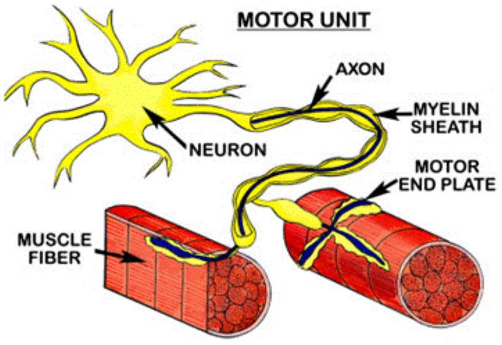
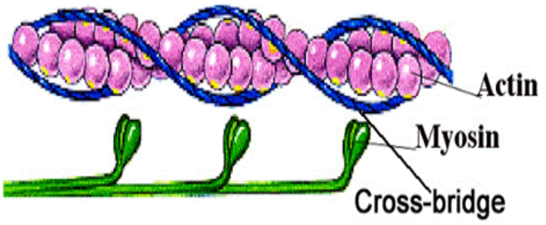
UNIT 4

THE SLIDING FILAMENT THEORY :

For a contraction to occur there must first be a stimulation of the muscle in the form of an impulse from a motor neuron .





Note that one motor neuron does not stimulate the entire muscle but only a number of muscle fibres within a muscle.

The individual motor neuron plus the muscle fibres it stimulates, is called a motor unit. The motor end plate is the junction of the motor neurons axon and the muscle fibres it stimulates.

When an impulse reaches the muscle fibres of a motor unit, it stimulates a reaction in each sarcomere between the actin and myosin filaments. This reaction results in the start of a contraction and the sliding filament theory.

The reaction, created from the arrival of an impulse stimulates the 'heads' on the myosin filament to reach forward, attach to the actin filament and pull actin towards the centre of the sarcomere. This process occurs simultaneously in all sarcomeres, the end process of which is the shortening of all sarcomeres.

stages:

1. Muscle activation: The motor nerve stimulates an action potential to pass down a neuron to the neuromuscular junction. This stimulates the sarcoplasmic reticulum to release calcium into the muscle cell.

2. Muscle contraction: Calcium floods into the muscle cell binding with troponin allowing actin and myosin to bind. The actin and myosin cross bridges bind and contract using ATP as energy

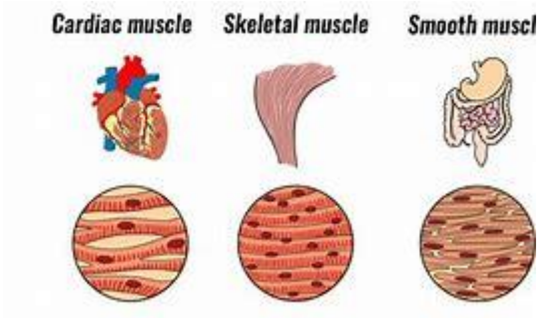
3. Recharging: ATP is re-synthesised allowing actin and myosin to maintain their strong binding state

4. Relaxation: Relaxation occurs when stimulation of the nerve stops. Calcium is then pumped back into the sarcoplasmic reticulum breaking the link between actin and myosin. Actin and myosin return to their unbound state causing the muscle to relax. Alternatively relaxation (failure) will also occur when ATP is no longer available.

In order for a skeletal muscle contraction to occur;

1. There must be a neural stimulus
2. There must be calcium in the muscle cells
3. ATP must be available for energy

Kinds of muscle:



There are three types of muscle found in the human body.

- **Skeletal Muscle**
- **Smooth Muscle**
- **Cardiac Muscle** (heart muscle)

Skeletal muscle

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.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.

Smooth muscle

Smooth muscle is also sometimes known as Involuntary muscle due to our inability to control its movements, or unstriated as it does not have the stripy appearance of Skeletal muscle. Smooth muscle is found in the walls of hollow organs such as the Stomach, Oesophagus, Bronchi and in the walls of blood vessels. This muscle type is stimulated by involuntary neurogenic impulses and has slow, rhythmical contractions used in controlling internal organs, for example, moving food along the Oesophagus or constricting blood vessels durings.

