

The Nervous System

This system can be divided into two:

- **The cerebrospinal** (voluntary) nervous system.
- **The Autonomic** (involuntary) nervous system.

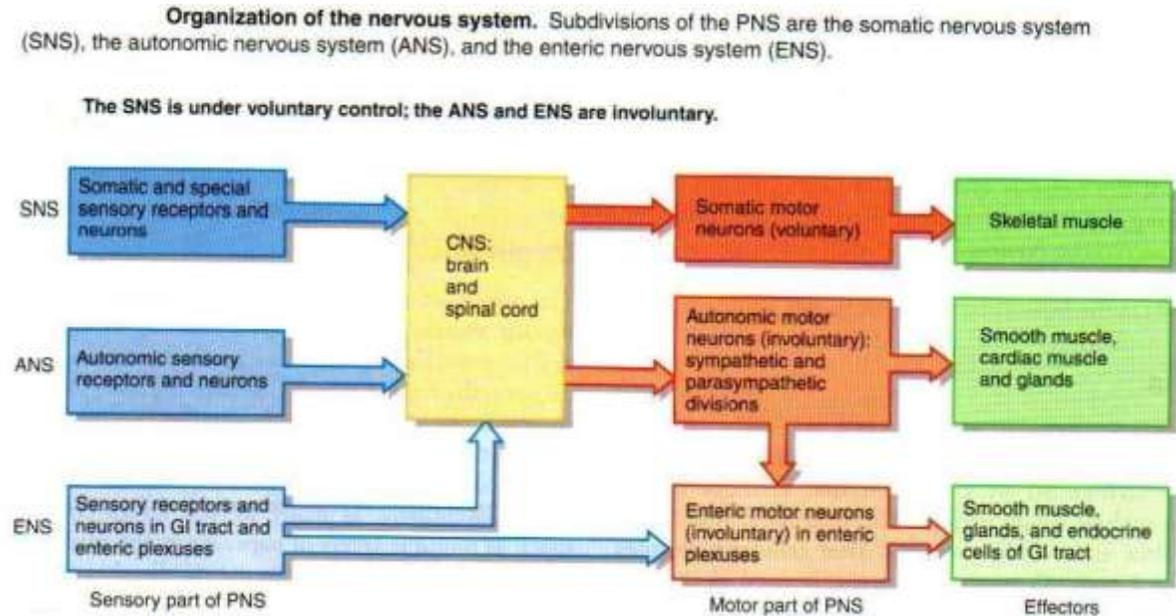
Or

- **Central**-that inside the brain and spinal cord.
- **Peripheral**-that outside the brain and the spinal cord.

The functions of the nervous system are:

1. **Sensory**-touch, taste, hearing, sight, smell.
2. **Integrative**-recognizing it, making sense of it, coordination.
3. **Motor**-capability of making action.

