

Spinal movements include:
- flexion: mostly in the cervical , little in the lumbar and minimal in the thoracic.
- extension: free in cervical and lumbar, limited in thoracic.
- lateral flexion: good in all regions but most marked in cervical and lumbar
- rotation: good in cervical and upper thoracic, minimal in lumbar

On the sides of each vertebra is a bony projection called **transverse processes**. These together form the spinous process which projects backwards and serves as point of attachment for ligaments and muscles.
The cervical vertebrae provide attachment for the neck muscles, the thoracic for the back muscles and have sideways projections for connections with the ribs. They also have a long pointed neural spine. The lumbar vertebrae are larger than the others and have broad projections for the attachment of back muscles.
The sacrum is fused to the pelvic girdle and supports the weight of the body organs above it.
The articular facets are adapted to allow movement with the neighbour vertebrae.



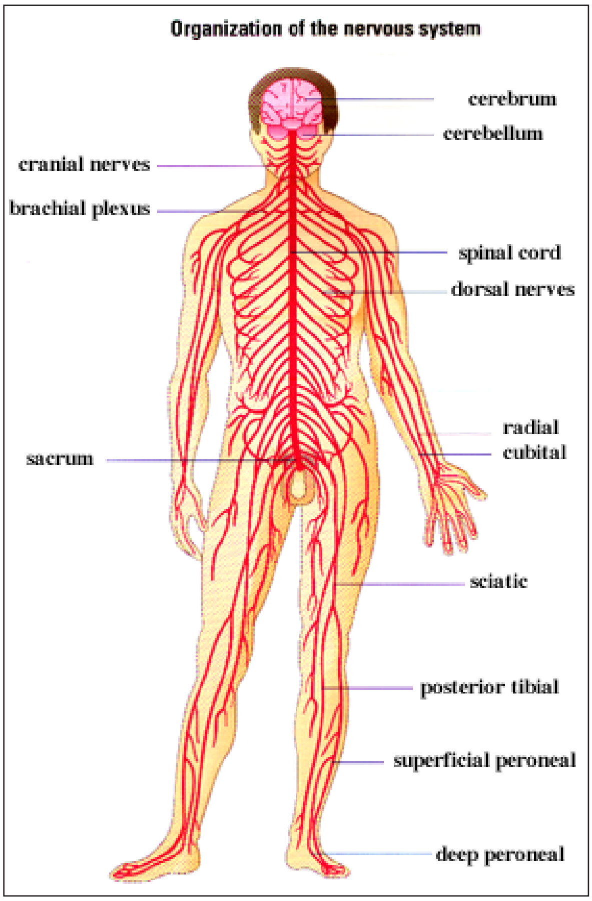
A typical vertebra

The vertebrae are joined by **intervertebral discs** which are composed mainly of fibrocartilage, with a jelly-like pulp in the centre. The discs are firmly attached to the vertebral bodies and act as shock-absorbers, preventing jarring of the brain and spinal cord during vigorous movements. In the central body and the neural arch encloses the vertebral foramen, in which lies the spinal cord.

Ligaments secure the bones together and encapsulate the facet joints: anterior longitudinal ligament, along the frontal body, posterior longitudinal ligament along the posterior body in the vertebral foramen, the ligamentum flavium posteriorly to the vertebral foramen, the infraspinosus ligament along the spinous process and the supra-spinous ligament, posterior to the infraspinous ligament. There is also the ligament nuchae posteriorly to the cervical vertebrae.

The nervous system

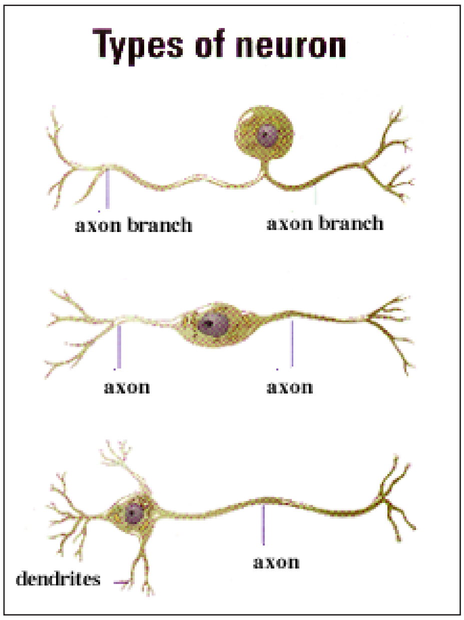
The nervous system is the most important control system in the human body. The other system involved in organ control is the endocrine system, but whereas this uses hormones as messagers, the nervous system uses electrical impulses which travel a great deal faster.
The nervous system consists of the central nervous system and periferal nervous system.



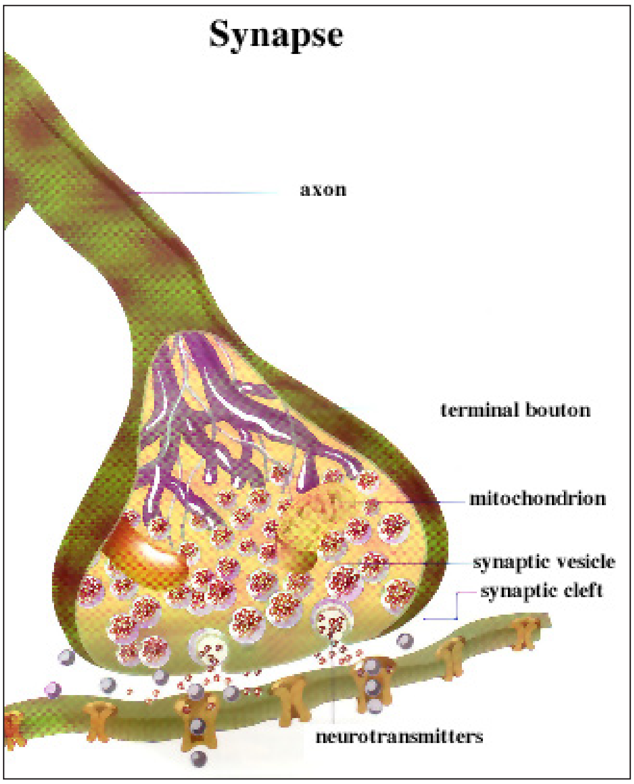
The **central nervous system** consists of the brain and the spinal cord. It is in the brain that cognitive and emotional sense are found. It is also responsible for producing sensations and controlling movement.

The **periferal nervous system** consists of all the nervous tissue outside the central nervous system: the periferal nerves that innervate muscles and the organs.

Nervous tissue consists of an intricate, interconnected network of specialised cells called neurons. Although neurons vary in form and size they all share the same basic structure, consisting of a cell body, an axon, extension from the cell body of variable length ending in a cluster of small protuberances or **dendrites** that make contact with other neurons.



The



dendrites at the tips of the axons establish communication with other neurons through **synapses**. There is no contact between cells at a synapse; the neurons are separated by a **synaptic cleft**, across which stimuli are transmitted via chemicals called neurotransmitters.
The **peripheral nervous system** can also be divided into two parts:

- somatic nervous system (SNS)
- autonomic nervous system (ANS)

The somatic nervous system is concerned with voluntary functions as walking, talking. It is particularly responsible for the innervation of skeletal muscle.

