COORDINATION continuation…….

V. NERVOUS COORDINATION IN ANIMALS

Coordination is the ability to make an appropriate response to a stimulus. Implying that it is a system of communication in which animals or organisms detect sudden changes in the specific conditions of their external and internal environment and responds accordingly.

A coordinating system contains several components and they include,

- Means of detecting stimuli.
- Means of transmitting information.
- Feedback, ensures that the degree of response is related to the intensity and direction.
- Means of directing information along the most appropriate of many possible channels.

The sudden changes in the environmental conditions that cause responses in the whole organism or its parts are known as **stimulus**.

Examples of common stimuli include; Light, Chemicals, Heat, Sound, touch, stretch (Mechanical stimuli)

The special cells or body tissue in an organism which detects stimulus is called **Receptors**. Most receptors detect only one type of a stimulus.

Response. Is the change in behaviour or activity of an organism or its parts in reaction to a stimulus.

Effector. Is the body structure or organ of an organism that responds to a stimulus. examples of effectors in organisms include; Muscles, Glands, Cilia, Chromatophores.

In very small, minute animals like amoeba, the detection and response to stimulus occurs within a single cell and so no need for very well-developed system of coordination.

However, in large multicellular animals such as mammals, stimuli are detected by sense organs, while the effectors respond. Due to large size, sense organs and effectors may be in quite different parts of the body.

In addition, responses usually involve the coordinated actions of many different parts of the body. To achieve effective coordination, one part of the body must be able to pass information to another part. In mammals there are two major systems that convey information,

- Nervous system.
- Hormonal system.

The nervous system.

In this type of coordination, information is passed in chemical and electrical forms. Transmission of messages is rapid and causes rapid responses. The changes they cause or their effects are localized and short lived.

Hormonal system.

This is the type of coordination where information are transmitted inform of chemical messengers called hormones. Transmission of messages and responses are slow but the changes that the y cause or their effects are wide spread and long term (lasts for longer periods.

SIGNIFICANCE OF CO-ORDINATION SYSTEMS TO ORGANISMS.

(i) Adapt organisms to changing environmental conditions, promoting survival values. It also provide animals with a precise information about their environment.

(ii) Enable animals to sense and escape from predators.

(iii) Important in nutrition. Enable animals detect food sources, capture their preys. It also controls intake of food, secretion of enzymes and egestion.

(iv) Reflex actions enable animals avoid injuries, body harm.

(v) Determines certain behavioral patterns in animals. For example, migration, hibernation/aestivation, fight or flight behaviours.

(vi) Important in reproduction. It controls reproductive cycles and reproductive behavioral patter in animals for example menstrual cycles, lactation, courtship, oestrus, etc.

(vii) Stimulates muscular contractions which are important in the process of locomotion and support.

(viii) Important in control of Homeostasis.

(ix) Maintenance of blood circulation and heart beat.

THE CLASSIFICATION OF NERVOUS SYSTEM.

Nervous system of mammals is classified into,

- Central nervous system.
- Peripheral nervous system.

Central nervous system (CNS) further consists of **brain** and **spinal cord**. The main role of central nervous system is to coordinate and controls many activities of the body.

Peripheral nervous system further consists of **sensory nervous system** and **motor nervous system**. Sensory system consists of nerve fibers that convey information from sense organs to the central nervous system. While motor system consists of nerve fibers that carry information from Central Nervous System to effector organs such as muscles and glands.

Motor system consists of,

(i) Somatic nervous system.

(ii) Autonomic nervous system.

1. **Somatic nervous system** consists of nerve fibers (neurones) that convey information (impulses) from central nervous system (CNS) to voluntary organs (effectors) especially the skeletal muscles.
2. **The Autonomic nervous system (ANS)** consists of nerve fibres (neurones) that convey impulses (electrical informations) from the Central nervous system (CNS) to involuntary

internal organs of the body such as smooth muscles, cardiac muscles and glands. Autonomic nervous system is concerned with control of internal environment. It is further divided into,

(i) **Sympathetic nervous system**. It basically increases rate of most metabolic activities in the body.
(ii) **Parasympathetic nervous system**. It basically decreases rate of most metabolic activities in the body.

THE STRUCTURE AND FUNCTIONS OF THE NERVOUS SYSTEM.

The basic structure of Nervous system consists of Receptors protected within supplementary structures called **the sense organs** where the receptors are best placed to detect stimuli. Receptors convert stimuli into form of electrical impulses in a process known as **transduction**. Impulses are transmitted through specialized nerve cells called Sensory neurones. These impulses are transmitted across junctions that occur at certain points between neurones called **synapses**. The impulses are systematically transmitted from receptors, via synapses to the central nervous systems. Central nervous system consists of Brain or spinal cord, where they are received, correlated and interpreted (Intergrated) in the CNS, the interpreted impulses are transmitted by **motor neurones** via **synapses** to either effector organs mostly under conscious control such as the skeletal muscles or to effectors organs such as smooth muscles, cardiac muscles and glands which are not under conscious control (involuntary organs). Transmission of the impulses from the CNS to involuntary organs through motor neurones is called the **autonomic nervous system**. Autonomic nervous system further consists of **sympathetic nervous system** that increases many metabolic activities and the **parasympathetic nervous system** that decreases many metabolic activities.

The nervous system has the following functions,

- collects information about the internal and external environment.
- processes and integrates the information often in relation to previous experience.
- receives impulses from all sensory organs of the body.
- stores information
- correlates various stimuli from different sensory organs
- sends messages to all parts of the body making them function accordingly.

The nervous system is made up of cells called neurons. A neuron is a functional unit cell of the nervous
system that transmits an impulse or an electrical message.

NEURONES

Are the basic structural and functional components of the nervous system. There are three types of neurons and they are the following motor, sensory and intermediate neurons.

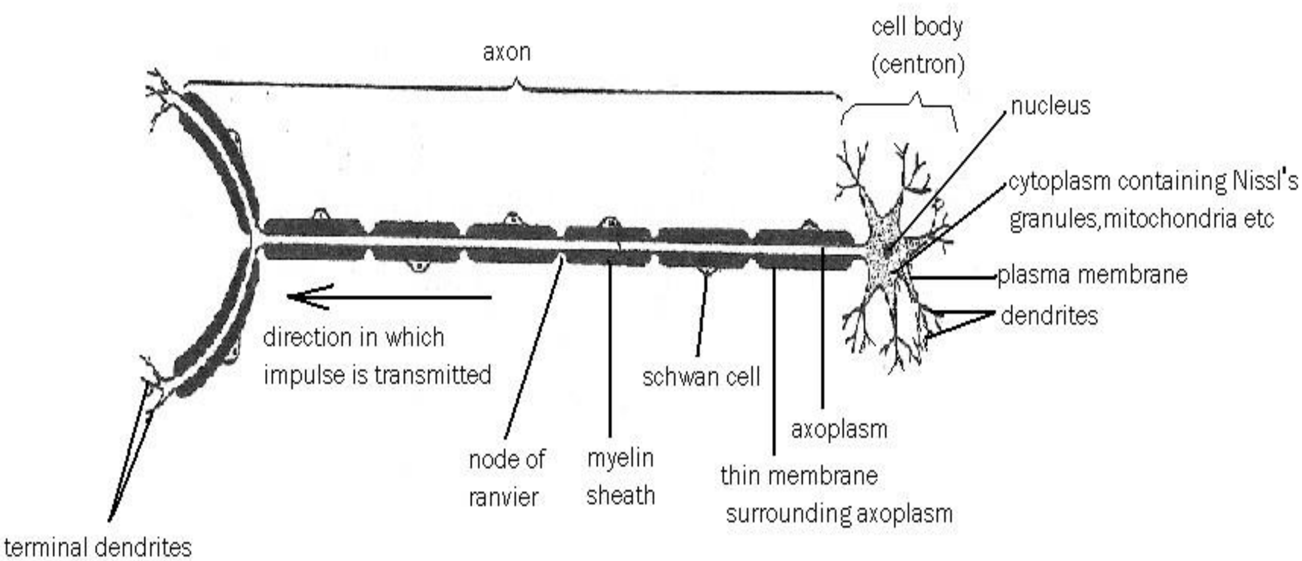
MOTOR NEURONES

They are also called effectors or efferent neurons. They transmit impulses from the central nervous system (CNS) to muscles and glands. They possess more than two cytoplasmic extensions and are referred to as multi-polar neurons.

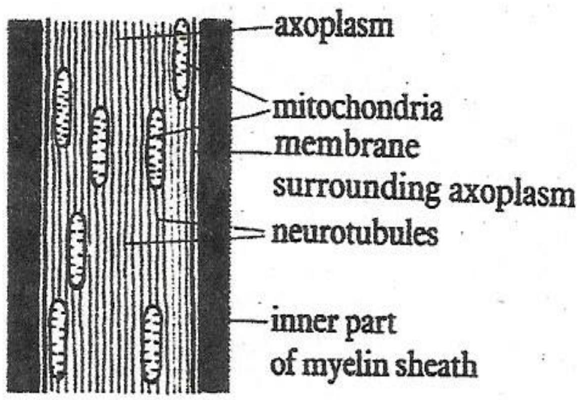
THE STRUCTURE OF THE MOTOR NEURONES

It contains nucleus, mitochondria, cell membrane, etc. Its cytoplasm contains granules called Nissl's granules, which are group of ribosomes concerned with protein synthesis. The nucleated part called the cell body (centron) is located within the CNS and is connected with neighbouring neurons by slender dendrites. One of the dendrites is drawn to form an axon (nerve fibre) which enters a peripheral nerve and terminates in a muscle or glands. A fatty myelin sheath, this is not part of the neurone but the membrane of another cell.

STRUCTURE OF MOTOR NEURONE



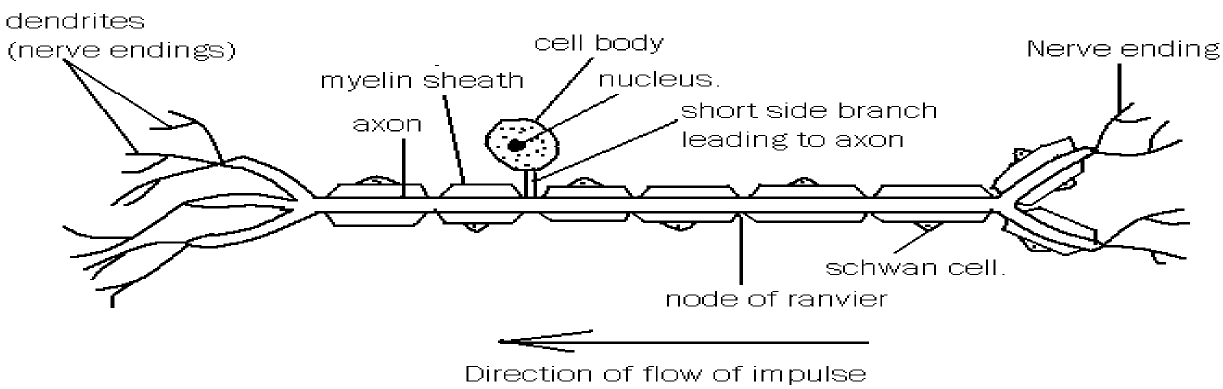
CROSS-SECTION THROUGH THE AXON



SENSORY NEURONES

These are also called receptor or afferent neurons. They transmit impulses from receptors to the central nervous system (brain and spinal cord). Their cell bodies are located in the dorsal root ganglia of the spinal nerves. They possess only one cytoplasmic extension and are referred to as unipolar neurone.