Cardiac muscle (heart muscle)

This type of muscle is found solely in the walls of the heart. It has similarities with skeletal muscles in that it is striated and with smooth muscles in that its contractions are not under conscious control. However, this type of muscle is highly specialised. It is under the control of the autonomic nervous system, however, even without a nervous input contraction can occur due to cells called pacemaker cells. Cardiac muscle is highly resistant to fatigue due to the presence of a large number of mitochondria, myoglobin and a good blood supply allowing continuous aerobic metabolism.

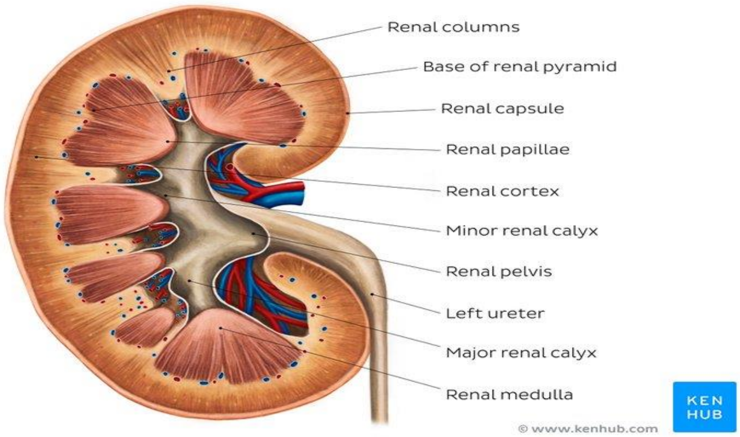
Muscle Contraction:

Muscle fibers contract in response to nerve stimuli from your central nervous system. This is an active process that involves the release of calcium at the cellular level of the muscle fiber, and causes a "ratcheting" effect that results in the shortening, or contracting, of individual muscle fibers.

Muscle Relaxation:

Once your muscle contracts, the space between the motor end plate and the fibers releases an enzyme called acetylcholinesterase, which ends the stream of action. This causes the muscle to stop contracting and begin relaxation. When relaxation begins, the opposing muscle contracts and pulls the original contracting muscle back into place.

Kidney-Structure:



- The kidneys are two bean-shaped organs in the renal system.
- They help the body pass waste as urine.
- They also help filter blood before sending it back to the heart.

- Each kidney is enclosed by a thin tough fibrous connective tissue called renal capsule that protects it from infections and injuries. Around the capsule there is a layer of fat (adipose tissue) which is further enclosed by another layer of fibrous membrane known as **renal fascia**. The bean shaped kidney have outer convex surface and inner concave surface.
- **Location:** The kidneys lie on the posterior abdominal wall, one on each side of the vertebral column, behind the peritoneum and below the diaphragm.
- **Position:** It is situated at the level of T12-L3. The right kidney is usually slightly lower than the left, probably because of the considerable space occupied by the liver.

Longitudinal section of the kidney shows following parts.

- **Capsule**: It is an outermost covering composed of fibrous tissue surrounding the kidney.
- **Cortex**: It is a reddish-brown layer of tissue immediately below the capsule and outside the renal It consists of renal corpuscles and convoluted tubules.
- **Medulla**: It is the innermost layer, consisting of conical areas called the renal pyramids separated by renal columns. There are 8-18 renal pyramids in each kidney. The apex of each pyramid is called a **renal papilla,** and each papilla projects into a small depression, called a **minor calyx** .
- Several minor calyces unite to form a **major calyx.** In turn, the major calyces join to form a funnel shaped structure called **renal pelvis** that collects urine and leads to ureter.

FUNCTION:

- Regulating pH Balance

- maintaining overall fluid balance
- regulating and filtering minerals from blood
- filtering waste materials from food, medications, and toxic substances
- creating hormones that help produce red blood cells, promote bone health, and regulate blood pressure

Nephrons

- Nephrons are the most important part of each kidney.
- They take in blood, metabolize nutrients, and help pass out waste products from filtered blood.
- Each kidney has about 1 million nephrons. Each has its own internal set of structures.

Renal corpuscle

After blood enters a nephron, it goes into the renal corpuscle, also called a Malpighian body.

- **The glomerulus.** This is a cluster of capillaries that absorb protein from blood traveling through the renal corpuscle.
- **The Bowman capsule.** The remaining fluid, called capsular urine, passes through the Bowman capsule into the renal tubules.

Renal tubules

The renal tubules are a series of tubes that begin after the Bowman capsule and end at collecting ducts.