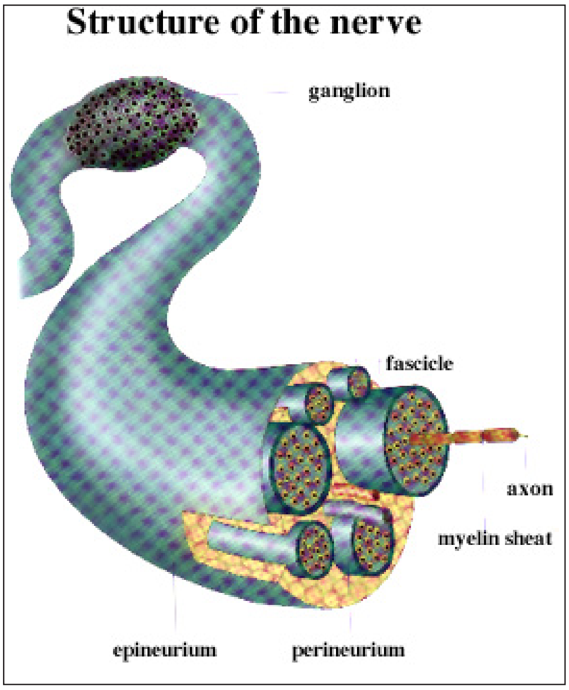
The autonomic nervous system is concerned with functions which are generally not under conscious control eg. heartbeat, digestion, pupillary constriction and dilation, glandular secretion.

The autonomic nervous system is further subdivided in sympathetic and parasympathetic:

- sympatethic division is mostly concerned with responses to external environment
- parasympatethic division is mostly concerned with vegetative functions.

The nerves

The nerves are the element responsible for conveying nerve stimuli in the periferal nervous system. They form bundles and some are long, extending from the spinal cord to the tip of a finger or a toe.



Nerves are structures of different thickness and length. The cell bodies of the neuronal axons that form the nerve are situated in the central nervous system or in the collections of the cell bodies (ganglia) that lie next to the spinal cord.
Each nerve is formed by one or more bundles of nerve fibers. Each individual nerve fiber is the axon of a neuron which is covered by the cytoplasm of a supporting cell known as Schwann cell. Several layers of Shwann cells form a sheat of myelin which also increases the speed the nerve impulses.
Each bundle of nerve fibers is surrounded by a layer of connective tissue called the **perineurium**; if the nerve contains many bundles, these are surrounded by another layer known as the **epineurium**.

Muscles physiology


The muscles: posterior view

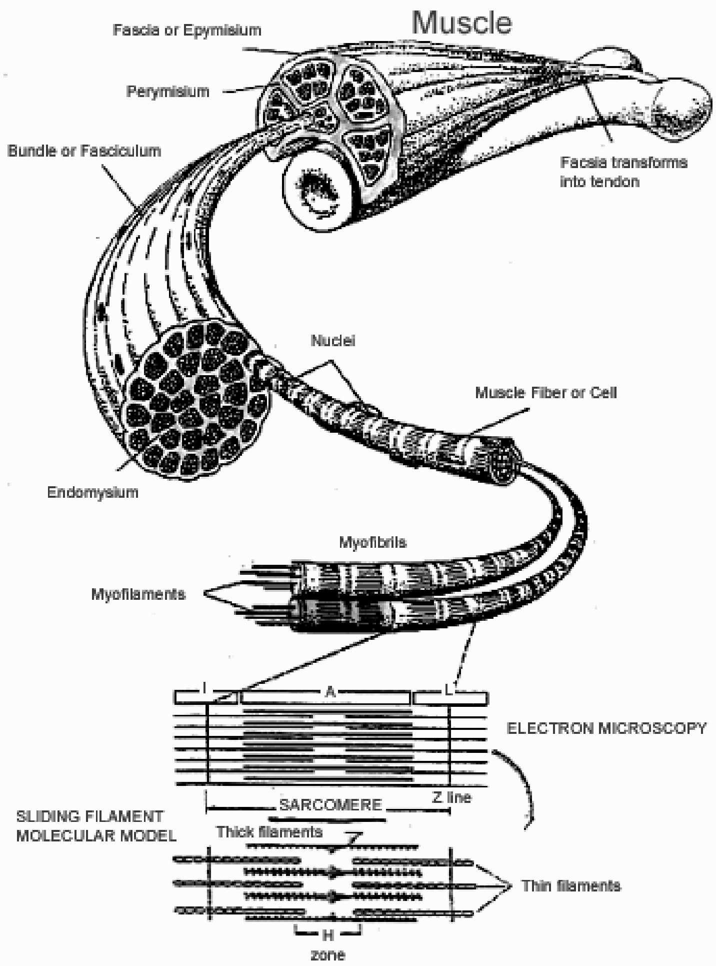
There are three types of muscles found in the body:
- **Skeletal** or voluntary muscle, concerned with movement. They are attached to the skeleton and are controlled consciously.
- **Cardiac** muscle found only in the heart. Contracts and relaxes continuously to provide pumping action. It is an involuntary muscle
- **Smooth** muscle found in the digestive tract, circulatory system and respiratory system. They are involuntary muscles.

Voluntary muscles are controlled by the peripheral nervous system.
Involuntary muscles are controlled by the autonomic nervous system.

Skeletal muscles


The muscles: anterior view

The muscles lie beneath the skin and are in close relationship with the skeleton. There are more than 600 muscles in the human body and their role is to provide movement via their insertion at key points in the bones. At these points muscle tendons connect the muscles and the bones.



Skeletal muscle structure

Muscles consist of 30% protein and 70% salt solution (water).
Muscle also contains:
- connective tissue to bind it together
- nerves so that messages can be sent from the brain and the spinal cord
- blood vessels to bring oxygen, remove waste products, supply energy and maintain fluid levels.

The structure of the muscle is made up from individual **muscle fibres** (muscle cells). The muscle fibres are the largest cells in the body; each one is wrapped in a sheath of connective tissue. Fibers are grouped together in bundles by connective tissue, and the whole thing is wrapped up in more connective tissue.
When a muscle fibre is examined in more detail it is possible to see how it is able to shorten and produce tension to move the bones.When the muscle contracts, actin filaments are pulled

along the myosin, shortening the sarcomere, which is the distance between the linked ends of the actin strands (the Z lines).
The regular pattern of sarcomeres is repeated along the full length of the muscle fibre so that combined effect of all shortening is considerable.

Fibre types

The major classification scheme for muscle fibres is based on how fast they produce a twitch contraction in response to an electrical stimulus.
There are slow twitch (type I) and fast twitch (type IIa and IIb) fibers. Slow twitch fibers tend to be smaller and produce less overall force than fast twitch fibers. But slow fibers are more energy-efficient and thus well adapted for prolonged exercise, when energy supply might be a limiting factor. Thus, when compared to slow twitch fibers, fast twitch fibers are easily fatigable.