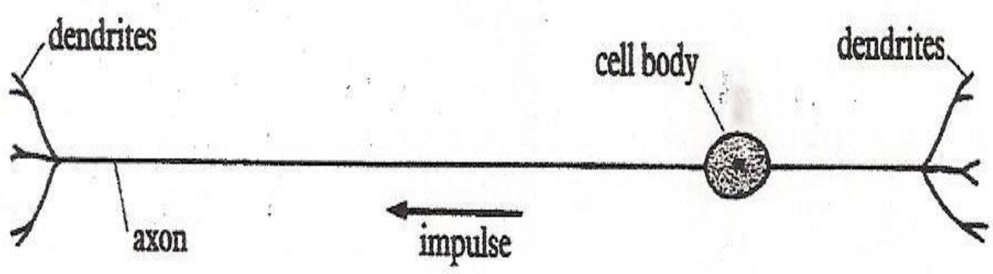
DIAGRAM OF VERTEBRATES SENSORY NEURONE



INTERMEDIATE NEURONES

These are also called relay or internuncial or associate neurons. They are found in the central nervous system (CNS) where they connect sensory and motor neurons with each other. They possess two cytoplasmic extensions and are referred to as bi-polar neurone.

SIMPLIFIED DIAGRAM OF INTERMIATE NEURONE:



Note: All neurons possess similar essential parts as shown in motor neurone.

BASIC STRUCTURE AND FUNCTIONS OF THE PARTS OF A NEURONE

(i) **Dentrites:** these are fine structures on the neuron that link up nerve cells to form a complex network of communication.

(ii) **Dendron:** it is a branch through which impulses are transmitted to the body.

(iii) **Axoplasm:** Transmit the nerve impulses. It contains numerous mitochondria which provides the required energy synthesis.

(iv) **Cell body**: Contains all the cell organelles e.g. Mitochondria, ribosomes, endoplasmic reticulum and the nucleus which controls the activities of the cell etc.

(v) **Schwann cells**: Produce the myelin sheath.

(vi) **Myelin sheath**: this is a fatty material that covers the axon. It Speeds up the transmission of the impulses. It also protects the axon from any injuries especially which may be as a result of
contraction from muscles.

(vii) **Synaptic knobs**: Release chemical transmitters that allow impulses to cross the synapse.

(viii) **Nissl's granules**; these are groups of ribosomes responsible for protein synthesis.

(ix) **Node of Ranvier**; this is the space on the axon between two adjacent myelin sheaths. It speeds up nervous transmission.

(x) **Cytoplasm**; this is a site for chemical reactions in the neuron.

Transmission of nerve impulses

1. **Polarization of the neuron's membrane:**

Sodium is on the outside, and potassium is on the inside.

Cell membranes surround neurons just as any other cell in the body has a membrane. When a neuron is not stimulated — it's just sitting with no impulse to carry or transmit — its membrane is **polarized**. Being polarized means that the electrical charge on the outside of the membrane is positive while the electrical charge on the inside of the membrane is negative. The outside of the cell contains excess sodium ions (Na+); the inside of the cell contains excess potassium ions (K+).

Question. How can the charge inside the cell be negative if the cell contains positive ions?

The answer is that in addition to the K+, negatively charged protein and nucleic acid molecules also inhabit the cell; therefore, the inside is negative as compared to the outside. Then, if cell membranes allow ions to cross, how does the Na+ stay outside and the K+ stay inside? If this thought crossed your mind, you deserve a huge gold star! The answer is that the Na+ and K+ do, in fact, move back and forth across the membrane. However, Mother Nature thought of everything. There are Na+/K+ pumps on the membrane that pump the Na+ back outside and the K+ back inside. The charge of an ion inhibits membrane permeability (that is, makes it difficult for other things to cross the membrane).

2. **The resting potential**.

When a neurone (nerve cell) is at rest, the inside of its membrane is more negative while the out side of the membrane is more positive, the membrane is said to be polarized, resulting into formation of a potential difference across the membrane of the neurone (axon) that is at rest referred to as **a resting potential**. And its magnitude is about -70mV (-60mV to -70mV). This membrane potential is maintained by **sodium-potassium pump mechanism.**

The pump is carrier proteins that exist across the membrane of the nerve cell and it can alter its shape to actively pump 3 molecules of sodium ions out and 2 molecules of the potassium ions into the membrane. While the membrane remains impermeable to outward diffusion of the negative ions such as the chloride ions which are retained inside (in the axoplasm). This creates more positive charges outside the membrane and more negative charges inside the membrane. The membrane is polarized and there exists the resting potential across the membrane.

The nerve cell has a higher concentration of positive ions like sodium and potassium ions outside the cell than the inside, while concentrations of negative ions like the chloride ions is higher inside than outside. This is because the membrane of the neurone is impermeable to outward diffusion of chloride ions and inward diffusion of sodium ions while at rest.

In addition, the membrane is permeable to outward diffusion of potassium ions while at rest. The inside of the membrane has a higher concentration of potassium ions than sodium and the surrounding tissue fluid (outside of the membrane) has a higher concentration of sodium and low concentration of potassium ions. This creates a gradient across known as electrochemical gradient.

The electrochemical gradient of an ion is due to its electrical and chemical properties. The electrical property is its charge, where attractions and repulsions can occur. While, the property of the ion is due to concentrations of the ion.

The value of the resting potential is largely determined by the potassium ion electrochemical gradient. This is because the membrane is more permeable to outward movements of potassium and less permeable for movement by diffusion of sodium ions inside, so, potassium ion loss from the axon is greater than sodium ions gain by passive diffusion. Across the membrane are channels proteins with pores.

The sodium ion channels and the potassium ion protein channels are called **gated channels**. These protein channels can be opened or closed with polypeptide chains called gates. When the neurone is at rest, sodium gates are closed, while the potassium gates remain open.

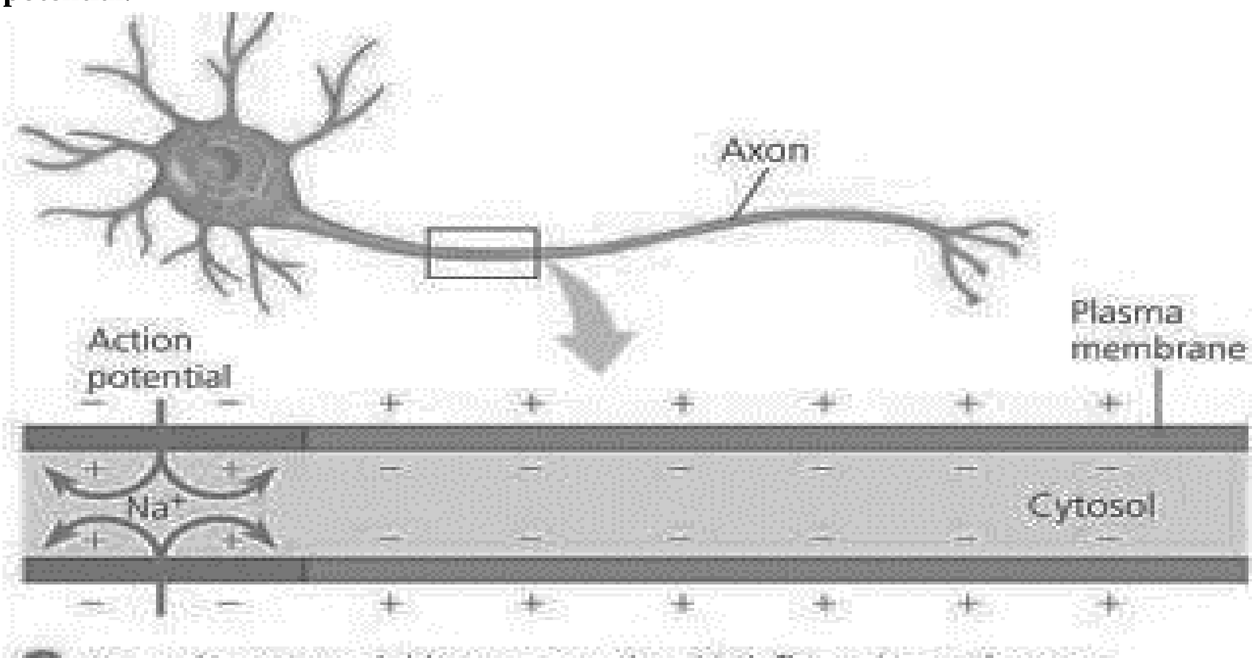
NOTE: Resting potential is determined largely by rapid diffusion of potassium ions outside the membrane to maintain high concentration of positive charges out the membrane.

3. **The action potential**.

When the nerve cell (neurone) is at rest (no stimulus). The inside of its membrane is more negative, while the outside is more positive and there exists a potential difference across the membrane called the **resting potential** maintained by the activities of the sodium-potassium pump that actively pumps 3 molecules of sodium ions out and 2 molecules of potassium ions inside.

When the neurone receives a stimulus, sodium- potassium pump mechanism breaks down (Ceases in its functions), some sodium gates open, while the potassium gates close. The permeability of the membrane of the axon to sodium ions increases. Sodium ions diffuse rapidly inside the axon. The inside of the membrane become more positive and the outside become more negative and the membrane become depolarized.

The sodium gates are sensitive to slight depolarisation and responds by more sodium gates opening, this means that, the influx of sodium ions begin to depolarize the membrane and this depolarization in turn increases the membrane permeabiolity to sodium, leading to greater influx and further depolarization, which is an example of positive feedback, resulting into formation of a new potential difference across the membrane which increases to reach **a threshold value**, causing a greater wave of depolarisation across the entire membrane of the axon called **action potential.**



1 An action potential is generated as Na^+ flows inward across the membrane at one location.

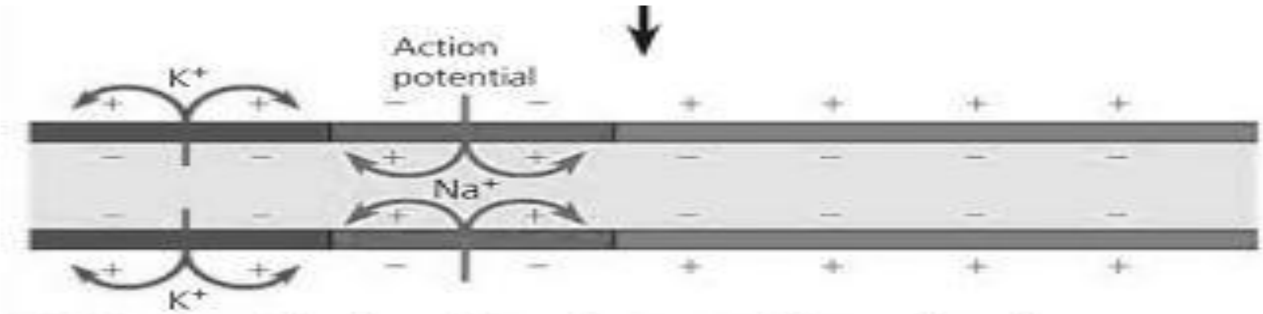
In this case depolarisation is propagated along the axon such that one point depolarizes the next until the synapse is reached. This leads to transmission of a nerve impulse.