Each tubule has several parts:

- **Proximal convoluted tubule.** This section absorbs water, sodium, and glucose back into the blood.
- **Loop of Henle.** This section further absorbs potassium, chloride, and sodium into the blood.
- **Distal convoluted tubule.** This section absorbs more sodium into the blood and takes in potassium and acid.

By the time fluid reaches the end of the tubule, it’s diluted and filled with urea. Urea is byproduct of protein metabolism that’s released in urine.

Renal cortex

- The renal cortex is the outer part of the kidney. It contains the glomerulus and convoluted tubules.
- The renal cortex is surrounded on its outer edges by the renal capsule, a layer of fatty tissue.
- Together, the renal cortex and capsule house and protect the inner structures of the kidney.

Renal medulla

The renal medulla is the smooth, inner tissue of the kidney. It contains the loop of Henle as well as renal pyramids.

Renal pyramids

Renal pyramids are small structures that contain strings of nephrons and tubules. These tubules transport fluid into the kidney.

This fluid then moves away from the nephrons toward the inner structures that collect and transport urine out of the kidney.

Collecting ducts

There’s a collecting duct at the end of each nephron in the renal medulla. This is where filtered fluids exit the nephrons.

Once in the collecting duct, the fluid moves on to its final stops in the renal pelvis.

Renal pelvis

The renal pelvis is a funnel-shaped space in the innermost part of the kidney. It functions as a pathway for fluid on its way to the bladder

Calyces

The first part of the renal pelvis contains the calyces. These are small cup-shaped spaces that collect fluid before it moves into the bladder. This is also where extra fluid and waste become urine.

Hilum

The hilum is a small opening located on the inner edge of the kidney, where it curves inward to create its distinct beanlike shape.

- **Renal artery.** This brings oxygenated blood from the heart to the kidney for filtration.
- **Renal vein.** This carries filtered blood from the kidneys back to the heart.

Ureter

The ureter is a tube of muscle that pushes urine into the bladder, where it collects and exits the body.

composition of urine:

Urinary solids are primarily made up of organic matter, largely volatile solids. Urine has large amounts of **nitrogen, phosphorus, and potassium**. Nitrogen content in urine is high, mostly in urea, which makes up more than 50 percent of the total organic acids.

URINE:

Urine is a liquid produced by the kidneys to remove waste products from the bloodstream. Human urine is yellowish in color and variable in chemical composition

Primary Components

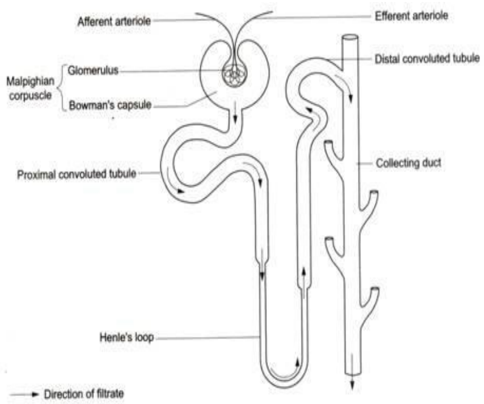
Human urine consists primarily of water (91% to 96%), with organic solutes including urea, creatinine, uric acid, and trace amounts of enzymes, carbohydrates, hormones, fatty acids, pigments, and mucins, and inorganic ions such as sodium (Na^+), potassium (K^+), chloride (Cl^-), magnesium (Mg^{2+}), calcium (Ca^{2+}), ammonium (NH_4^+), sulfates (SO_4^{2-}), and phosphates (e.g., PO_4^{3-}).1

Chemical Composition of Urine

- Water (H_2O): 95%
- Urea (H_2NCONH_2): 9.3 g/l to 23.3 g/l
- Chloride (Cl^-): 1.87 g/l to 8.4 g/l
- Sodium (Na^+): 1.17 g/l to 4.39 g/l
- Potassium (K^+): 0.750 g/l to 2.61 g/l
- Creatinine ($C_4H_7N_3O$): 0.670 g/l to 2.15 g/l
- Inorganic sulfur (S): 0.163 to 1.80 g/l

The pH of human urine ranges from 5.5 to 7, averaging around 6.2. The specific gravity ranges from 1.003 to 1.035. Significant deviations in pH3 or specific gravity4 may be due to diet, drugs, or urinary disorders.