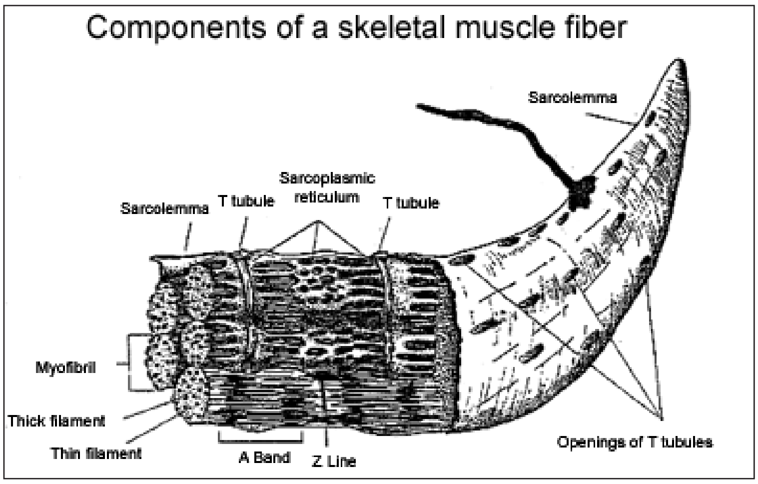
There is a large variability proportion of slow to fast twitch fibers in a given muscle among different groups of subject, depending on their physical activities.
The difference in speed contraction is largely based on the fact that they have different degrees of myosin ATPase activity. Slow fibers also appear to have a very poorly developed sarcoplasmic reticulum which is important for the quick release of calcium to trigger contraction. Muscle fibers can also be distinguished by different metabolic properties.
Slow twitch fibers have greater capacity to produce energy for long periods because they have more mitochondria with the enzymes necessary to break down fats and carbohydrate completely to carbon dioxide and water. Since this breakdown requires oxygen, they have more capillaries supplying blood. Slow twitch fibers, however, are more handicapped when it comes to produce energy rapidly for very intense contractions because they have little stored carbohydrate (glycogen) and little capacity to break the carbohydrate down to lactic acid for energy.
Fast twitch fibers IIa can produce energy both by complete oxidation and also by breaking carbohydrate down to lactic acid.
Type IIb fibers have few mitochondria and a large capacity to break down carbohydrate in absence of oxygen. Both IIa and IIb fibers have large stores of glycogen for quick energy.

Energy systems

Energy for muscle contraction comes from the breakdown of a chemical component named adenosine triphosphate (ATP). The breakdown of ATP releases energy which stimulates the rowing motion of the myosin cross bridges.
Sources of ATP are protein, carbohydrates and fats.
There are three different chemical systems that produce ATP:

- **aerobic**: using glucose, triglicerides and fatty acids and oxygen, produces ATP and wastes ($CO2$ + water). The chemical reaction producing this aerobic ATP occurs in the mitochondria, in the muscle fibers and later transported to the myosin cross bridges. This system provides energy for muscle contraction for low-intensity tasks lasting five min or more.
It does not produce toxic waste.
- **anaerobic glycolysis** (lactic acid system): stored glycogen is converted to

glucose, then converted by enzymes into lactic acid, giving ATP. This system provides energy for high intensity tasks of 30 sec to 2 min duration.
Lactic acid is toxic in large amounts and therefore produces fatigue.



- **ATP-CP system**: ATP stored at the myosin cross bridges is broken down to release energy for contraction. The ADP and the phosphate are then converted back to ATP by the creatine phosphate (CP). This system provides energy for tasks of about 0-10 sec duration.

The ATP breakdown is triggered by the arrival of the electrical impulse, called **action potential**, at the sarcolemma from the motor neuron, where it spreads rapidly. The action potential is transmitted down the
T-tubules toward the interior of the fibers which causes calcium to be released from the sarcoplasmic reticulum. Calcium ions then bind with troponin molecules and pulls tropomyosin away from the sites on actin.
This allows the myosin heads, activated by ATP, to form cross-bridges with actin, and spilt ATP into ADP plus phosphate with simultaneous release of chemical energy to cause the myosin heads to swivel, the z-line moves closer together and H-zone disappears, creating muscle contraction.
This enzyme action of myosin to split ATP is called myosin ATPase activity.
The amount of ATPase activity in a muscle seems to determine its speed of contraction.

Nerve cells are connected to muscle cells (or muscle fibres) to form a **motor unit.** One nerve cell will be connected to more than one muscle cell; the number depending upon the function of the muscle. If fine control is required, one nerve cell will connect with only a few muscle fibres.This happens in the muscle of the eyes, where a high level of accuracy is important. In gross body movement, one nerve cell will connect with numerous muscle fibres, for less accurate nervous control is required. This is the case with the muscles responsible for maintaining the posture.

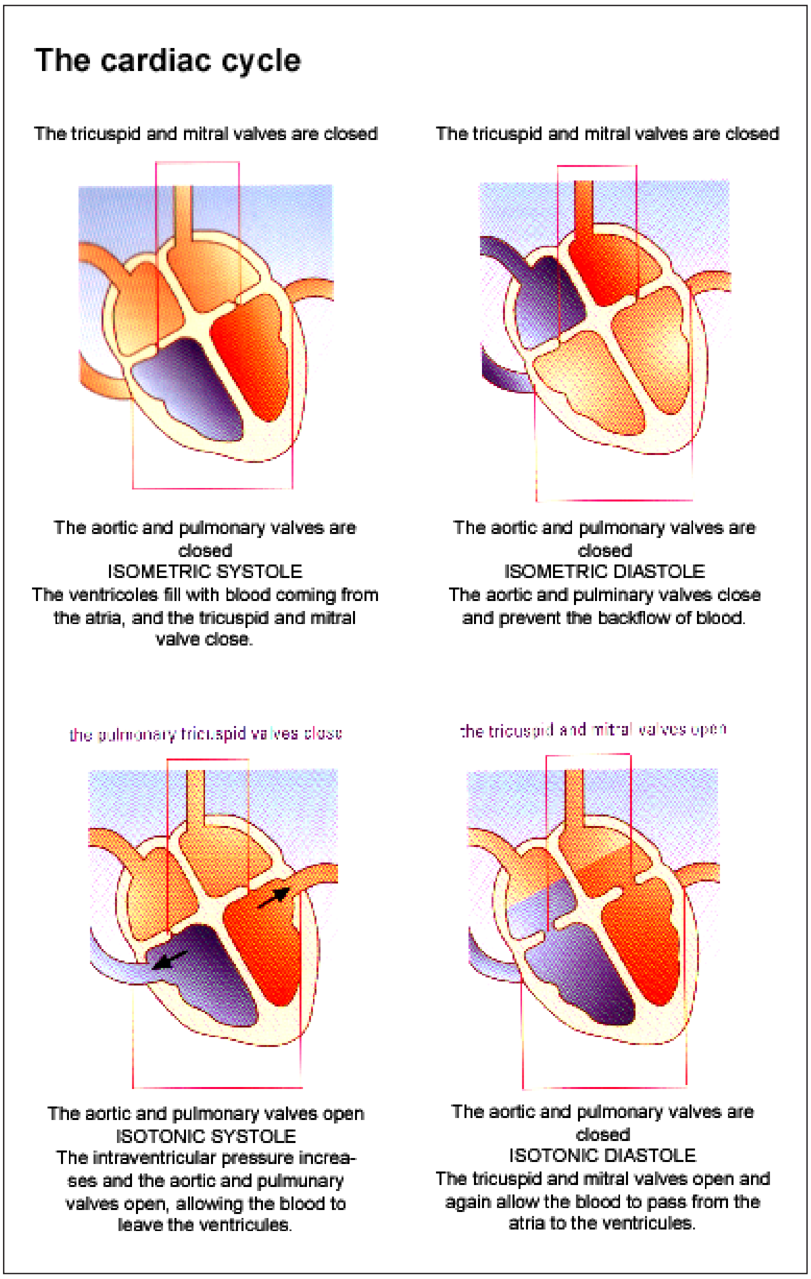
All or nothing law:

The “all-or-none” law of muscle physiology applies to the muscle cell, not to the whole muscle.
It states that a muscle cell will contract to its fullest extent when it is stimulated adequately; it never partially contracts. However, skeletal muscles are organs that consist of thousands of muscle cells, and they react to stimuli with graded responses, or different degrees of shortening.