And when sufficient sodium ions have entered to create a positive charge inside the membrane permeability of the membrane to sodium ions start to decrease.

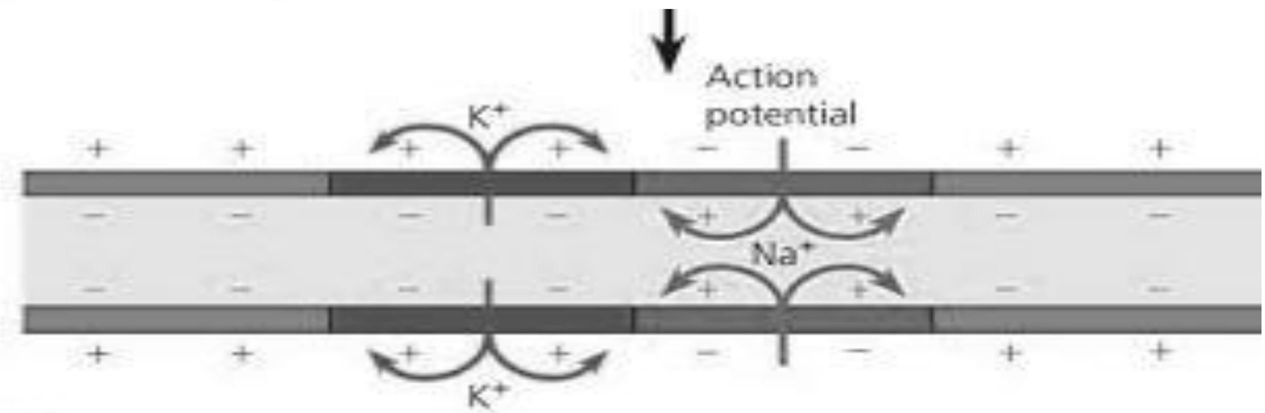
Action potential is a new potential difference (Positive voltage) that exists across the membrane of an axon of the neurone, due to the existence of more positive charges inside and more negative charges outside the membrane (due to depolarisation of the membrane/sudden reversal of the resting potential) when the neurone receives stimulus. And **an impulse** is the propagated negative charge on the outside of the membrane caused by wave of depolarisation. A threshold value is the maximum potential difference across membrane of receptor cells and neurones or axons which when reached, causes generation of action potential and leads to transmission of impulses. It peaks at about +40mV.

4. **Repolarization: Potassium ions move outside, and sodium ions stay inside the membrane.**

After the inside of the cell becomes flooded with Na^+, the gated ion channels on the inside of the membrane open to allow the K^+ to move to the outside of the membrane. With K^+ moving to t he outside, the membrane's repolarization restores electrical balance, although it's opposite of the initial polarized membrane that had Na^+ on the outside and K^+ on the inside. Just after the K^+ gates open, the Na^+ gates close; otherwise, the membrane couldn't repolarize.



2 The depolarization of the action potential spreads to the neighboring region of the membrane, reinitiating the action potential there. To the left of this region, the membrane is repolarizing as K+ flows outward.



3 The depolarization-repolarization process is repeated in the next region of the membrane. In this way, local currents of ions *across* the plasma membrane cause the action potential to be propagated *along* the length of the axon.

5. **Hyperpolarization: More potassium ions are on the outside than there are sodium ions on the inside.**

When the K+ gates finally close, the neuron has slightly more K+ on the outside than it has Na+ on the inside. This causes the membrane potential to drop slightly lower than the resting potential, and the membrane is said to be hyperpolarized because it has a greater potential. (Because the membrane's potential is lower, it has more room to "grow."). This period doesn't last long, though (well, none of these steps take long!). After the impulse has traveled through the neuron, the action potential is over, and the cell membrane returns to normal (that is, the resting potential).

6. Refractory period puts everything back to normal: Potassium returns inside, sodium returns outside.

The refractory period is when the Na+ and K+ are returned to their original sides: Na+ on the outside and K+ on the inside. While the neuron is busy returning everything to normal, it doesn't respond to any incoming stimuli. *It's kind of like letting your answering machine pick up the phone call that makes your phone ring just as you walk in the door with your hands full.* After the Na+/K+ pumps return the ions to their rightful side of the neuron's cell membrane, the neuron is back to its normal polarized state and stays in the resting potential until another impulse comes along.

Figure showing variation in membrane potential during transmission of a nerve impulse

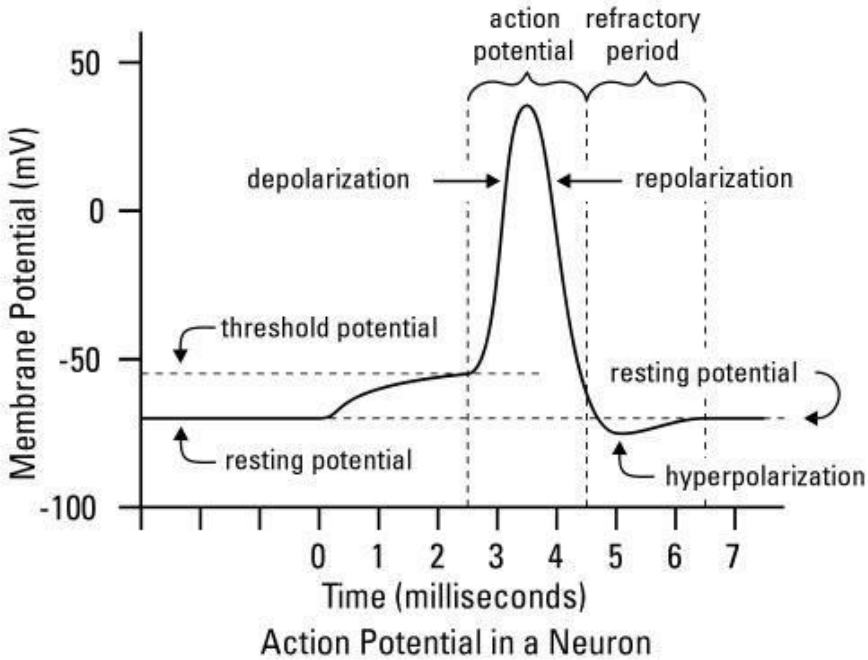
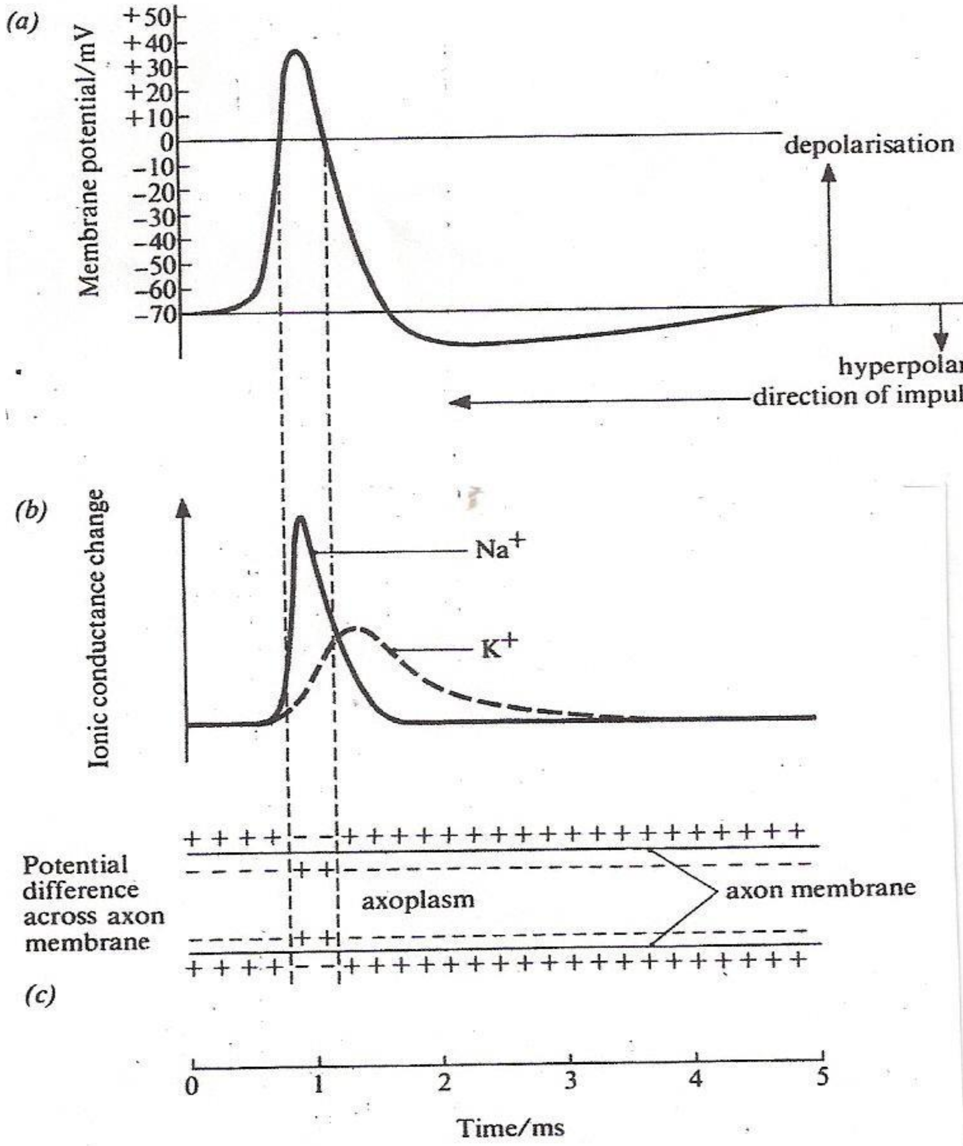


Diagram showing exchange of ions across the membrane of an axon before, after and during transmission of an impulse



The membrane is more permeable to outward diffusion of K+ than inward diffusion of Na+. This will leave a surplus negative charge inside and positive charges outside hence resting potential. When an impulse is passing, the membrane suddenly become permeable to Na+ and they diffuse into the axon rapidly and reverse the resting potential by making the inside positive and leaving the outside negative hence an action potential which is propagated along the axon as a current of propagation.

As sodium ions enter the axon, potassium ions leave to the outside and this restores the negative charges inside. The sodium ions are later expelled from the inside by Na-K pump and return potassium hence restoring the distribution of ions as normally exist when an axon is at rest.

PROPERTIES/FEATURES OF NERVE IMPULSES OR ACTION POTENTIAL.

(i) **Stimulation.** Most of the time impulses are as a result of excitation of receptors. However, the axon can be excited by exact direct application of appropriate stimulus that cause local depolarization of the axon membrane. Usually nerves are stimulated by mechanical, osmotic, chemical, thermal and electric stimuli.

(ii) **Propagation (Conduction) of nerve impulse.** Nerve impulse is propagated as wave of depolarisation that moves along the surface of a nerve cell as local currents.

(iii) **The all or nothing law**; It states that if the strength of the stimulus is below certain threshold intensity, no action potential is evoked. If, however the stimulus is above the threshold, a full-sized potential is evoked and remain the same however-much intensity the stimulus becomes.

Note:

- Threshold is the minimum strength of stimulus at which or above which action potential is transmitted in the axon/receptors.
- The weak and strong stimuli can be determined by determining the frequency of the action potential.