Anatomy of the Nephron



Different parts of a nephron

The anatomy of the nephron is important to understand the urine formation process.

- Renal Corpuscle
- Renal Tubule

The renal corpuscle is divided into the glomerular capillaries or glomerulus and the Bowman's capsule. It is in the renal corpuscle that the blood is filtered at high pressure. The arteriole that brings blood into the glomerulus is called the afferent arteriole whereas the artery that takes blood away from the glomerulus is known as the efferent arteriole.

Between these arterioles forms, a network of capillaries called the glomerular capillaries of the glomerulus. The Bowman's capsule is a cup-shaped structure in which this glomerulus is located. The glomerulus along with the Bowman's capsule achieve the filtration of blood to form urine.

- The proximal convoluted Tubule(PCT)
- The U-shaped Loop Of Henle
- The Distal Convoluted Tubule(DCT)

Once the blood is filtered in the renal corpuscle, the resultant fluid is called the glomerular filtrate. This glomerular filtrate now passes into the PCT. In the PCT, substances like NaCl, K+, water, glucose, and bicarbonate are reabsorbed into the filtrate whereas urea, creatinine, uric acid are added to the filtrate.

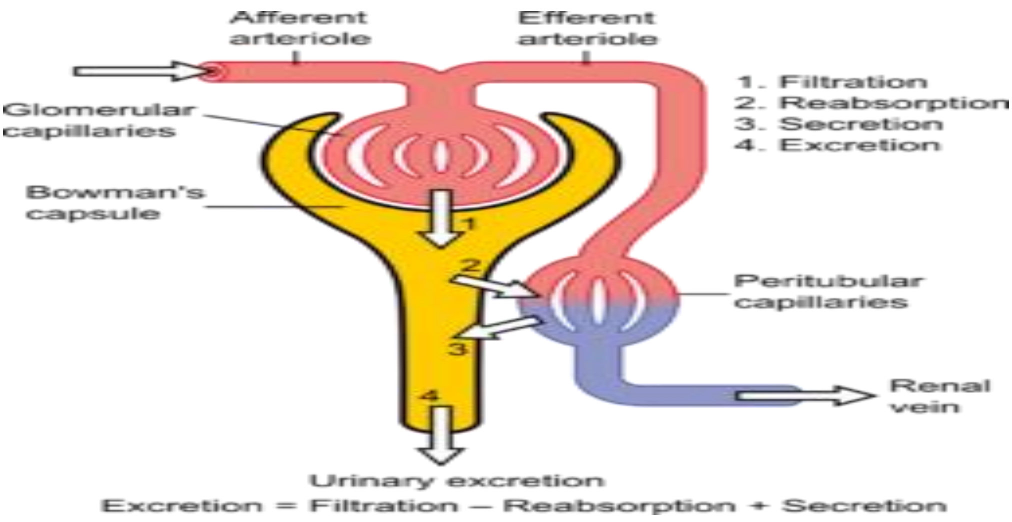
From the PCT, the filtrate enters the U-shaped Loop of Henle where reabsorption and secretion of water and various metabolites occurs. The filtrate then passes into the DCT. From the DCT, the filtrate passes into the collecting tubules, into the renal pelvis and the ureters as urine to be stored int he urinary bladder.

Urine Formation

Urine is the liquid waste product of the human body. It contains urea, uric acid, salts, water and other waste products that are the result of various metabolic processes occurring in the body. It is formed in the primary excretory organs– the kidneys. The structural and functional unit of the kidneys is called the nephrons. Millions of nephrons are involved in the process of urine formation.

The formation process occurs in 3 steps or phases:

- Glomerular Filtration
- Tubular Reabsorption
- Tubular Secretion



Glomerular Filtration

This process occurs in the glomerular capillaries. The process of filtration leads to the formation of an ultrafiltrate. The blood gushes into these capillaries with high pressure and gets filtered across the thin capillary walls. Everything except the blood cells and proteins are pushed into the capsular space of the Bowman's capsule to form the ultrafiltrate. The glomerular filtration rate (GFR) is 125ml/min or 180 Litres/day.

Tubular Reabsorption

During glomerular filtration, all substances except blood cells and proteins are pushed through the capillaries at high pressure. At the level of the Proximal Convoluted Tubule(PCT), some of the substances from the filtrate are reabsorbed. These include sodium chloride, potassium, glucose, amino acids, bicarbonate, and 75% of water.