The cardiovascular system

The cardiovascular system carries the blood throughout the body. Central to the functioning of the system is the heart, which acts as a pump to propel the blood around the arterial system, and draws it back again through the venous system.
The walls of the heart have three layers: endocardium (internal membrane), myocardium (muscular tissue) and pericardium (external membrane). The movements of the myocardium are entirely automatic and involuntary.

Inside the heart there are four chambers: two atria in the upper part, and two ventricles in the lower part. The right chambers communicate through the tricusoid valve, the left chambers through the mitral valve.
The superior and inferior venae cavae lead into the right atrium, bringing back venous blood from the body.



The pulmonary artery leaves from the right ventricle, which delivers the blood to the lungs where it is oxygenated. The pulmonary veins, carrying oxygenated blood, arrive in the left atrium, while the aorta leaves from the left ventricle taking blood through the arterial system again.

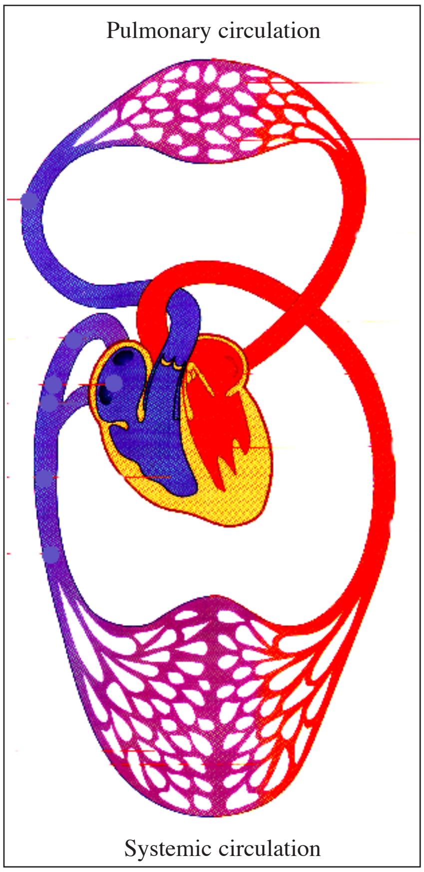
The heart has a circulation of his own, which provides it with oxygen for its constant movement. It is known as the **coronary circulation**.
In order to perform its pumping action the heart carries out two types of movement:

- **ventricular contraction**, or systole, which dispatches the blood under pressure into the arterial system to reach all the parts of the body.

- **venrticular relaxation**, or diastole, which allows the venous blood to flow back again into the heart.

Systole and diastole take place in a rhythmic and automatic manner. Pulse rate is between 60-80 per min.

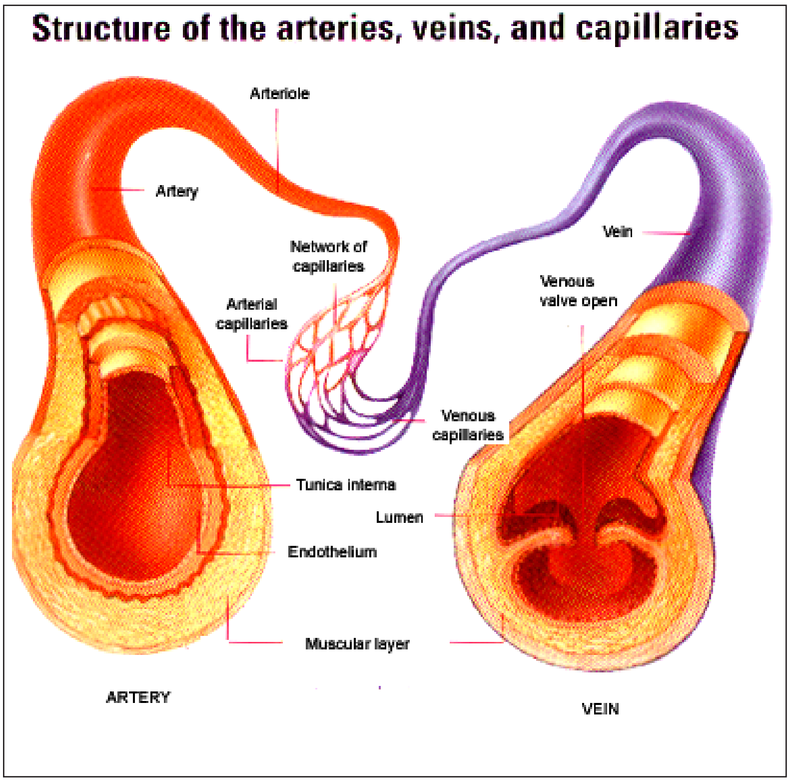
Systemic and pulmonary circulation



The blood is pumped by the heart through double circulation:
- the **systemic circulation** which carries arterial blood from the left ventricle to all the tissues and returns it to the right atrium as venous blood.
- the **pulmonary circulation** carries venous blood from the right ventricle to the lungs, where it is oxygenated and returns it to the left artrium.

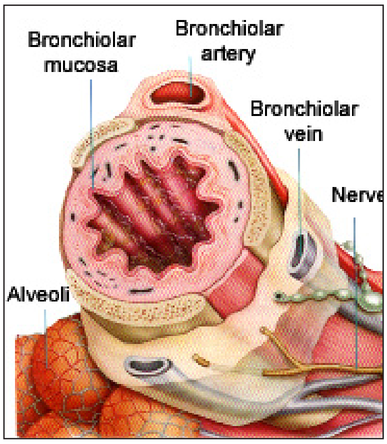
The arterial system consists of a network of blood vessels carrying the oxygen that is essential for the cell to function. The further these vessels are from the heart, the thinner they become. They are initially known as arteries, then arterioles, and finally capillaries, which are of microscopic size. It is at this final level that the transfer of oxygen to the tissues takes place through **diffusion** (exchange of O2 and CO2).

The venous system consists of a network of blood vessels that runs in the opposite direction to the arterial. These collect the deoxygenated blood, loaded with waste substances (venous blood), to the right-hand chambers of the heart.
The walls of the veins are less elastic and muscular than the arteries, because the blood circulating through them is being drawn in by the suction effect of the heart. Inside the veins, any backflow of blood is prevented by a system of valves.
The arteries have a thicker muscular wall to endure the pressure.
Arterial pressure is at its greatest at the moment of systole, or ventricular contraction and at its lowest during diastol, or ventricular relaxation.



Arterial pressure is conventionally measured in millimiters of mercury (mmHg); in a young adult, systolic pressure is on average about 120 and diastolic pressure about 80.

The respiratory system



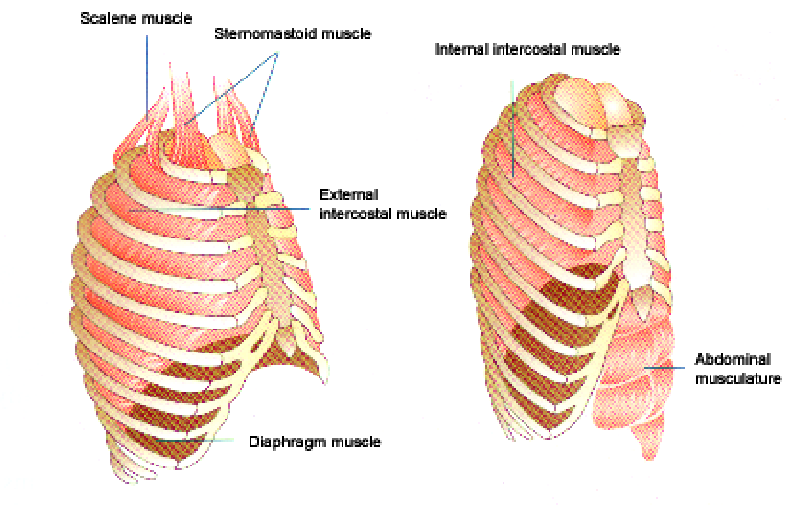
The respiratory system consists of a number of anatomical structures:

- the upper respiratory tract (nasal fossae and buccal cavity, upper pharinx and oropharinx. These are air passages where the incoming air is filtered, warmed and humidified.
- the lower respiratory tract (larinx, trachea which divides in two bronchi). The bronchi lead into the lungs through the pulmonary hiluses.