(iv) **High speed of transmission**; neurone impulses are transmitted very rapidly along the axon. The transmission of an impulse along the axon is determined by two factors.

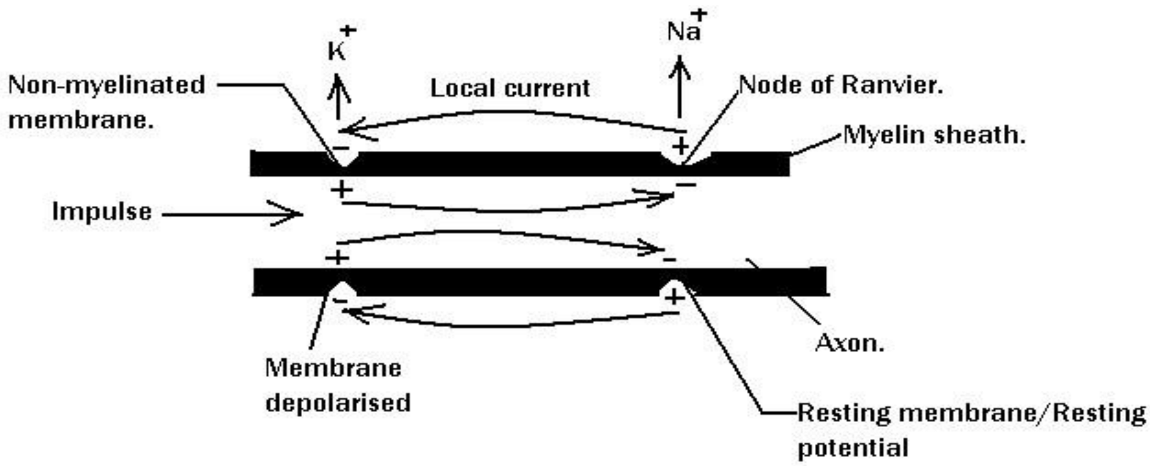
- Possession of myelin sheath.
- the diameter of the axon.
- temperature

MYELIN SHEATH.

Myelin sheath consists of 70% lipid and 30% proteins in a usual bimolecular layer of the cell membrane. Nerves possessing myelin sheath are said to be myelinated, while those without it are said to be non-myelinated. The speed of transmission is faster in myelinated nerve and slower in a non-myelinated one of the same size. The reason being that myelin sheath is an insulator (being a lipid sheath) and so when myelinated axon is transmitting an impulse, only the membranes at the nodes of ranvier undergoes depolarization, and ionic exchange occurs at that point of the membrane of the axon. And in this case, the action potential jumps from one node of ranvier to another, thereby speeding up its transmission along the axon. A condition referred to as **saltatory conduction**. So, rapid transmission in most vertebrates is achieved by myelination.

In non-myelinated neurones, the action potential occur as series of small local currents across the entire membrane, slowing down the speed of transmission of action potential.

DIAGRAM SHOWING HOW AN IMPULSE IS TRANSMITTED A LONG-MYELINATED AXON.



AXON DIAMETER (CROSS-SECTIONAL AREA).

The greater the diameter, the faster the speed. The thicker the axon the faster it will transmit impulses. This is because there will be greater area of membrane over which ionic exchange can take place and less resistance is offered.

The development of giant axon is adaptation found mainly amongst the invertebrates e.g. Annelids (earthworms, marine worms) Cray fish, prawns, crustacean squids (cephalopod mollusks). Giant axons are associated with rapid escape responses which occur due to quick transmission of impulses from receptors to muscles.

Note: - Myelination provides greater speed of transmission of impulse.

- Speed of transmission of impulse is higher in endotherms than ectotherm. Speed of transmission is higher in fast moving than slow moving animals.

Gradual degradation of myelin sheath leaving some areas bare(demyelinated) and cannot conduct impulses is referred to as **multiple sclerosis (MS)**. It mainly affects optic nerves, cerebellum, cervical, spinal cord, areas around ventricles of brain. However peripheral nerves are not affected. Symptoms of multiple sclerosis (MS) include, weakness of the limbs, pins and needles, blurring of vision and pains in the eyes.

Temperature:

Organisms with high body temperature have high impulse speed transmission than those with low temperature.

(v) **REFRACTORY PERIOD**; This is a very brief moment of about 1-3 milliseconds immediately after-action potential when an axon is incapable of transmitting the next impulse or any further action potential cannot be generated in an axon (neurone). This is because for about one millisecond after an action potential the inward movement of sodium is prevented in that region of the neurone. The membrane does not undergo depolarisation, a threshold value is not reached and no further action potential generated.

IMPORTANCE OF THE REFRACTORY PERIOD

(i) It ensures that an impulse can only flow in one direction along an axon since the portion of the axon behind the impulse cannot be depolarized again.

(ii) It limits the frequency with which successive impulses can pass along axons. This together with transmission speeds will determine the pattern of muscular responses and that of other effectors.

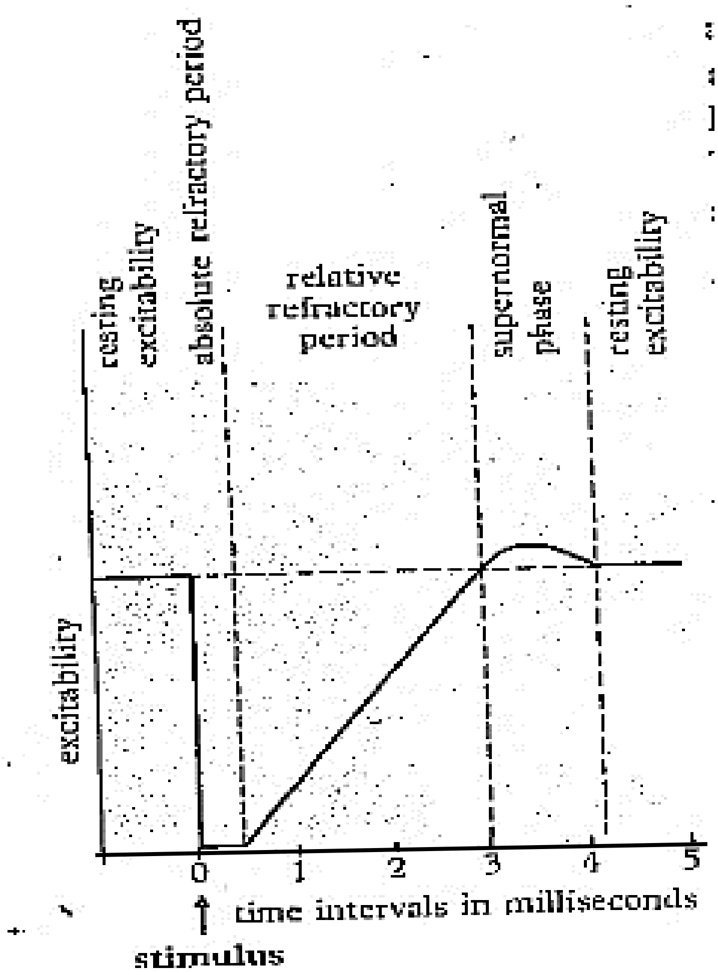
Refractory period is further divided into two,

- Absolute refractory period.
- Relative refractory period.

❖ **Absolute refractory period** is the brief period immediately after an action potential or after passage of an impulse when the axon cannot completely generate new action potential or transmit new impulses however intense the stimulus.

❖ **Relative refractory period is** a brief period immediately after an action potential was generated, during which new action potential or impulses can only be generated if the stimulus is more intense (stronger) than normal threshold value. It lasts for about 5 milliseconds.

A GRAPH SHOWING RELATIVE REFRACTORY PERIOD



THE SYNAPSE

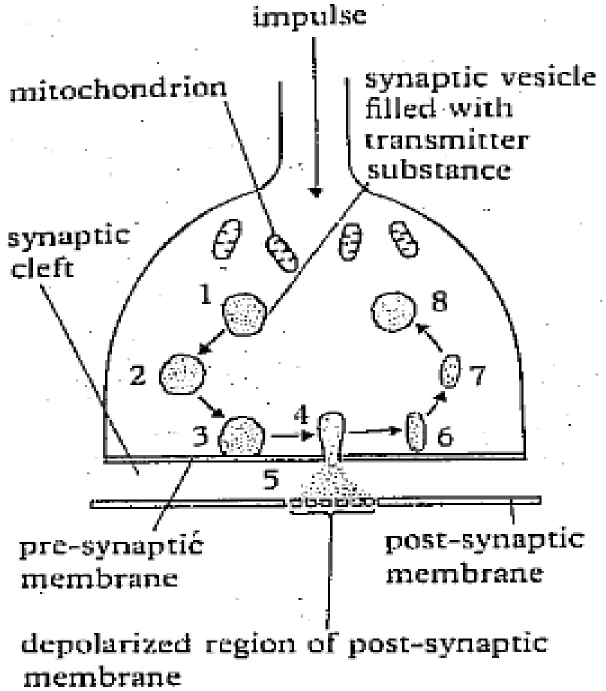
A synapse is the precise point where one nerve cell connects with another or with muscle fibrils. In other words. It is a junction between two neurons; this junction is not air tight but leaves a gap in between the two neurons known as the synaptic cleft. The axon terminal of a neuron ends in a small bulb-like structures known as synaptic knobs.

Synaptic connections are of two types;

- Nerve to nerve synapses.
- Nerve to muscle (Neuro-muscular) synapse/junction

STRUCTURE AND FUNCTIONS OF SYNAPSES.

STRUCTURE OF NERVE-NERVE SYNAPSE



STRUCTURE AND FUNCTIONS OF PARTS OF THE SYNAPSE

(i) **Synaptic vesicles**; store neuro-transmitter substance (acetylcholine).

(ii) **Neuro-transmitter substance**; conduct impulses across the synapse.

(iii) **Mitochondria**; provide energy required for the ionic movements at the synaptic membranes (the sodium –pump mechanism).

(iv) **Synaptic cleft**; contains a high concentration of calcium ions which are diffusing into the synaptic knob, excite movement of synaptic vesicles to move and fuse with pre-synaptic membrane and release neuro-transmitter substance into the synaptic cleft.

(v) **Post –synaptic membrane**; has receptor sites for the neuro transmitter substance. Has enzyme which hydrolyses the neuro-transmitter substance. Determines whether synapse is excitory or inhibitory.

(vi) **Pre-synaptic membrane** offers sites for the fusion of synaptic vesicles.

HOW A SYNAPSE FUNCTIONS

Transmission of nerve impulses across a neurone to neurone junction.

The transmission of an impulse across a synapse is by chemical means.

When an impulse arrives at the synaptic knob, it causes the presynaptic membrane to become more permeable to calcium ions. Calcium ions diffuse into the synaptic knob from the synaptic cleft. These calcium ions cause the synaptic vesicles to move towards the pre-synapitc membrane. The vesicles attach themselves to the membrane and discharge the transmitter substance into the synaptic cleft (exocytosis). The neuro-transmitter substances then diffuse a cross the synaptic cleft and attach to its specific receptor sites on the post synaptic membrane.