Figure 1 - Classification of Nervous System

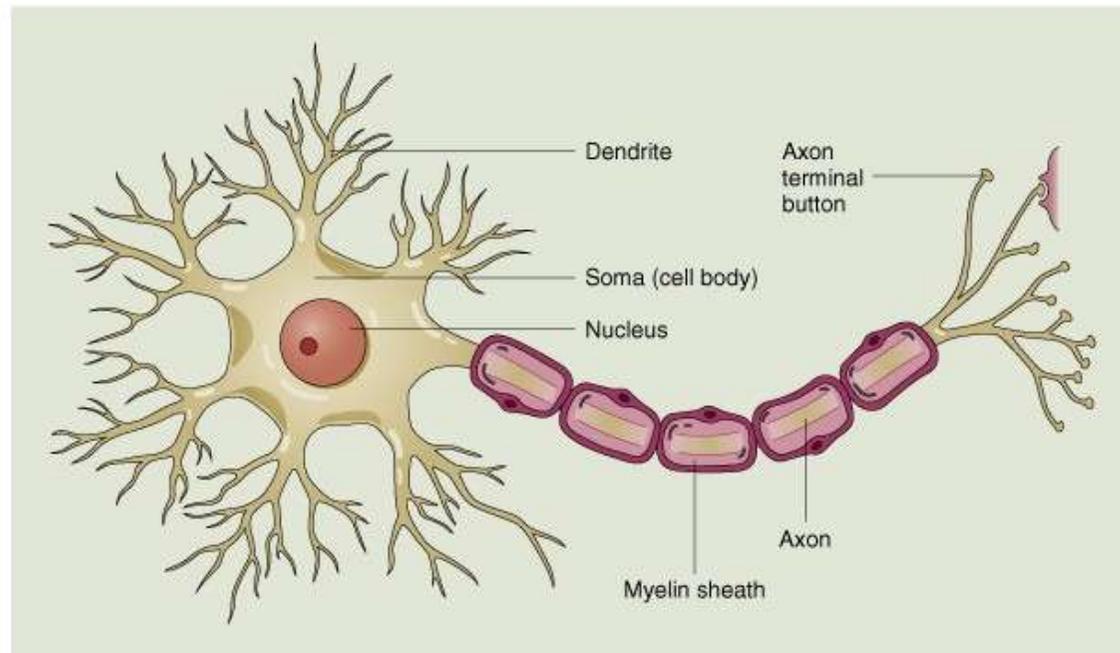


The **Neuron** is the basic unit of the nervous system.

It consists of a **nerve cell and it's processes** (the axon and dendrites)

- **Axon**: which takes impulses away from the cell body.
- **Dendrite** (Gr. Dendron or "tree"), which are the receiving processes.

Figure 2 - A Typical Neuron



A neuron must not be confused with a nerve, which is a collection of nerve fibres, dendrites and axons together.

Hence:

- **A nerve fibre** is one process (towards or away from the cell body)
- **A nerve** is seen anatomically as a single unit but consists of hundreds of nerve fibres, both sensory and motor (some myelinated, some not – see later)

A collection of cell bodies outside the brain or spinal cord is called a **ganglion** (plural –ganglia); inside the brain or spinal cord they are called a **nucleus** (plural –nuclei).

All nerve fibres can look grey or white, depending on whether the fibre is myelinated or not:

- If it is white, it does have a myelin sheath.
- If it is grey, it doesn't have a myelin sheath.

Nerves carrying impulses **towards** the brain or spinal cord are called **afferent** (sensory) nerves.

Nerves carrying impulses **away** from the brain or spinal cord are called **efferent** (motor).

Individual neurons need to communicate with each other and with their target structure e.g. a muscle or a gland. Usually they have numerous connections, sometimes thousands as in the case of the brain.