The main bronchi progressively subdivide and diminish in size to become bronchioles that terminate in bunches of globular structures - **the alveoli** - where gaseous exchange takes place. The lungs contain hundreds of millions of alveoli.

As well as the bronchi, veins and arteries also lead into the lungs through the pulmonary hiluses, respectively bringing carbon dioxide rich blood and carrying away oxygenated blood to the arteries.

Thoracic movement during breathing and the musculature that produces it



Inspiration
The floor of the thoracic cavity descends.
The ribs rise

Expiration
The diaphragm rises through abdominal compression.
The ribs descend

The lungs are covered in a thin membrane called **pleura** which attaches to the ribs and the diaphragm. They are enclosed and protected within the ribs; their angled base rests on the **diaphragm**, the muscle forming the limit of the thoracic cavity.

The pleural cavity is completely air tight and contains a partial vacuum: its internal pressure is always less than the atmospheric pressure outside the body. Since the pressure difference is maintained during breathing movements, when the thoracic cavity increases in volume the lungs inflate to fill the extra space available.

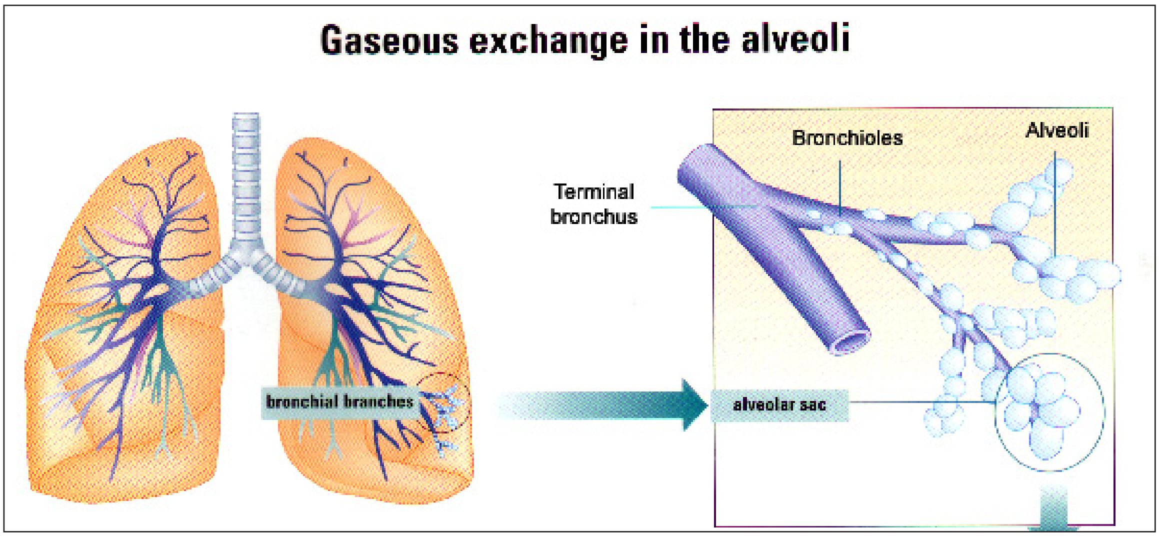
The functioning of the whole complex respiratory system depends on the action of the thoracic muscles.

The principal muscles involved in inspiration are the diaphragm and the external intercostal, sternocleido mastoid, scalene and major serratus muscles.

The effect of the contraction of any of these is to increase the size of the thoracic cavity, temporarily reducing the air pressure inside the lungs and force the air to rush in.

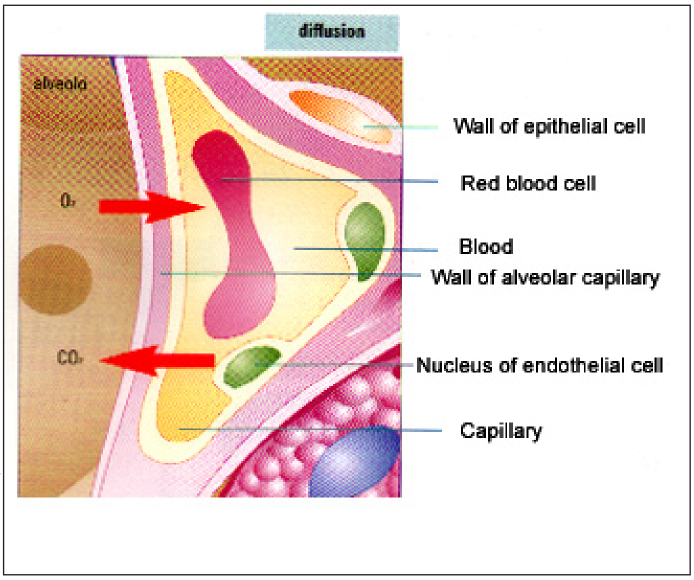
The principal muscles involved in expiration are the abdominal, the intrernal intercostal and the posterior serratus muscles.

When these muscles relax the lungs return to their original size forcing the air out of the lungs.



The whole outer surface of each alveolus is covered by a dense network of capillaries. All of these capillaries originate from the pulmonary artery and eventually drain into the pulmonary vein.
Blood flowing through the immense network of capillaries absorbs oxygen which diffuses through the alveoli walls.

At the same time the blood releases carbon dioxide which diffuses in the opposite direction into the alveoli.

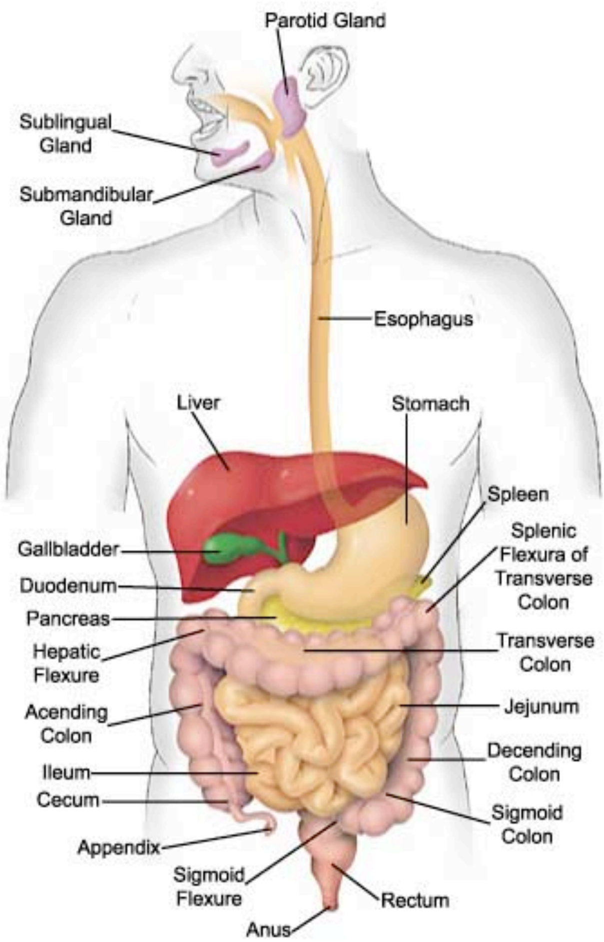


Blood entering the lungs is deoxygenated, because the haemoglobin in its red cells has given up all its oxygen to the body tissues.