This process takes about 0.5ms. The empty vesicles move back into the cytoplasm where they are later refilled with neuro transmitter substances

In excitatory synapse, neuro-transmitter substance bind onto specific receptors on postsynaptic membrane, causing the specific receptors to change their configuration and their protein channels specific to sodium ions (sodium gates) open up, allowing sodium ions to diffuse into post synaptic neurone, causing depolarization of the post synaptic membrane resulting into excitatory post synaptic potential (EPSP). The excitatory post synaptic potential build up as more neuro-transmitter substances arrive until sufficient depolarization occurs to exceed the threshold value, causing generation of action potential in the postsynaptic neurone. This additive effect is called summation.

Once acetylcholine has depolarized the postsynaptic neurone, it is hydrolysed by the enzyme acetylcholinesterase which is found on postsynaptic membrane to form choline and ethanoic acid acid(acetyl). This prevents successive impulses merging at the synapse. The choline and acetyl(ethanoic acid) diffuse back across synaptic cleft and are actively transported into the synaptic knob of presynaptic neurone, where they are recoupled together to regenerate the neuro-transmitter substances. This process consumes energy.

In inhibitory synapses, the change in the configuration of the specific receptors following the attachment of transmitter substance into them, results in opening up of only those protein channels which are specific to chloride and potassium ions. Potassium ions diffuse from the post synaptic knob into the synaptic cleft, while chloride ions diffuse from the synaptic cleft into the post synaptic knob. This makes the post synaptic membrane more polarized, the resulting polarization is known as the inhibitory post synaptic potential (IPSP), which makes it more difficult for the threshold needed to generate action potential in it to be reached and thus no impulses pass cross. Therefore whether a synapse is excitatory or inhibitory depends on the nature of the receptor sites on the post-synaptic membrane rather than the nature of the transmitter substances. E.g. the transmitter substance acetylcholine has inhibitory effect on heart muscle and gut muscle but an excitatory effect on the skeletal muscles.

Inhibitory synapses in central nervous system control antagonistic muscles.

Note: After it has performed its function, the neuro-transmitter is hydrolysed by enzymes located on the post synaptic membrane.

THE NEURO-MUSCULAR JUNCTION (NERVE –MUSCLE SYNAPSE)

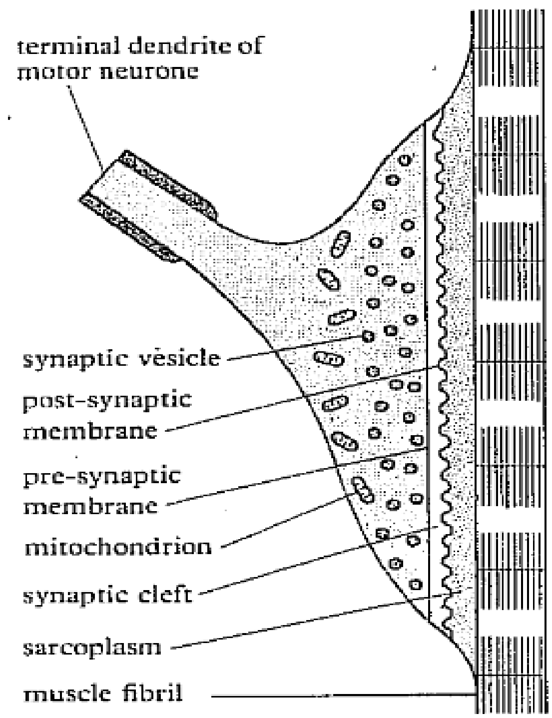
This is a point where the effector nerve meets a skeletal muscle. It is also referred to as the end plate. Each muscle fibre has a specialized region, the motor end plate, this is where the axon of the motor neurone divides and forms fine branches ending in synaptic knobs. The branches lack a myelinated sheath. The Neuro-muscular junction includes both motor end plate and synaptic knob., the membrane of the muscle is the muscle fibre (sarcolema).

TRANSMISSION ACROSS THE NEURO MUSCULAR JUNCTION

This is a special kind of synapse and the transmission at the nerve muscle junction takes place in the same way as at the synapse-synapse junction.

When an impulse arrives at the nerve-muscle junction, the pre-synaptic membrane become permeable to calcium ions. Calcium ions diffuse into the pre-synaptic knob, this causes the synaptic vesicles to move and attach on the pre-synaptic membrane and it releases the neuro-transmitter substance known as acetylcholine into the synaptic cleft. The acetylcholine then attaches on specific receptor sites on post synaptic membrane which are caused to change their configuration resulting into their protein channels to open. This allows sodium ions to diffuse into the sarcoplasm, causing depolarization of the muscles end plate. End plate potential (EPP) results, which builds up to reach threshold and an action potential is fired.

DIAGRAM OF NEURO-MUSCULAR JUNCTON



There are three possible ways of removing neurotransmitters from the synaptic clefts,

- Reabsorbtion by the presynaptic membrane.
- Diffusion out of the cleft.
- Hydrolysis by the enzymes.

PROPERTIES / ROLES OF A SYNAPSE.

1. SUMMATION.

This is where excitatory post synaptic potentials (EPSP) add up together or build up as more transmitter substances are released until depolarisation occurs to exceed threshold value and so generate an action potential in the post-synaptic neurone where a single EPSP is un able to cause sufficient depolarisation to reach threshold value to generate action potential. There are two types of summation.

(i) Spatial summation.
(ii) Temporal summation.

Spatial summation.

This is where neurotransmitter substances released simultaneously from two or more different pre-synaptic knobs of neurones, cause two or several Excitatory post synaptic potential that add up together to sufficient levels to produce sufficient depolarisation on the same post synaptic membrane of a neurone that enable a threshold value to be reached and action potential generated.

Temporal summation

This is where the same synaptic knob of a neurone is strongly and repeatedly stimulated to release sufficient transmitter substances that generate individual Excitatory post synaptic potentials (EPSP) that add up together to produce sufficient depolarisation to reach threshold value and cause action potential on the post synaptic membrane of a neurone.

2. FACILITATION.

This is where Excitatory post synaptic potential (EPSP) creates an effect and increases sensitivity and responsivess of the post synaptic membrane, giving chance to the subsequent weaker EPSP to cause depolarisation that is sufficient to reach threshold and causes action potential, where the first single EPSP was unable to produce sufficient depolarisation to reach the threshold required to cause an action potential.

3. INHIBITION.

Is where arrival of impulse at certain synaptic knobs makes the inside of the post-synaptic nerve cells more negative and the outside more positive than usual preventing passage of an impulse across. The negative charge which builds up is called the inhibitory post-synaptic potential (IPSP); making it difficult for the threshold to be reached to generate action potential. This is caused by the activities of some neurotransmitters or drugs.

4. ADAPTATION AND FATIGUE

This is where the amount of transmitter substance released by a synapse slowly reduces in response to constant stimulation for a long time until the supply of the transmitter substances is exhausted and the synapse is described as fatigued or accommodated or adapted. This occurs because the supply of transmitter substance gets exhausted and its resynthesis can not keep pace with the rate at which impulses reach the synapse.

FUNCTIONS OF A SYNAPSE.

- Transmit information between neurones and between motor neurones and muscle fibres.
- It ensures that nerve impulses (action potential) pass only in one direction. As the transmitter substances can only be released from one side of a synapse that is from presynaptic knob and the receptor molecules are only on the postsynaptic membrane. This gives precision to the nervous system, allowing nerve impulses to reach their destinations.
- **Increases sensitivity of the central nervous system by Amplification**. Release of transmitter substances due to each nerve impulses that can at times add up together to produce response where a single nerve impulse from a weak stimulus could not, increases sensitivity of the system.
- Act as junctions. Through spatial summation, responses to a single stimulus may be coordinated.
- It prevents damage to effectors through over stimulation. Achieved through **adaptations and fatigue**. Synapses allow adaptation to intense stimulation. Powerful stimulus causes high frequency impulses in the presynaptic neurone, this causes considerable release of neuro-transmitter substances into the synaptic cleft, continued high level stimulation may result into the rate of release of transmitter exceeding the rate at which it can be reformed. In this case the release of neuro- transmitter ceases and hence any response to the stimulus also stops. The synapse is said to be fatigued. The purpose is to prevent over stimulation which would damage an effector.
- **Integration, convergence and spatial summation**. A postsynaptic neurone may receive impulses from several excitatory and inhibitory presynaptic neurones. This is known as **convergence.** The postsynaptic neurone can add together these stimuli from all the presynaptic neurone to reach threshold that is sufficient to causes depolarisation and action potential at the post synaptic membrane. This is known as **spatial summation**. Spatial summation enables the synapse to act as centre for integration of stimuli from a variety of sources and the production of a coordinated response.
- **Facilitate transmission of impulses by facilitation.** This is where the first stimulus that reaches the synapse presynaptic neurone may not cause depolarisation of the post synaptic membrane of the neurone but leaves an effect or leaves the postsynaptic neurone more responsive and sensitive to the next stimulus.
- They act as filters by filtering off weak or low frequency impulses and allow only the perception of strong stimuli. This is important if the nervous system is to relay useful information about the organism and its environment.Synapses in the brain play an important part in **learning and memory.** Modification in the pattern of synaptic transmission provides means by which information from different sense organs are associated and stored within the brain.

PROBLEMS RESULTING FROM A SYNAPSE.

(i) They slow down the rate of transmission because the process of release, diffusion and effect of the transmitter substance takes longer time than conduction of action potential along the axon. So, the passage of impulse from one neurone to the next is delayed.
(ii) They are highly susceptible to drugs and fatigue which may inhibit transmission.

NEURO-TRANSMITER SUBSTANCES.

In the mammalian nervous system, there are several neuro-transmitter substances. These include;

(a) Acetylcholine.

This is an ammonium base (a nitrogenous organic base). It is formed from a combination of an acetyl CoA and choline in the presence of the enzyme choline-acetyl transferase. It is the most widespread transmitter substance. Neurones which produce acetyl choline are known as **cholinergic nerves** and these include all the parasympathetic nerves. In neuromuscular junctions and in some areas of the central nervous system (CNS), autonomic nervous system as well as membranes, normally hydrolysed by the enzyme acetyl cholinesterase present in the synaptic cleft to choline and Ethanoic acid. These two compounds are then reabsorbed by the pre-synaptic membrane and stored in the synaptic vesicles ready for use again

(b) Noradrenalin.

This is found in the autonomic nervous system. It is a monoamine hormone secreted by the adrenal gland and a neurotransmitter in the sympathetic nervous system which prepares the body for action. It also exists in the brain, increasing alertness and helping to maintain the state of arousal. It enhances response to new stimuli.

Nerves which produce noradrenalin are known as **adrenergic nerves.** It works the same way as acetylcholine and is also destroyed by oxidation in the presence of an enzyme, mono-amine oxidase, it is then after absorbed into the pre-synaptic knob. It is inhibited by drugs like mescaline and lysergic acid diethyl amide (LSD)

c)Some other minor transmitter substances include,

- **Amino acids.**

- The major excitatory neuro-transmitter in the brain is the amino acid glutamate (Glutamic acid).

- Glycine is inhibitory causing chloride channels to open in postsynaptic membrane and resulting in hyperpolarisation, preventing transmission of impulses. Glycine is important in the spinal cord where it helps control skeletal movements by making muscles relax (preventing their stimulation). Another transmitter strychnine blocks effects of glycine and allows muscle contraction.