Types of neurons

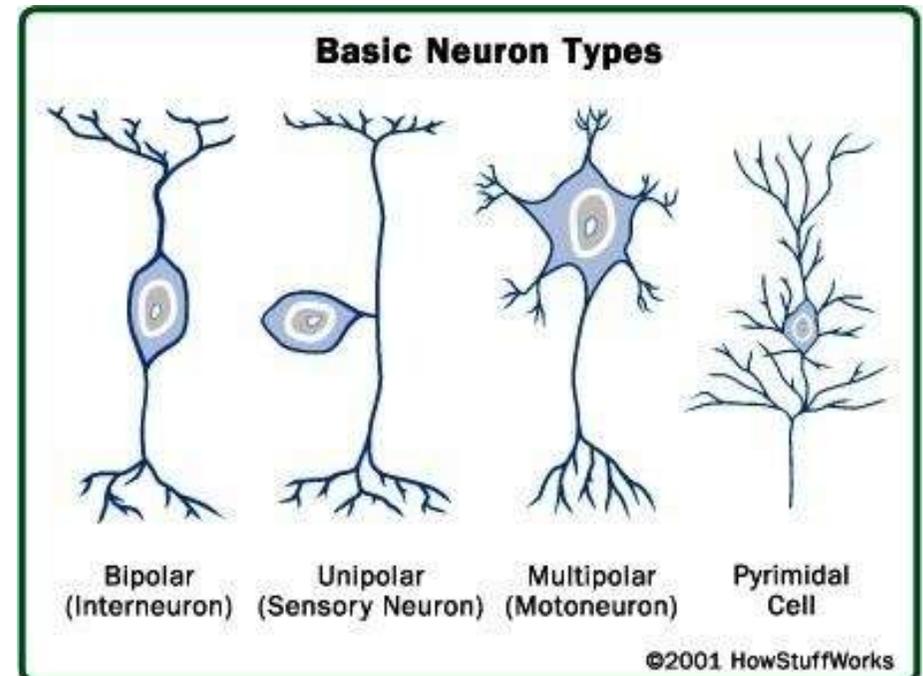
Neurons

These diagrams are somewhat simple and schematic, but they demonstrate the overview of different types of neurons. They are not all just like the typical nerve shown above. It demonstrates the cell body with all its organelles, and its processes.

Nerve impulses

A nerve impulse is a wave of electricity that flows along the nerve fibres. For this to occur the nerve fibre has to create a situation that is 'ready' for an impulse - **a resting potential**. It achieves this by pumping sodium out of the cell and potassium in, this being done by the sodium/potassium ATPase pump. This pumps out three sodium ions for every two potassium it pumps in (see video). So along with each ion is taken a positive charge. The end result of this is there is an 'electrical difference' between the inside and outside of the

Figure 3 - Different Types of



cell. Hence the nerve, even at rest, is constantly at work. It has to work to maintain an electrical charge across its membrane, creating a polarity. When a stimulus comes along the nerve cell membrane is 'excitable', in that it will respond to that stimulus. This stimulation manifests as a wave of electrical excitation flowing along the nerve fibre.

Figure 4 - Diagram Showing An Action Potential In Non-Myelinated and Myelinated Nerves

The flow of the action potential along the nerve fibre once it has started, cannot be

stopped (bar injury) and its speed is dependent upon certain factors:

- The diameter of the nerve fibre – the **bigger** the diameter, the **faster** it flows.
- Whether or not the fibre is **myelinated**; if they are myelinated, the speed of the impulse is faster
- The temperature – the **colder** it is, the **slower** the impulses

Myelination

Myelination is formed by specialised cells, **Schwann cells**, wrapping around the nerve fibres during the embryological development of the nervous system.