The internal diameter to the lung capillaries is actually smaller than the diameter of the red cells which pass through them.

The red cells are therefore squeezed out of shape as they are forced through the lungs by blood pressure, exposing more surface area to the capillary walls, thereby absorbing more oxygen, and also their slow rate of progress increases the time available for oxygen to diffuse into them and combine with haemoglobin.

The Digestive System



The digestive system is made up of the digestive tract—a series of hollow organs joined in a long, twisting tube from the mouth to the anus—and other organs that help the body break down and absorb food (see figure).

Organs that make up the digestive tract are the mouth, esophagus, stomach, small intestine, large intestine —also called the colon—rectum, and anus. Inside these hollow organs is a lining called the mucosa. In the mouth, stomach, and small intestine, the mucosa contains tiny glands that produce juices to help digest food. The digestive tract also contains a layer of smooth muscle that helps break down food and move it along the tract.

Two "solid" digestive organs, the liver and the pancreas, produce digestive juices that reach the intestine through small tubes called ducts. The gallbladder stores the liver's digestive juices until they are needed in the intestine. Parts of the nervous and circulatory systems also play major roles in the digestive system.

Why is digestion important?

When you eat foods—such as bread, meat, and vegetables—they are not in a form that the body can use as nourishment. Food and drink must be changed into smaller molecules of nutrients before they can be absorbed into the blood and carried to cells throughout the body. Digestion is the process by which food and drink are broken down into their smallest parts so the body can use them to build and nourish cells and to provide energy.

How is food digested?

Digestion involves mixing food with digestive juices, moving it through the digestive tract, and breaking down large molecules of food into smaller molecules. Digestion begins in the mouth, when you chew and swallow, and is completed in the small intestine.

Movement of Food Through the System

The large, hollow organs of the digestive tract contain a layer of muscle that enables their walls to move. The movement of organ walls can propel food and liquid through the system and also can mix the contents within each organ. Food moves from one organ to the next through muscle action called peristalsis. Peristalsis looks like an ocean wave traveling through the muscle. The muscle of the organ contracts to create a narrowing and then propels the narrowed portion slowly down the length of the organ. These waves of narrowing push the food and fluid in front of them through each hollow organ.

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

Swallowed food is pushed into the esophagus, which connects the throat above with the stomach below. At the junction of the esophagus and stomach, there is a ringlike muscle, called the lower esophageal sphincter, closing the passage between the two organs. As food approaches the closed sphincter, the sphincter relaxes and allows the food to pass through to the stomach.

The stomach has three mechanical tasks. First, it stores the swallowed food and liquid. To do this, the muscle of the upper part of the stomach relaxes to accept large volumes of swallowed material. The second job is to mix up the food, liquid, and digestive juice produced by the stomach. The lower part of the stomach mixes these materials by its muscle action. The third task of the stomach is to empty its contents slowly into the small intestine.

Several factors affect emptying of the stomach, including the kind of food and the degree of muscle action of the emptying stomach and the small intestine. Carbohydrates, for example, spend the least amount of time in the stomach, while protein stays in the stomach longer, and fats the longest. As the food dissolves into the juices from the pancreas, liver, and intestine, the contents of the intestine are mixed and pushed forward to allow further digestion. Finally, the digested nutrients are absorbed through the intestinal walls and transported throughout the body. The waste products of this process include undigested parts of the food, known as fiber. These materials are pushed into the colon, where they remain until the feces are expelled by a bowel movement.

Production of Digestive Juices

The digestive glands that act first are in the mouth—the salivary glands. Saliva produced by these glands contains an enzyme that begins to digest the starch from food into smaller molecules. An enzyme is a substance that speeds up chemical reactions in the body.

The next set of digestive glands is in the stomach lining. They produce stomach acid, the hydrochloridric acid, and an enzyme that digests protein, pepsin. A thick mucus layer coats the mucosa and helps keep the acidic digestive juice from dissolving the tissue of the stomach itself. In most people, the stomach mucosa is able to resist the juice, although food and other tissues of the body cannot.

After the stomach empties the food and juice mixture into the small intestine, the juices of two other digestive organs mix with the food. One of these organs, the pancreas, produces a juice that contains a wide array of enzymes to break down the carbohydrate, fat, and protein in food. Other enzymes that are active in the process come from glands in the wall of the intestine.

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

Absorption and Transport of Nutrients

Most digested molecules of food, as well as water and minerals, are absorbed through the small intestine. The mucosa of the small intestine contains many folds that are covered with tiny fingerlike projections called villi. In turn, the villi are covered with microscopic projections called microvilli. These structures create a vast surface area through which nutrients can be absorbed. Specialized cells allow absorbed materials to cross the mucosa into the blood, where they are carried off in the bloodstream to other parts of the body for storage or further chemical change. This part of the process varies with different types of nutrients.

Carbohydrates. Foods rich in carbohydrates include bread, potatoes, dried peas and beans, rice, pasta, fruits, and vegetables. Many of these foods contain both starch and fiber. The digestible carbohydrates—starch and sugar—are broken into simpler molecules by enzymes in the saliva, in juice produced by the pancreas, and in the lining of the small intestine. Starch is digested in two steps. First, an enzyme in the saliva and pancreatic juice breaks the starch into molecules called maltose. Then an enzyme in the lining of the small intestine splits the maltose into glucose molecules that can be absorbed into the blood. Glucose is carried through the bloodstream to the liver, where it is stored as glycogen or used to provide energy for the work of the body.

Sugars are digested in one step. An enzyme in the lining of the small intestine digests sucrose, also known as table sugar, into glucose and fructose, which are absorbed through the intestine into the blood. Milk contains another type of sugar, lactose, which is changed into absorbable molecules by another enzyme in the intestinal lining.

Fiber is undigestible and moves through the digestive tract without being broken down by enzymes. Many foods contain both soluble and insoluble fiber. Soluble fiber dissolves easily in water and takes on a soft, gel-like texture in the intestines. Insoluble fiber, on the other hand, passes essentially unchanged through the intestines.

Protein. Foods such as meat, eggs, and beans consist of giant molecules of protein that must be digested by enzymes before they can be used to build and repair body tissues. An enzyme in the juice of the stomach starts the digestion of swallowed protein. Then in the small intestine, several enzymes from the pancreatic juice and the lining of the intestine complete the breakdown of huge protein molecules into small molecules called amino acids. These small molecules can be absorbed through the small intestine into the blood and then be carried to all parts of the body to build the walls and other parts of cells.

Fats. Fat molecules are a rich source of energy for the body. The first step in digestion of a fat such as butter is to dissolve it into the watery content of the intestine. The bile acids produced by the liver dissolve fat into tiny droplets and allow pancreatic and intestinal enzymes to break the large fat molecules into smaller ones. Some of these small molecules are fatty acids and cholesterol. The bile acids combine with the fatty acids and cholesterol and help these molecules move into the cells of the mucosa. In these cells the small molecules are formed back into large ones, most of which pass into vessels called lymphatics near the intestine. These small vessels carry the reformed fat to the veins of the chest, and the blood carries the fat to storage depots in different parts of the body.