- GABA is the most common neurotransmitter in the brain, it is also inhibitory and helps control muscle movements

•
Monoamines.
- Noradrenaline. Amphetamine is a drug that increase the level of noradrenaline in the brain
- Monoamine oxidase inhibitor treats depression by prolonging the effects of noradrenaline. It also promotes activities of all monoamines.
- Dopamine. Is concerned with voluntary control of complex muscular movements. Its deficiency results into Parkinson's disease. Dopamine is also involved in emotional responses in the cerebral cortex and has been linked with schizophrenia. It can also stimulate the "pleasure" centre of the hypothalamus. Amphetamines trigger the release of dopamine.
- Serotonin. Is associated with control of moods, depression, elation and mania. It is also involved in the onset of sleep, sensory perception and temperature regulation in the hypothalamus.

THE EFFECTS OF DRUGS AND POISONS

Any chemical that destroys acetylcholine, inhibits its formation or prevents its action, will stop synaptic transmission. They fall into two categories according to the way in which they affect transmission,

Excitatory drugs.

These increase the process of synaptic transmission in the following ways,

(i) By acting on the receptor molecules of the postsynaptic neurone in exactly the same way as the natural transmitter substances does that is they mimic the transmitter.

(ii) By stimulating the release of more of the natural transmitter.

(iii) By slowing down or even preventing the normal breakdown of the transmitter thus leaving it to continue to stimulate the post synaptic neurone. Examples.

• **Nicotine.**

They stimulate nicotinic receptors found in sympathetic and parasympathetic nervous system. Nicotine causes vasoconstrictions in guts and limbs, slowing heart rate, causes muscular contractions as they mimic acetylcholine, stimulate release of dopamine which is associated with stimulation of reward and pleasure pathways.

• **Poisonous nerve gases**; this also enhance synaptic transmission and upon nerve gas poisoning, the individual gets convulsive muscular contractions.

•
Caffeine.

Is a stimulant but relatively weak, it causes release of dopamine in brain and therefore stimulates reward pathways. It also accelerates cell metabolism leading to the release of more natural transmitters like dopamine.

- **Amphetamine** which mimic the action of noradrenaline by causing its release from nerve endings.

Inhibitory drugs.

These decrease the process of synaptic transmission in one of the following ways,

(i) By preventing release of the synaptic transmitter.

(ii) By blocking the action of the transmitter at the receptor molecules on the postsynaptic neurone. Examples,

- **Atropine.**

It stops acetylcholine from depolarizing the post-synaptic membrane and cause synaptic block.

- **Curare**. This is a poison, which prevents acetylcholine from depolarizing the post- synaptic membrane especially on nerve-muscle junctions.
- **Eserine**: it prevents the enzyme acetyl cholinesterase from destroying acetylcholine and so enhances and prolongs the effects of acetylcholine.
- **Propanol** is one of a group of substances known as Beta-blockers.
- **LSD (Lysergic acid diethyl-amide)** and **mescaline** are drugs that inhibit release and effects of noradrenaline. They have similar effects to the serotonin and are drugs known to cause hallucinations in humans.

THE CENTRAL NERVOUS SYSTEM (CNS)

The central nervous system consists of the **brain** and the **spinal cord.**

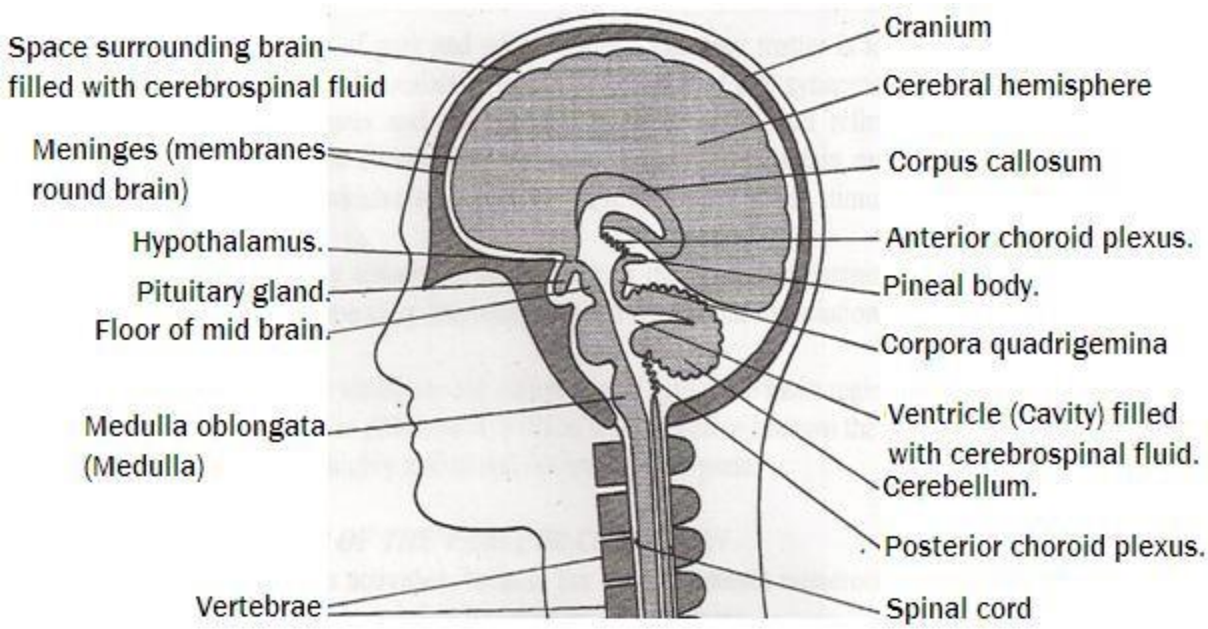
GENERAL STRUCTURE OF THE CENTRAL NERVOUS SYSTEM.

The entire central nervous system is enveloped by a system of membranes called meninges. The inner most membrane, called the pia matter, is a very delicate layer of connective tissue and blood capillaries. The outermost membrane is the dura matter is tougher. These two membranes are separated by a narrow space called the arachnoid layer, containing a network of delicate fibres filled with cerebrospinal fluid, the arachnoid layer cushions and protects the CNS. The cerebrospinal fluid is produced by vascular membranes which are anterior and posterior choroids plexuses. They form the roof of tween-brain and hind brain respectively. The roof tissues here are so thin that the pia matter lies very close to the ventricles. The pial blood vessels are well developed in these areas and cerebrospinal fluid is formed from them by mainly the process of utra-filtration. The whole of CNS and its meninges are enclosed within the cranium protecting the brain and the cranium is pierced by holes called foramina, through which passes the peripheral nerves and blood vessels. Blood vessels supply the CNS with oxygen and nutrients.

The brain and spinal cord is also made up of grey and white matter. The grey matter is located in the inner cortex of the brain and consists of group of cell bodies and synapses. These are known as association centres and are the areas where conditioned reflexes such as memory, judgement etc are coordinated. This is because they contain many synaptic connections in their cells, which allows a variety of responses to given stimuli.
The white matter is mainly situated in the interior of the brain and contains myelinated nerve fibres in groups. These carry impulses between the various association centres.
In the embryonic brain the structures are differentiated into three main regions, the fore, mid and hind brains, while in adults such division is not possible because the fore brain is very large (cerebrum) and highly folded and covers up other parts.

STRUCTURE AND FUNCTION OF THE HUMAN BRAIN.

VERTICAL STRUCTURE OF THE HUMAN BRAIN



GENERAL FUNCTIONS OF THE VERTEBRATES BRAIN

(i) To coordinate the body's activities, because the brain possesses numerous centres for coordinating specific functions such as locomotion, breathing etc.
(ii) Brain receives impulses from sensory receptors and from the whole body via the spinal cord and the 12 cranial nerves.
(iii) The association centres in the brain correlates the sensory impulses with past experiences within the stored memory that is, it rehearses the possible consequences of different responses. It also integrates (interprets) the impulses from the sense organs. This is the integration of stimuli.
(iv) It initiates the activities of the effectors by sending impulses to the effector organs such as muscles and glands.

(v) The brain stores information and builds up the memory.

(vi) It is important in the process of learning. It enables individuals to imagine, create, plan, calculate, predict. So it is site for personality and emotions.

FUNCTIONS OF THE MAIN PARTS OF THE BRAIN IN MAMMALS.

(i) CEREBRUM: Is the most superficial layer of the cerebral hemisphere, it is also called cerebral cortex its function include; -

- Controls the body's voluntary activities such as learning, walking, reasoning, personality and memory (center of intelligence and higher activities of the brain.
- It controls the two senses of smell and sight.
- Forms the bulk of human brain.
- Consists of nerve cells and myelinated nerve fibres.
- Coordinate the body's voluntary and involuntary activities.
- The bulk of the front part of the cerebral hemispheres is concerned with personality, thought (Imagination) and intelligence.
- Interior part controls emotions, behaviour and memory.
- The base of the cerebrum concerned with muscular contractions connects to other parts of the brain.

Note: An animal whose cerebral cortex is removed is known as decorticated animal.

(ii) CORPUS CALLOSUM; Connects the left and right cerebral hemispheres allowing the two sides of the cerebrum to communicate. Note. Cerebrum is divided into left and right halves known as cerebral hemispheres. These are joined by the corpus callosum. The outer and largest part of cerebral hemisphere is called cerebral cortex.

(iii) THE THALAMUS: It forms an important relay centres, connecting other regions of the brain. It functions to process all sensory impulses before relaying them to the appropriate part of the brain. (i.e. cerebral hemispheres). It is also responsible for perception of pain and pleasure.

(iv) THE HYPOTHALAMUS; this is the main controlling regions for the autonomic nervous system. It has two centres, one for the sympathetic nervous system and the other for the parasympathetic nervous system.

- The hypothalamus contains centre controlling such functions as sleep and wakefulness, feeding and drinking, speech, body temperature and Osmo-regulation, it also controls hunger, thirst, aggression, behaviour and reproductive behaviour.
- Regulates the activities of the pituitary gland through production of release factor like.
    1. Thyrotrophin releasing hormone (TRH), stimulates the anterior pituitary to release thyroid stimulating hormone (TSH)

2. Luteinising hormone releasing hormone (LHRH)/Gonadotrophin releasing hormones which stimulates the anterior pituitary to secrete the lutinizing hormone (LH) and FSH.
3. Growth hormone release-inhibiting hormone (GHRIH)/ Somatostatin which inhibits secretion of the growth hormones by the pituitary and suppresses the secretion of the thyroid stimulating hormone.
4. Adrenocorticotropin releasing factor stimulates the anterior of the pituitary gland to secrete Adrenocorticotrophic hormone.
5. Growth hormone releasing factor stimulates anterior pituitary gland to secrete growth hormone.
6. Production of oxytocin, and antidiuretic hormone.(ADH)

(v) CORPORA QUADRIGEMINA

Found in the mid brain, it controls eye movements and certain auditory reflexes.

On the floor of the mid-brain is a centre called red-nucleus. It plays an important part in controlling movement and posture of limbs and it also inhibits excessive contraction of the postural muscles. The destruction of the red nucleus results into a condition known as decerebrate rigidity. In which the extensor muscle of the limbs go into a state of tonic contraction, the limbs are held out rigidly from the body.

(vi) MEDULLA OBLONGATA; it contains reflex centres for control of blood circulation (i.e. heart rate, blood pressure) and breathing. It also controls swallowing, salivation, vomiting, coughing and sneezing.

(vii) PONS; contains centres which relay impulses to the cerebellum.