Absorption of some substances is passive, some substances are actively transported while others are co-transported. The absorption depends upon the permeability of different parts of the nephron. The distal convoluted tubule shows selective absorption. The substances and water which is reabsorbed are taken up by the peritubular capillaries to be returned to the blood.

Tubular Secretion

The peritubular capillaries that help in transporting the reabsorbed substances into the bloodstream, also help in actively secreting substances like H+ ions, K+ ions. Whenever excess K+ is secreted into the filtrate, Na+ ions are actively reabsorbed to maintain the Na-K balance. Some drugs are not filtered in the glomerulus and so are actively secreted into the filtrate during the tubular secretion phase.

Unit-5

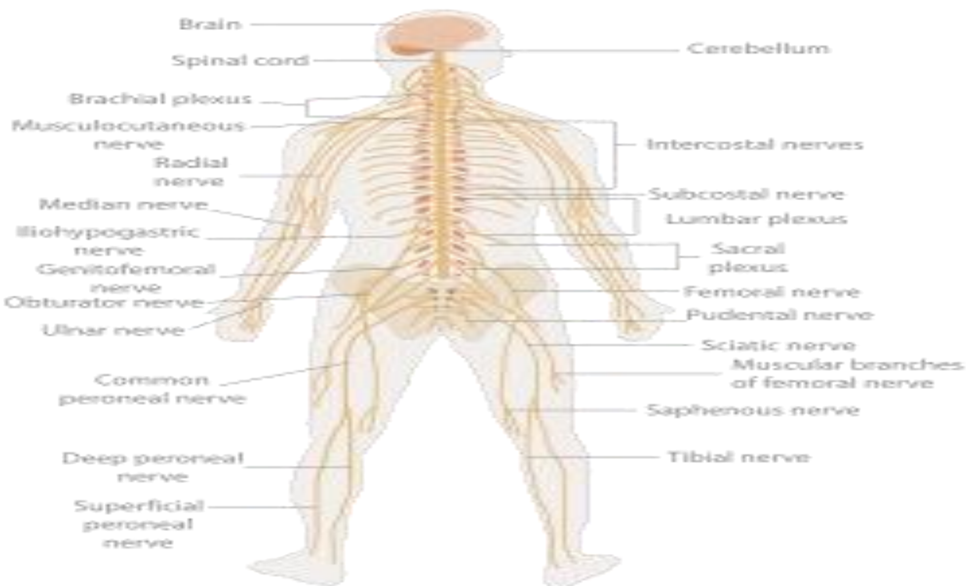
Endorphin and Enkephalin:

- Endorphin and enkephalin are the body's natural painkillers. When a person is injured, pain impulses travel up the spinal cord to the brain.
- The brain then releases endorphins and enkephalins. Enkephalins block pain signals in the spinal cord.
- Endorphins are thought to block pain principally at the brain stem. Both are morphine-like substances whose functions are similar to those of opium-based drugs.
- These naturally occurring opiates include enkephalins ,endorphins and a growing number of synthetic compounds.

The Nervous System;

It consists of two main parts.

- The Central Nervous System (CNS)
- Peripheral Nervous System (PNS)