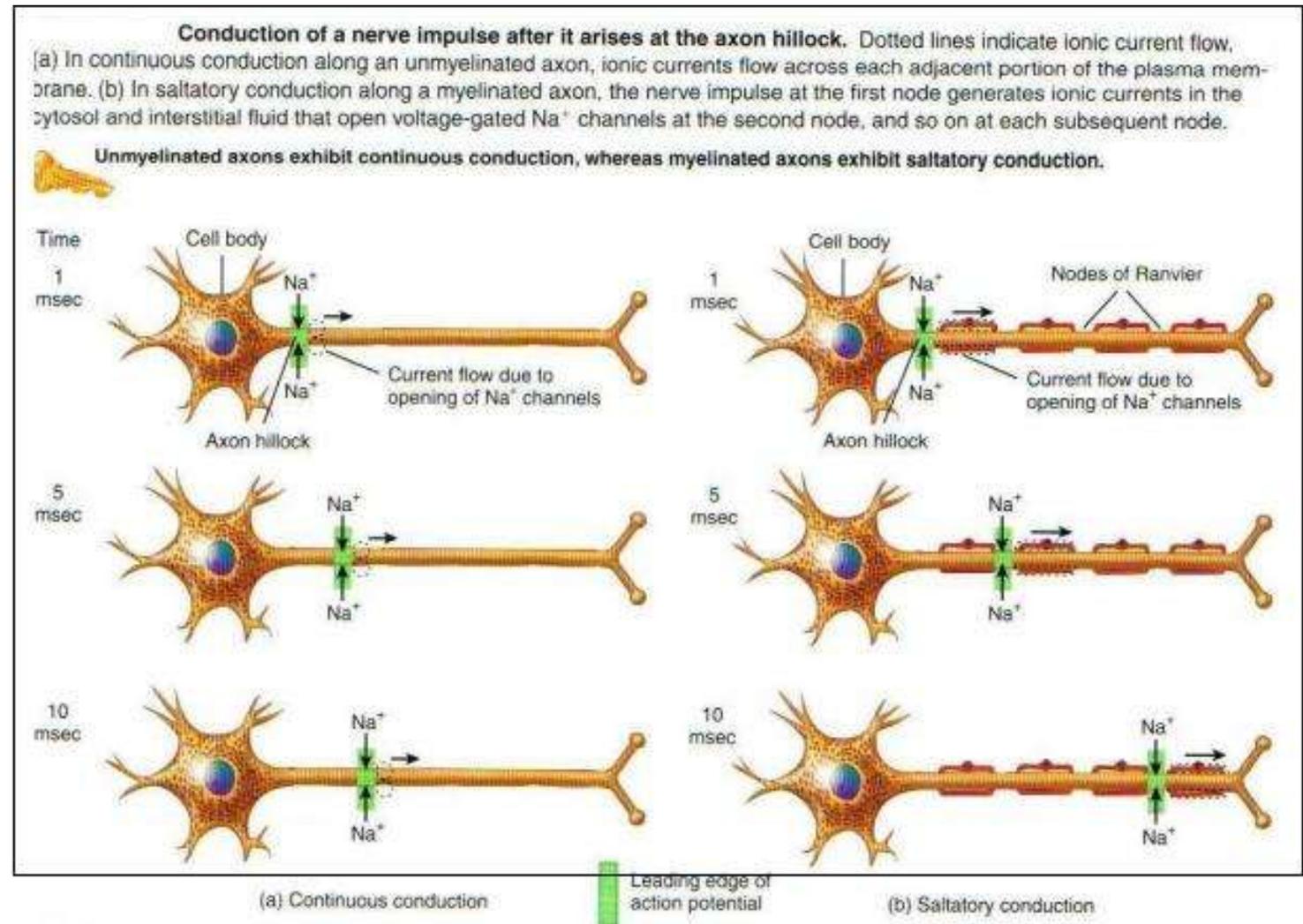


Figure 5 - Diagrams showing Myelination of Nerve Fibres by Schwann cells

Schwann cells only exist in the Peripheral nervous system (PNS); in the CNS oligodendroglia - one type of specialised connective tissue cells found in CNS (glia=glue), i.e. it hold it together. In PNS get a high degree of repair and regeneration with the Schwann cells playing a major part in this. In the CNS, the damage is permanent, e.g. a stroke - the nerve cells die, but recovery shows training of spare nerve cells this is an example of the plasticity of the nervous system