(viii) CEREBELLUM;

- It is responsible for maintenance of posture and equilibrium and the fine adjustment of movement. Receives information from the muscles and take care about posture and balance. Coordinate smooth movements.

Note: parts of forebrain include; cerebrum, corpus callosum, the thalamus, and the hypothalamus,

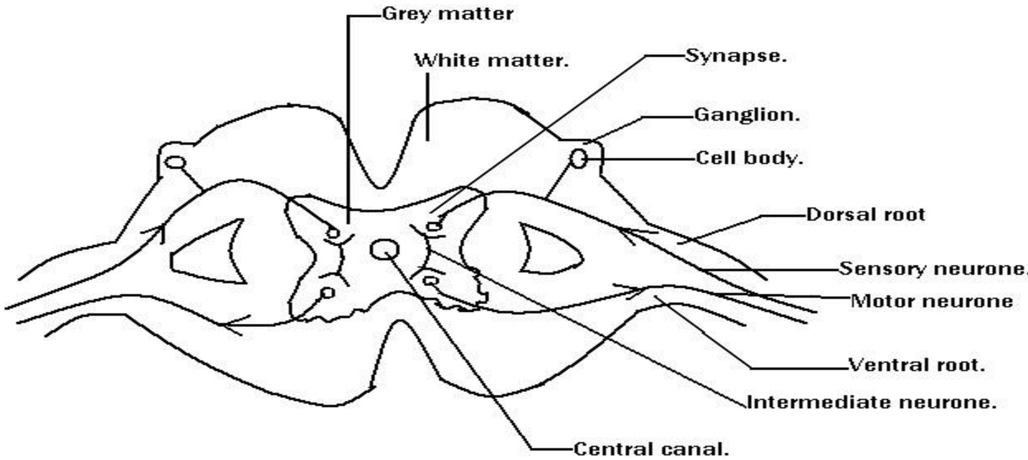
- The mid brain includes, corporaquadrigemina
- Hind brain include, medulla oblongata, pone and cerebellum.

THE SPINAL CORD.

It is a cylindrical structure with a tiny central canal. It runs dorsally along the length of the body. The central canal is filled with cerebrospinal fluid. The canal is continuous with the ventricles of the brain. The inner and central part of the spinal cord is the grey matter; it contains cell bodies, synapses and non-myelinated relay neurones. The outer part of the cord is the white matter. It contains myelinated fibres running longitudinally. Spinal cord is enclosed and protected by the vertebrae. Between two vertebrae is a pair of spinal nerves arises.

Each spinal nerve joins the spinal cord at two roots (points). The sensory fibres enter through the dorsal root. Motor fibres leave through the ventral root

STRUCTURE OF THE SPINAL CORD



Note: numerous reflex arcs do exist corresponding to the series of spinal nerves. The reflex arcs, are inter connected by longitudinal neurones located in the white matter of the cord. The longitudinal tracts also connect the spinal cord to the higher centres of the brain.

FUNCTIONS OF SPINAL CORD

- **(i)** To relay impulses in and out of spinal cord at any particular point along the cord.
- **(ii)** It connects the peripheral nervous system to the brain by way of interneurones and transmits the appropriate action potential to the effector via motor nerves.
- **(iii)** It is a coordinating centre for simple reflexes like knee Jerk and withdrawal reflex. Center for conditioned reflex. Is the type of response which is modified by past experience.
- **(iv)** Receives impulses from sense organs and relay them to the brain, they also receive impulses from the brain and them to effector organs.

THE REFLEX ACTION

Is a rapid, simple, automatic response resulting from nervous impulses initiated by a stimulus. A reflex action involves the central nervous system that consists of the brain and spinal cord, involves sensory and motor neurones and it controls involuntary activities. Examples; opening and closing of the pupil coordinated by the brain, knee jerk reflex coordinated by the spinal cord.

THE VERTEBRATE REFLEX ARC

Reflex arc represents the series of units through which impulses have to pass in order to bring about a reflex action. Reflex arc consists of receptors, whose stimulations results in impulses being generated in sensory (afferent) neurones located in the peripheral nerves. These impulses enter the spinal cord (CNS) Via the dorsal roots. The sensory neurones make synaptic connection with the intermediate (internuncial) neurones within the grey matter. These

in turn connect with motor (efferent) neurones in the ventral roots and eventually reach the effectors usually glands or muscles, which are caused to respond accordingly.
What happens in the spinal reflex response is shown during the withdrawal of ones' hand from a hot object. Stimulation of pain receptors in the skin fires off impulses in sensory neurones contained in the nerve supplying the hand. These impulses enter the spinal cord via dorsal roots, traverse the intermediate neurones, the grey matter and leaves spinal cord via the appropriate motor neurones in the ventral roots. Eventually they reach the flexor muscles in the arm which contract accordingly and the arm is lifted.

Note: The structure of the spinal cord provides a good example of a vertebrate reflex arc. Most reflexes are involuntary.

The simplest form of response in the nervous system is the **reflex action**. A more complex reflex involves the sensory neurones in the spinal cord with a secondary sensory neurone which passes to the brain. The brain identifies this sensory information and can store it for further use or send a motor nerve impulse via a motor neurone to cause response in an effector.
Conditioned reflexes. These are forms of reflex actions where the type of response is modified by the past experience. These reflexes are coordinated by the brain. **Learning** forms the basis of all conditioned reflexes, such as in toilet training, salivation on the sight and smell of food and awareness of danger.
Another reflex system exists for the control of involuntary activities. This is the **Autonomic nervous system**. Most of the activities of the autonomic nervous system is controlled within the spinal cord or brain by reflexes known as **visceral reflexes**. And does not involve the conscious control of higher centres of the brain.

IMPORTANCE OF REFLEXES TO ORGANISMS

- **(i)** Are important in making involuntary responses to various changes in both the internal and external environment in this way homeostatic control of body posture is maintained.
- **(ii)** Control of breathing, blood pressure and their systems are made effective through a series of reflex responses. This provides a greater survival value to an organism.
- **(iii)** Constriction or dilation of the Iris diaphragm of the eye in response to changes in light intensity is another example of reflex response which enables the organism to have a clear view of vision of its environment.
- **(iv)** Brain reflexes are called conditioned reflexes which play a role in the process of learning, memory and perception.

THE PERIPHERAL NERVOUS SYSTEM

The sensory and effector neurons are collectively called the peripheral nervous system (PNS). It further consists of sensory nervous system and motor nervous system. Sensory system consists of nerve fibres that convey informations from sense organs to the central nervous system while motor system consists of nerve fibres that carry information from central nervous system to effector organs such as muscles and glands. Motor system consists of somatic nervous system and Autonomic nervous system. Somatic nervous system consists of nerve fibres that convey information (impulses) from central nervous system to voluntary organs (effectors) like skeletal muscles. While autonomic NS consists of nerve fibers that carry impulses from central NS to involuntary internal organs of the body like smooth muscles, cardiac muscles and glands. Peripheral nervous system consists of two groups of nerve fibres, these are,

- Spinal nerves.
- Cranial nerves.

SPINAL NERVES.

Are connected to spinal cord. Spinal nerves form regular series, one pair on each body segment. Spinal nerves are connected to the spinal cord by a dorsal and ventral root. They are associated with receptors and effectors in the rest of the body other than the head (brain). They contain both sensory and motor fibres, for which reason they are described as mixed nerves. At the periphery side spinal nerves split into branches of nerve fibres connecting to receptors and effectors in that area of the body.

Examples of spinal nerves in humans include cervical nerves, thoracic nerves, lumber nerves, sacral nerves and pelvic nerves.

CRANIAL NERVES.

Cranial nerves arise from the brain and supply effectors and receptors of the head except the vagus nerve that supply parts of the body other than the head.

There are 12 cranial nerves in mammals and they are named from cranial nerve I to XII. Cranial nerves form irregular series, this is because,

- Dorsal and ventral roots are not joined and are widely separated.
- The further development of brain and other specialized structures in the head such as sense organs and jaws have led to the distortions in the patterns of the cranial nerves.

In all vertebrates, the cranial nerves serve the head and neck except the vagus nerves, “the wandering nerve” which passes down the neck through the thorax into abdominal cavity giving off branches to such organs as the heart, gut, lungs, kidney, spleen and liver. The vagus nerve form part of the parasympathetic nervous system.

Examples of cranial nerves in mammals include,

- Olfactory nerve (*cranial nerve I*). It is sensory nerve which runs from olfactory organs to the brain.
- Optic nerves (*cranial nerve II*). This is sensory nerve, running from the retina of the eye to the brain.
- Oculomotor nerve (*cranial nerve III*). This is a motor nerve running from the brain to the four eye muscles and controls eye movements.

- Auditory nerves (*Cranial nerve VIII*). It a sensory nerve which runs from semi-circular canals of the of the ear to the brain.
- Vagus nerve (*cranial nerve X*).

It is both sensory and motor nerves. Therefore it is a mixed nerve. It runs between the brain and the heart, gut and part of the respiratory tract and decreases heart rate, it stimulates peristalsis and is concerned with speech and swallowing. It includes an important motor nerve of the autonomic nervous system supplying the heart, bronchi and gut.

Spinal and cranial nerves that help move your head, trunk, limbs are called somatic nerves. Their motor axons deliver information from receptors in the skin, skeletal muscles and tendons to central nervous system (CNS). The motor axons deliver commands from CNS to body's skeletal muscles.

Spinal nerves and cranial nerves that carry signals to and from smooth muscles, cardiac (heart) muscles and gland cells are called autonomic nerves. They deal with internal organs and structures.

THE AUTONOMIC NERVOUS SYSTEM (ANS)

It is part of the peripheral nervous system. It consists of neurones that convey impulses from Central nervous system (CNS) to smooth muscles, cardiac muscle and glands which are not under conscious control. It controls **involuntary actions** and internal environment. Nerve fibres of the Autonomic nervous system run from CNS to the various internal organs like the heart, lungs, intestines and glands. It is concerned with controlling the body's involuntary activities such as the beating of the heart, movements of the gut, and secretion of sweat.

The autonomic nervous system is divided into two parts;

i. Sympathetic systems.
ii. Parasympathetic systems.

Sympathetic and parasympathetic systems both contain nerve fibres serving structures or effector organs under involuntary control. In both nerve fibres emerge from brain or spinal cord and pass to involuntary organs. Along the nerve fibres from CNS to the involuntary organs there exists a complex set of synapses constituting a ganglion. **Ganglion** is a mass of nervous tissue containing many cell bodies and synapses enclosed in a connective tissue sheath.

The nerve fibres from CNS towards the ganglion (proximal to ganglion) is called **pre-ganglionic fibres** while nerve fibres from the ganglion towards the effector organs (distal to the ganglion) are called **post-ganglionic fibres**.

The sympathetic and parasympathetic nervous are antagonistic effects on organs they supply and enables the body to make rapid and precise adjustments of involuntary activities in order to maintain a steady state. The structures of the two systems differ in the organization of their neurones.