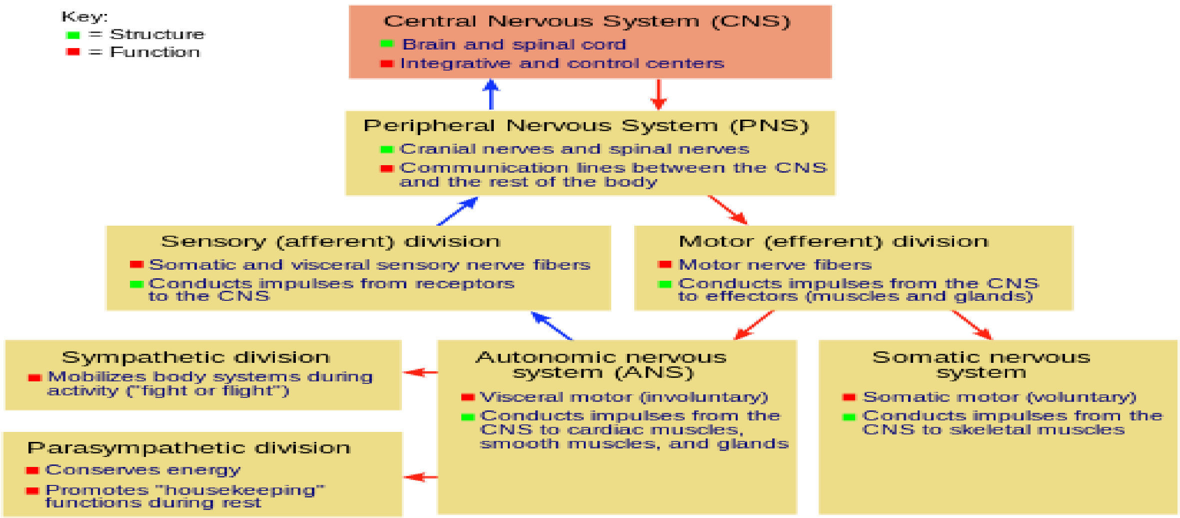
Central Nervous System

This system consists of the Brain and Spinal Cord. Find more about human brain in the related posts.

Peripheral Nervous System

It consists of the cranial nerves coming from the brain and the spinal nerves coming from the spine. There are 12 pairs of cranial nerves and 31 pairs of spinal nerves in humans.

The peripheral nervous system is made of up of the Autonomic nervous system and Somatic Nervous System. The Sympathetic nervous system and Parasympathetic nervous system fall under the autonomic nervous system.



Nerves :

A nerve is a thread like structure that comes out of the brain and the spinal cord. So these nerves branch out to all the parts of the body and are mainly responsible for carrying information and messages from part to the other. All the nerves make up the peripheral system. They carry information between the brain and spinal cord.

Types of Nerves

There are different types of nerves, according to the action they perform. They are:

- *Sensory Nerves* – These send messages to the brain from all the sensory organs,
- *Motor Nerves* – They carry messages from the brain to the muscles in the body.
- *Mixed Nerves* – They carry the sensory and motor nerves. They help in conducting the incoming sensory information and also the outgoing information to the muscle cells.

Based on which part the nerves connect to the Central Nervous System, they are classified as:

- *Cranial Nerves* – They start from the brain and carry messages from the brain to the rest of the body. Certain nerves are sensory nerves while some are mixed nerves.
- *Spinal Nerves* – These nerves originate from the Spinal Cord. They carry messages to and from the central nervous system. They consist of mixed nerves.

Neurons:

Typical structure of neuron:

Neuron is the structural and functional unit of nervous system.It consists of a nerve cell body or soma and two types of processes-axon dendrite.

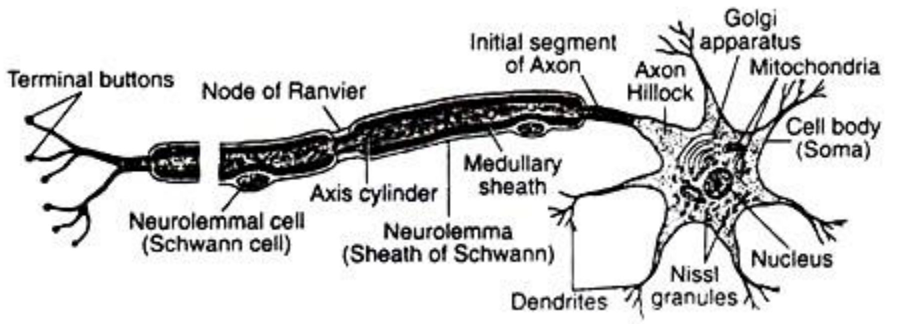


Fig. 8.29 : A neurone with all its processes and the formation of a medullated neurone

Soma:
It is an irregular- shaped structure in thecentre of which there lies a spherical nucleus with prominent nucleolus and nissl granules.

Dendrite:

It is the process of the cell body that carries impulse towards the cell body.It is usually short with many branches and contains nissl granules.

Axon:

It is the process of a nerve cell body that carries impulse away from it.It terminates into branches with terminal buttons.