Vitamins. Another vital part of food that is absorbed through the small intestine are vitamins. The two types of vitamins are classified by the fluid in which they can be dissolved: water-soluble vitamins (all the B vitamins and vitamin C) and fat-soluble vitamins (vitamins A, D, E, and K). Fat-soluble vitamins are stored in the liver and fatty tissue of the body, whereas water-soluble vitamins are not easily stored and excess amounts are flushed out in the urine.

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

The lymphatic system

The lymphatic system is a system of thin tubes that runs throughout the body. These tubes are called lymph vessels or lymphatic vessels.

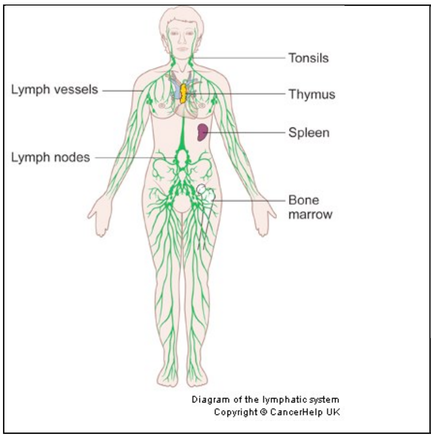


Diagram of the lymphatic system
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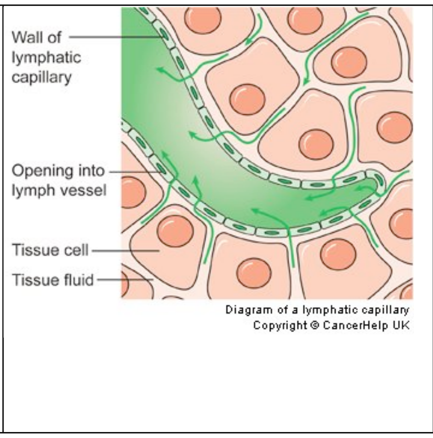

Diagram of a lymphatic capillary
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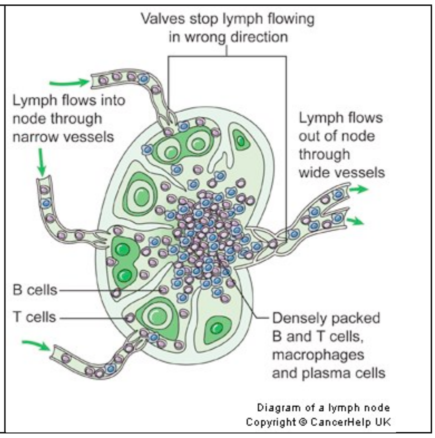

Diagram of a lymph node
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The lymphatic system is like the blood circulation - the tubes branch through all parts of the body like the arteries and veins that carry blood. But the lymphatic system tubes are much finer and carry a colourless liquid called lymph.

Lymph is a clear fluid that circulates around the body tissues. It contains a high number of lymphocytes (white blood cells). Plasma leaks out of the capillaries to surround and bathe the body tissues. This then drains into the lymph vessels. The fluid, now called lymph, then flows through the lymphatic system to the biggest lymph vessel - the thoracic duct. The thoracic duct then empties back into the blood circulation.

Lymph glands

Along the lymph vessels are small bean-shaped lymph glands or 'nodes'. You can probably feel some of your lymph nodes.

There are lymph nodes in many parts of your body including

- Under your arms, in your armpits
- In each groin (at the top of your legs)
- In your neck

There are also lymph nodes that you cannot feel in

- Your abdomen
- Your pelvis
- Your chest

The lymphatic system includes other body organs. These are the

- Spleen
- Thymus
- Tonsils
- Adenoids

The spleen is under your ribs on the left side of your body. The spleen filters lymph fluid.

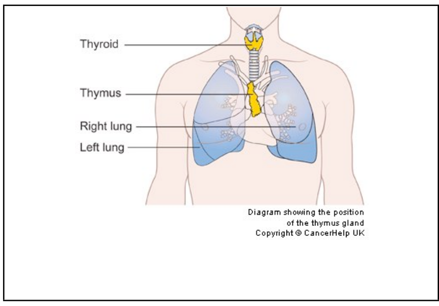

Diagram showing the position of the thymus gland
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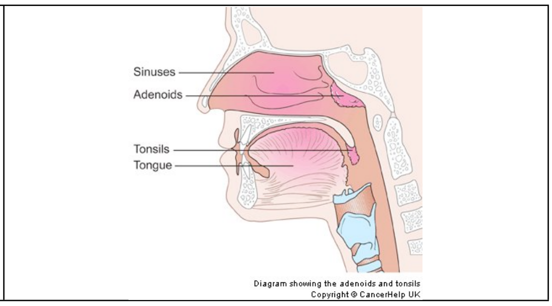

Diagram showing the adenoids and tonsils
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The thymus is a small gland under your breast bone. The thymus helps to produce white blood cells. It is usually most active in teenagers and shrinks in adulthood.

The tonsils are two glands in the back of your throat. The tonsils and adenoids (also called the 'nasopharyngeal' tonsils) help to protect the entrance to the digestive system and the lungs from bacteria and viruses.

The adenoids are at the back of your nose, where it meets the back of your throat.

Functions of the lymphatic system:

The lymphatic system does several jobs in the body. It

- Drains fluid back into the bloodstream from the tissues
- Filters lymph
- Filters the blood
- Fights infections

Draining fluid into the bloodstream

As the blood circulates, fluid leaks out from the blood vessels into the body tissues. This fluid is important because it carries food to the cells and waste products back to the bloodstream. The leaked fluid drains into the lymph vessels. It is carried through the lymph vessels to the base of the neck where it is emptied back into the bloodstream. This circulation of fluid through the body goes on all the time.

Filtering lymph

The lymph nodes filter the lymph fluid as it passes through. White blood cells attack any bacteria or viruses they find in the lymph as it flows through the lymph nodes. If cancer cells break away from a tumour, they often become stuck in the nearest lymph nodes. This is why doctors check the lymph nodes first when they are working out how far a cancer has grown or spread.

Filtering the blood

This is the job of the spleen. It filters the blood to take out all the old worn out red blood cells and then destroys them. They are replaced by new red blood cells that are made in the bone marrow. The spleen also filters out bacteria, viruses and other foreign particles found in the blood. White blood cells in the spleen attack bacteria and viruses as they pass through

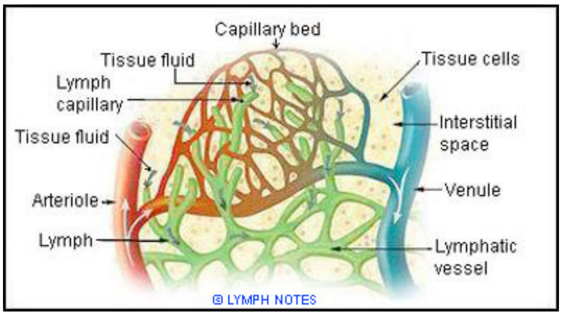
Fighting infection

When people say "I'm not well, my glands are up" they are really saying they have swollen lymph nodes because they have an infection. The lymphatic system helps fight infection in many ways such as