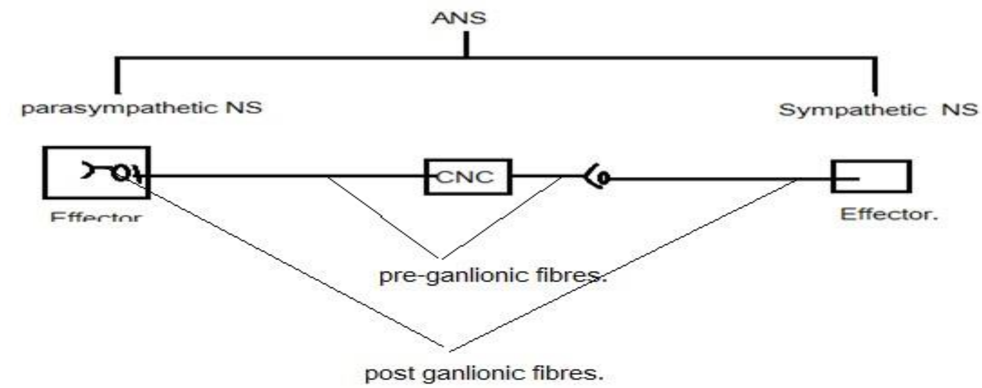
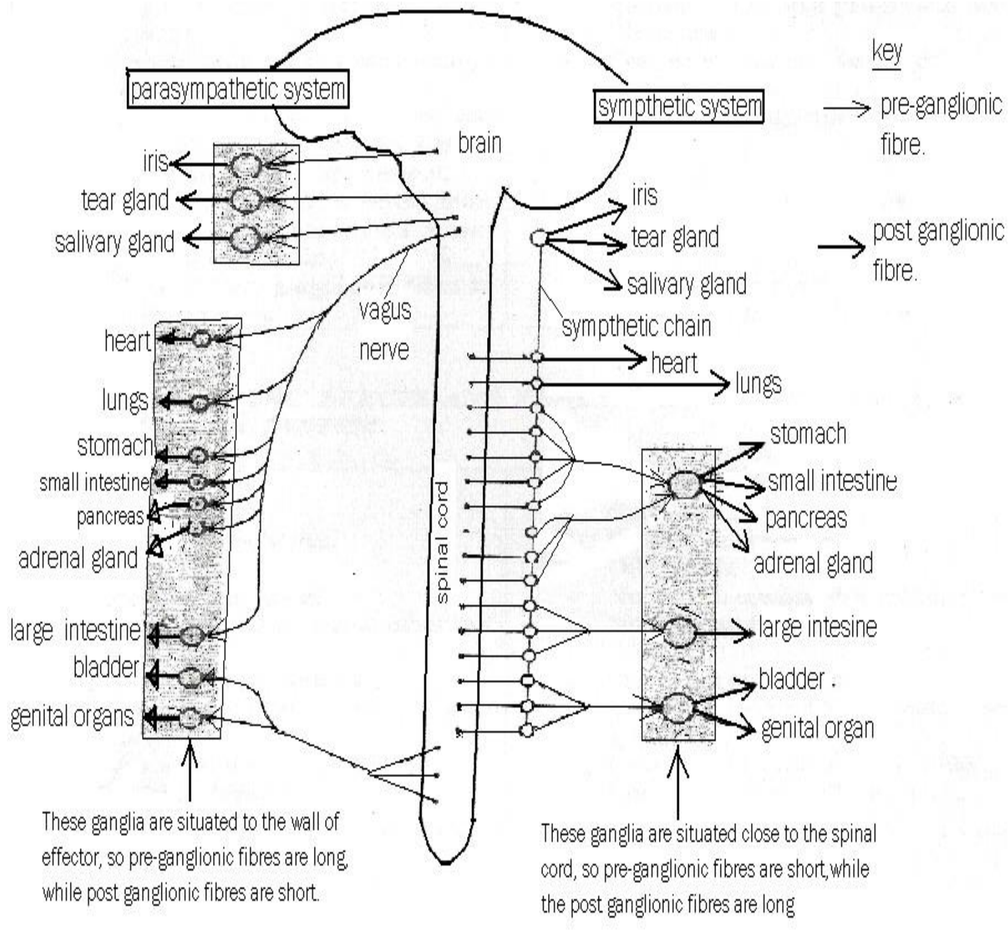


DIAGRAM OF SYMPATHETIC AND PARASYMPATHETIC NERVOUS SYSTEM (AUTONOMIC NERVUS SYSTEM)



COMPARISON BETWEEN THE STRUCTURE OF THE PARASYMPATHETIC AND SYMPATHETIC NERVOUS SYSTEM

SIMILARITIES

- Both consist of pre-ganglionic and post ganglion nerve fibres.
- Both consist of ganglia.
- In both nerves originate from the central nervous system (brain or spinal cord)
- In both pre-ganglionic fibres secrete acetylcholine.
- Both systems mainly consists of motor neurones.

DIFFERENCES

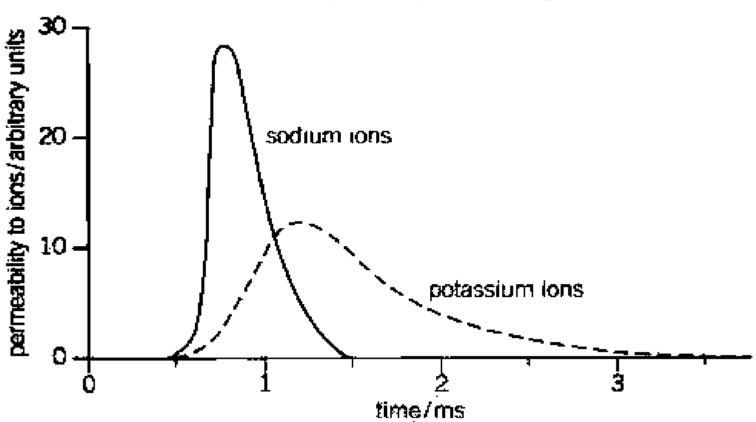
Sympathetic nervous system.	Parasympathetic nervous system
➢ Nerves emerge from mainly spinal cord (consists of only spinal nerves)	➢ Consists of mainly the cranial Nerves especially vagus nerves, though spinal nerves are too present.
➢ Ganglion close to spinal cord.	➢ Ganglion close to effectors.
➢ Pre-ganglionic fibre shorter, while post ganglionic fibre long.	➢ Pre-ganglionic fibre is longer, while post ganglionic nerve fibre is shorter.
➢ Pre-ganglionic fibre cover wide area.	➢ Pre-ganglionic fibre cover small area.
➢ Effects diffuse.	➢ Effects are localised.
➢ Releases noradrenaline at the effector.	➢ Releases acetylcholine at the effectors.
➢ Excites homeostatic effect.	➢ Inhibitory homeostatic effect.
➢ Dominant during anger, stress and controls reactions to stress.	➢ Dominant during rest and controls routine body activities.
➢ Increases metabolism, sugar level, heart rate, sensory awareness.	➢ Decreases metabolism, levels sugar, heart rate, sensory awareness.
➢ Sympathetic chains present (Ganglia form a series of inter connected chains)	➢ No sympathetic chain (Ganglia do not form a series of interconnected chain)

DIFFERNECES IN THE EFECTS AND FUNCTIONS OF PARASYMPATHETIC AND SYMPATHETIC SYSTEM.

PARASYMPATHETIC	SYMPATHETIC SYSTEM
- Slows heart rate.	- Accelerates heart rate.
- Dilates arterioles.	- Constricts arterioles.
- Constricts bronchioles.	- Dilates bronchioles.
- Constricts iris.	- Dilates Iris
- Stimulates tear gland.	- No known comparable effect.
- Causes flow of saliva and other gut secretions.	- No comparable effect.
- Speeds up gut movements.	- Slows gut movement.
- Relaxes bladder and anal sphincters.	- Contracts bladder and anal sphincter.
- Causes contraction of bladder.	- Causes relaxation of the bladder.
- No comparable effect.	- Contracts erector pili muscles.
- No comparable effect.	- Increases sweat secretion.

Exercise 4

1. *During an action potential, the permeability of the cell-surface membrane or an axon changes. The graph shows changes in permeability of the membrane to sodium ions (Na+) and to potassium ions (K+) during a single action potential.*



(a) Explain the shape of the curve for sodium ions between 0.5ms and 0.7ms. (03 marks)

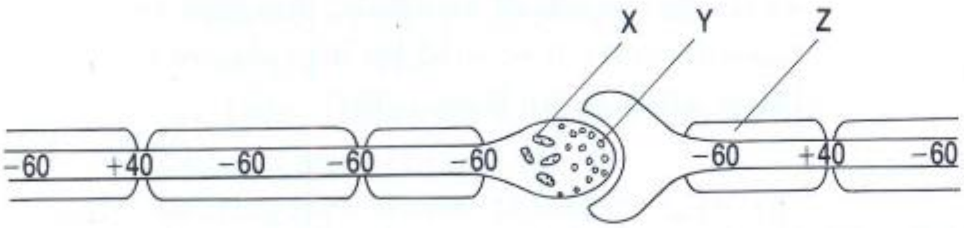
(b) (i) During an action potential, the membrane potential rises to +40 mv and then falls. Use information from the graph to explain the fall in membrane potential. (03 marks)

(ii) The refractory period of a neurone has two components, absolute and relative. Calculate the maximum number of impulses that can be generated in a neurone when the total refractory period is 5ms. (02 marks)

(iii) Calculate the percentage increase in nerve impulses if the stimulus intensity is raised high enough to overcome the relative refractory period of 4ms. (03 marks)

(c) After exercise, some ATP is used to re-establish the resting potential in axons. Explain how the resting potential is re-established. (02 marks)

2. *The diagram below shows part of two nerve fibres and a synapse. The figures indicate the value in mV of the potential across the membrane between the cytoplasmof the fibres and the extracellular fluid at intervals along each fibre.*



(a) (i) Draw a circle around one region of the diagram where an action potential exists. Explain your choice. (02 marks)

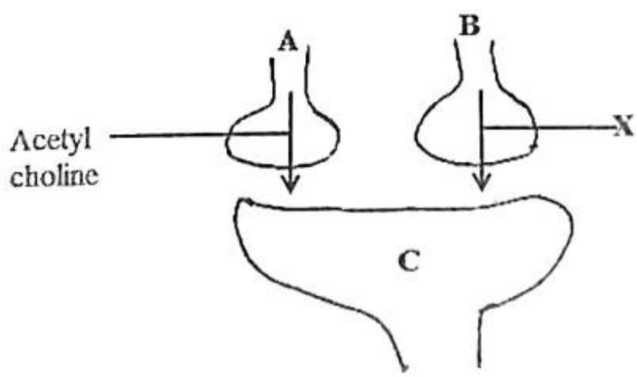
(ii) by means of an arrow on the diagram, indicate the direction in which action potentials would normally travel along these fibres. Explain your choice of direction (02 marks)

(b) *Identify structures X and Y, and state how each is involved in the transmission of nerve impulses. (04 marks)*

(c) *(i) what is the major chemical constituent of structure Z? (01 mark)*

(ii) state two effects of structure Z on the transmission of action potentials (02 marks)

3. *The figure below shows dendrites from neurons* ***A*** *and* ***B*** *forming synapses with neuron* ***C****.*



(a) Explain what would happen if

(i) Acetylcholine increased the permeability of the post synaptic membrane to Na^+ ions (03 marks)

(ii) X increased the permeability of the postsynaptic membrane to Cl^- ions (03 marks)

(b) State a benefit of neuron C forming synapses with two neurons A and B. (02 marks)

(c) *State* ***three*** *functions of a synapse (03 marks)*

End.