- Nerves are made up special cells called the nerve cells or neurons. These neurons are the basic unit of the nervous system.
- Three parts make up a neuron – axon, cell body and nerve endings. The cell body is the main part and has all the components of the cell such as the nucleus, mitochondria, endoplasmic reticulum etc. Axons are long cable-like projections that carry the messages along the length of the cell. These axons are covered by a protective covering called the myelin sheath.
- This myelin is made of fat and has a role in speeding up the transmission of messages down a long axon. Dendrites are the small branch-like projections that form connections with other neurons these dendrites can be present at both ends of the cell.
- Synapse is the junction between two nerve cells. It consists of a minute gap. Impulses or messages pass by diffusion of a neurotransmitter.

- Neurons have high energy requirements and are bundled with blood vessels.
- There are billions of neurons in the body, about 100 billion in the brain and 13.5 million in the spinal cord.
- Axons can transmit electrical signals at a rate of 2,500 per second.

The nervous system integrates and monitors the countless actions occurring simultaneously throughout the entire human body; therefore, every task a person accomplishes, no matter how menial, is a direct result of the components of the nervous system. These actions can be under voluntary control, like touching a computer key, or can occur without your direct knowledge, like digesting food, releasing enzymes from the pancreas, or other unconscious acts.
It is difficult to understand all the complexities of the nervous system because the field of neuroscience has rapidly evolved over the past 20 years; moreover, answers to new questions are being found almost daily. A thorough knowledge of the individual components of the nervous system and their functions, however, will lead you to a better understanding of how the human body works and will facilitate your future acquisition of knowledge about the nervous system.

The nervous system consists of two parts,

- The central nervous system (CNS) consists of the brain and spinal cord.

- The peripheral nervous system (PNS) consists of nerves outside the CNS.

Nerves of the PNS are classified in three ways. First, PNS nerves are classified by how they are connected to the CNS. Cranial nerves originate from or terminate in the brain, while spinal nerves originate from or terminate at the spinal cord.

Second, nerves of the PNS are classified by the direction of nerve propagation. Sensory neurons transmit impulses from skin and other sensory organs or from various places within the body to the CNS. Motor neurons transmit impulses from the CNS to effectors .

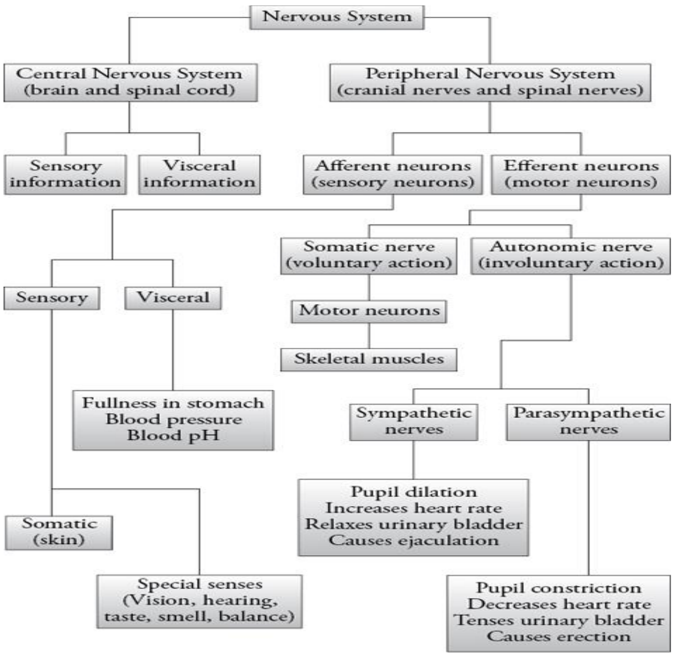
Third, motor neurons are further classified according to the effectors they target. The **somatic nervous system (SNS)** directs the contraction of skeletal muscles. The **autonomic nervous system (ANS)** controls the activities of organs, glands, and various involuntary muscles, such as cardiac and smooth muscles.

The autonomic nervous system has two divisions:

The sympathetic nervous system is involved in the stimulation of activities that prepare the body for action, such as increasing the heart rate, increasing the release of sugar from the liver into the blood, and other activities generally considered as fight-or-flight responses .

The parasympathetic nervous system activates tranquil functions, such as stimulating the secretion of saliva or digestive enzymes into the stomach and small intestine.

Generally, both sympathetic and parasympathetic systems target the same organs, but often work antagonistically. For example, the sympathetic system accelerates the heartbeat, while the parasympathetic system slows the heartbeat. Each system is stimulated as is appropriate to maintain homeostasis.