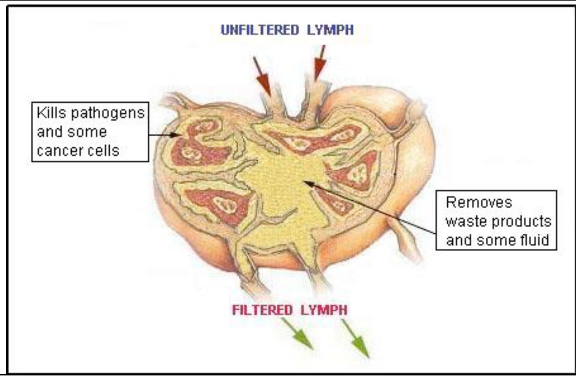
- Helping to make special white blood cells (lymphocytes) that produce antibodies
- Having other blood cells called macrophages inside the lymph nodes which swallow up and kill any foreign particles, for example germs (This function of the lymphatic system is really part of the immune system)

The lymphatic works in close cooperation with other body systems to perform these important functions:

- The lymphatic system aids the immune system in destroying pathogens and filtering waste so that the lymph can be safely returned to the circulatory system.
- The lymphatic system removes excess fluid, waste, debris, dead blood cells, pathogens, cancer cells, and toxins from the cells and the tissue spaces between them.
- The lymphatic system also works with the circulatory system to deliver nutrients, oxygen, and hormones from the blood to the cells that make up the tissues of the body.
- Important protein molecules are created by cells in the tissues. Because these molecules are too large to enter the capillaries of the circulatory system, these protein molecules must be transported by the lymph to the bloodstream at the terminus - the triangular area at the base of the neck, just above the collarbones, where the lymph returns to the circulatory system by flowing into the subclavian veins.



Blood capillaries allow fluid to leave, and enter, the circulatory system.



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

The Origin of Lymph

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

- Also known as intercellular fluid, or interstitial fluid, this tissue fluid delivers nutrients, oxygen, and hormones to the cells.
- As this fluid leaves the cells, it takes with it cellular waste products and protein cells.
- Approximately 90 percent of this tissue fluid flows into the venules. Here it enters the venous circulation as plasma and continues in the circulatory system.
- The remaining 10 percent of the fluid that is left behind is now known as lymph.

Blood Flow Compared with Lymphatic Flow

The bloodstream is pumped by the heart. It circulates throughout the body and is cleansed by being filtered by the kidneys. The lymphatic system does not have a pump to aid in its flow, instead this system is designed so that lymph only flows upward through the body traveling from the extremities (feet and hands) and upward through the body toward the neck.

As it travels through the body, lymph passes through lymph nodes where it is filtered. At the base of the neck, the lymph enters the subclavian veins and once again becomes plasma in the bloodstream.

Lymphatic Capillaries

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

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

Lymphatic Vessels

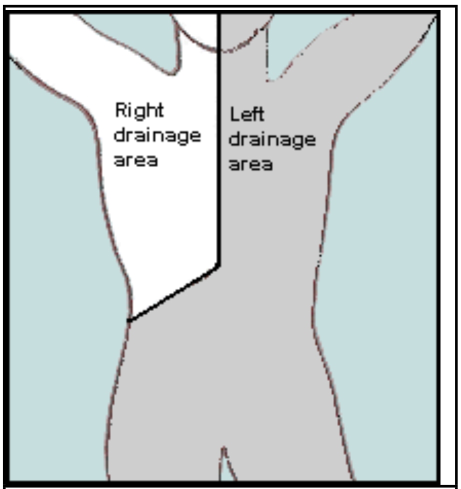
The lymphatic capillaries gradually join together to form a mesh-like network of tubes that are located deeper in the body. As they become larger, these structures are known as lymphatic vessels.

- Deeper within the body the lymphatic vessels become progressively larger and are located near major veins.
- Like veins, lymphatic vessels, which are known as lymphangions have one-way valves to prevent any backward flow.
- Each angions is a segment created by the space between two sets of valves.
- Smooth muscles in the walls of the lymphatic vessels cause the angions to contract sequentially to aid the flow of lymph toward the thoracic region. Because of their shape, these vessels are previously referred to as a string of pearls.

Lymph Nodes

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

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

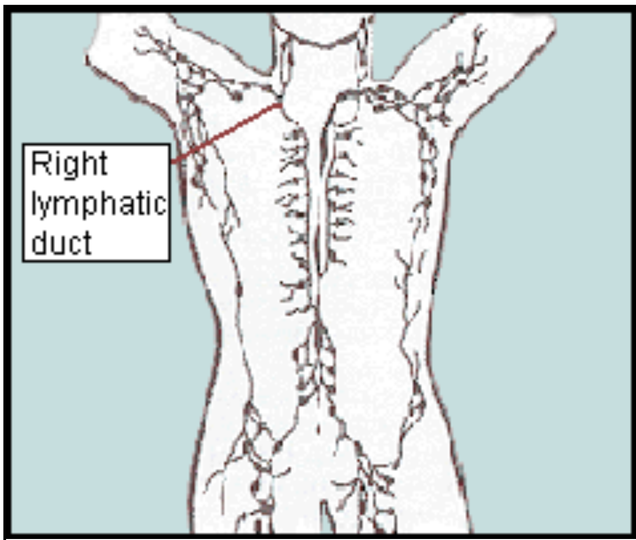


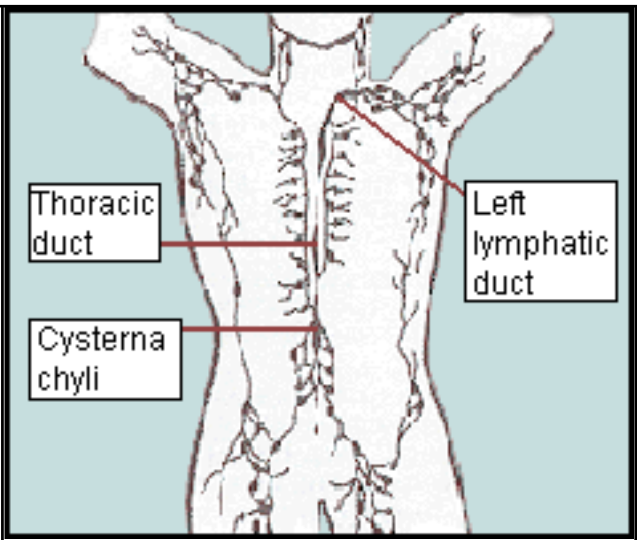
Lymphatic Drainage Areas

Drainage Areas

Lymphatic drainage is organization into two separate and very unequal drainage areas. These are the right and left drainage areas and normally lymph does not drain across the invisible lines that separate these areas. Structures within each area carry lymph to its destination, which is to return to the circulatory system.

Right Drainage Area	Left Drainage Area





Right drainage area landmarks	Left lymphatic drainage landmarks
· Drains lymph from the right side of the head and neck · The right arm · Upper right quadrant of the body. · Lymph from this area flows into the right lymphatic duct. · This duct empties the lymph into the right subclavian vein.	· Drains lymph from the left side of the head and neck · The Left arm and the left upper quadrant · The lower trunk and both legs · The cisterna chili temporarily stores lymph as it moves upward from the lower areas of the body. · The thoracic duct transports lymph upward to the left lymphatic duct. · The left lymphatic duct empties the lymph into the left subclavian vein.

cisterna chyli
An enlarged lymphatic vessel, about 6 centimeters long. It is located in the lumbar region of the abdominal cavity, just to the right of the abdominal aorta. It receives and temporarily stores lymph as it travels upward from the lower portion of the body.

thoracic duct
The lymphatic duct that carries lymph, from the left watershed upward and returns the to the venous circulation through the left subclavian vein.