. Propagation of Nerve Impulse 3. Rate of Conduction.

.

Propagation of nerve impulse

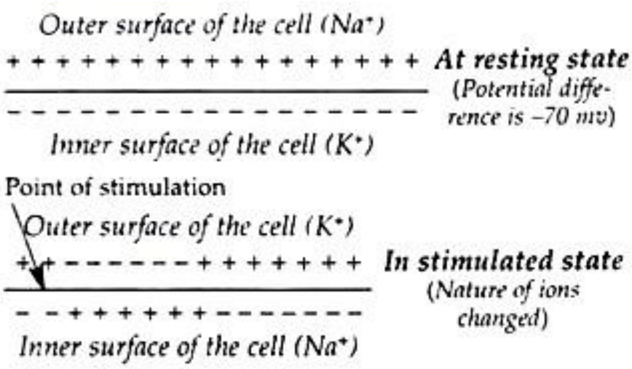
Two major parts

1.Stimulation of nerve impulse 2.Travelling of nerve impulse

1.Stimulation of nerve impulse:

In resting nerve cells,the surface is positively charged and the interior is negatively charged.Positive ions and negative ions are accumulated along the outer and inner surface of the cell membrane,respectively.

This is achived by Na-outside and K-inside the cell membrane,and Na-is placed above the K-in the series



2.Travelling of nerve impulse:

According to the membrane, nerve impulse is a propagated wave of de –polarisation.

When the fibre is excited at appoint,the polarity is reversed.This is due to increased permeability of Na- to the membrane,which develops de-polarisation wave.
The de-polarisation wave travels in all direction along the length of the nerve fibre.

This in myelinated action jumps from one node ranvier to the next.This is known as salutatory conduction.

Rate of conduction of nerve impulse:

The basic principle of origin and propagation of nerve impulse is same,both fibres but the salutatory mechanism of conduction in fibre increases the velocity of conduction more than 500 times.
The rate of conduction of anerve impulse with an increase in the cross sectional diameter of the neuron with myelin sheath.The rate of transmission for a given neuron is a constant.

Neurotransmitters :

Neurotransmitters play an important role in neural communication. They are chemical messengers that carry messages between nerve cells and other cells in the body, influencing everything from mood to involuntary movements. This process is generally referred to as neurotransmission or synaptic transmission.

Specifically, excitatory neurotransmitters have excitatory effects on the neuron.

Neurotransmitters can act in predictable ways, but they can be affected by drugs, disease, and interaction with other chemical messengers.

To send messages throughout the body, neurons need to transmit signals to communicate with one another. But there is no physical connection with each other, just a minuscule gap. This junction between two nerve cells is called a synapse.

To communicate with the next cell, a neuron sends a signal across the synapse by diffusion of a neurotransmitter.

Neurotransmitters affect neurons in one of three ways:

1. **Excitatory neurotransmitters** have excitatory effects on the neuron. This means they increase the likelihood that the neuron will fire an action potential.
2. **Inhibitory neurotransmitters** have inhibitory effects on the neuron. This means they decrease the likelihood that the neuron will fire an action.
3. **Modulatory neurotransmitters** can affect a number of neurons at the same time and influence the effects of other chemical messengers.

Some neurotransmitters, such as dopamine, depending on the receptors present, create both excitatory and inhibitory effects.

Excitatory neurotransmitters :

The most common and clearly understood types of excitatory neurotransmitters include:

Acetylcholine

This is an excitatory neurotransmitter that is found throughout the nervous system. One of its many functions is muscle stimulation, including those of the gastrointestinal system and the autonomic nervous system.

Epinephrine

Also called adrenaline, epinephrine is an excitatory neurotransmitter produced by the adrenal glands. It is released into the bloodstream to prepare your body for dangerous situations by increasing your heart rate, blood pressure, and glucose production.

Glutamate

This is the most common neurotransmitter in the central nervous system. It is an excitatory neurotransmitter and usually ensures balance with the effects of gamma-aminobutyric acid (GABA), an inhibitory neurotransmitter.

Histamine

This is an excitatory neurotransmitter primarily involved in inflammatory responses, vasodilation, and the regulation of immune response to foreign bodies such as allergens.

Dopamine

Dopamine has effects that are both excitatory and inhibitory. It is associated with reward mechanisms in the brain.