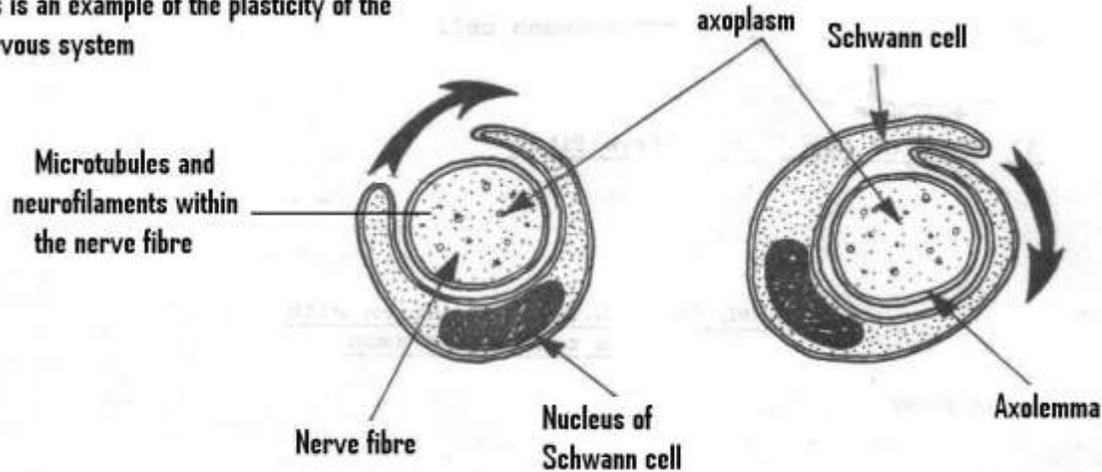
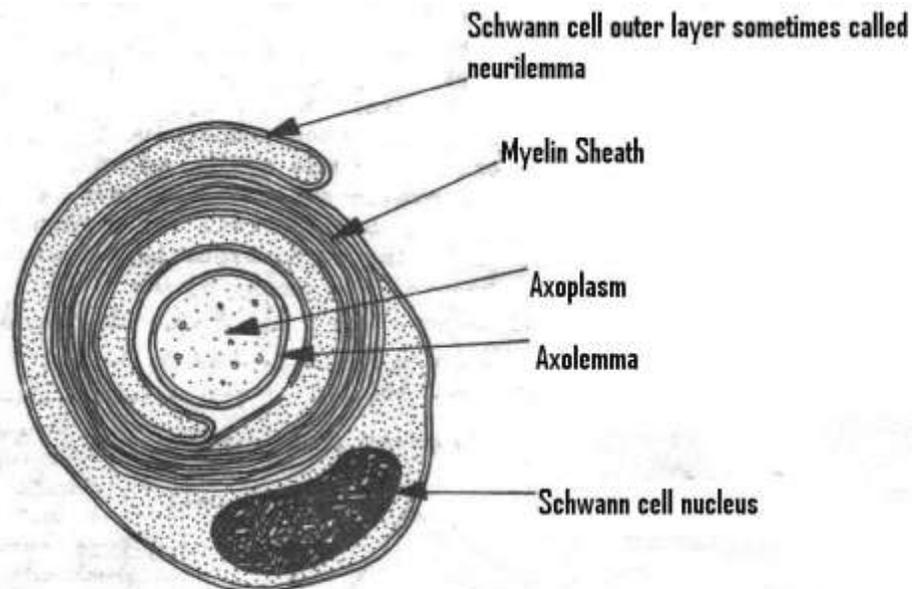


diagram showing jelly roll formation of Schwann cell around nerve fibre



Transverse section of myelinated nerve fibre

You will recall that the membrane of a cell consists of lipid (fat) and Schwann cells have even higher lipid content than normal; so many layers of cell membrane will create 'insulation' along that segment of the nerve fibre.

The end result of this is called This wrapping, and layers of fat, give the nerve fibre a white appearance, but on closer inspection there are spaces between the Schwann cells, known as **Nodes of Ranvier**. The end result of this is that only small, regular, exposed regions of the nerve fibre are exposed.

Here, the impulse doesn't 'flow' along the nerve fibres, but jumps from node to node; this being known as saltatory (leaping) conduction. This greatly affects the speed of the action potential along the nerve fibre:

- About 0.5 metres per second for non-myelinated fibres
- About 200 metres per second for myelinated.

Non-myelinated nerve fibres

Even though non-myelinated nerve fibres don't have the Schwann cell wrapped around them, as with myelinated fibres, Schwann cells are still involved as a support system; here several nerve fibres would share one Schwann cell:

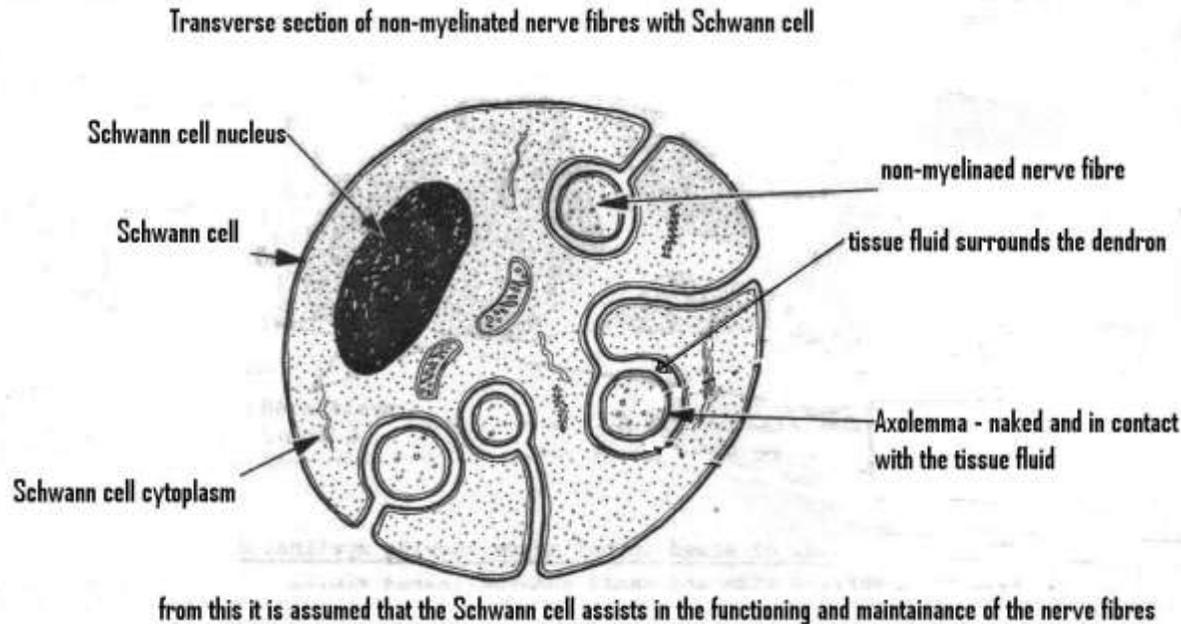
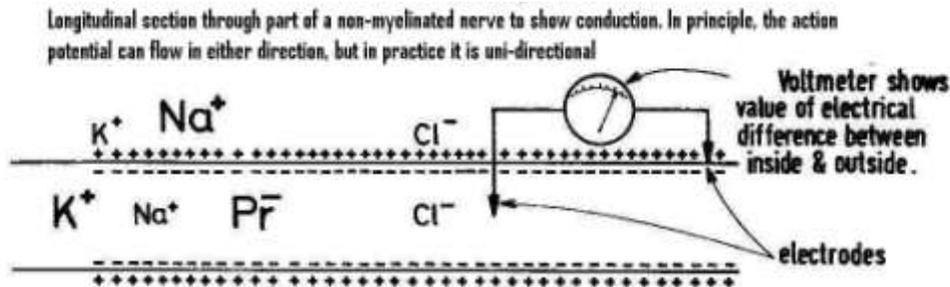


Figure 6 - Diagram Showing A Schwann Cell Enveloping Several Non-Myelinated Nerve Fibres

Not only do Schwann cells assist in speeding up action potentials, but also are thought to be important in recovery after injury (only in the peripheral nervous system) and to aid the passage of nutrients and ions to and from the enclosed neurons in their normal functioning.

All nerve cells are 'excitable' because they can be stimulated and are able to propagate electrical impulses from one point to another along the cell membrane. There are two types of 'potential' within nervous tissue:

- **The resting potential**—this is when the nerve is at rest. As was said earlier, the cell and processes have to constantly work to maintain an electrical imbalance across its membrane. In myelinated nerves this is about -70mv, cardiac muscle is about -45mv and some small non-myelinated nerves it is -30mv. It is ready to transmit an impulse, which is:
- **The action potential**—The duration of the action potential itself is only 1-2 milliseconds. This can arbitrarily be seen as an electrical impulse along the nerve fibre, but is actually caused by a flow of sodium and potassium ions, each flowing down their diffusion gradients, taking their electrical charge with them.



the has

From the diagram you can see that the distribution of ions inside and outside the cell membrane is not the same.

There are proteins with a negative charge (anions) inside fibre (their size means they cannot get out). Chloride also a negative charge, but it can move freely in and out, but it balances itself electrically with the protein and there is more outside

Sodium and potassium

1. Sodium is the primary extracellular cation.

- Sodium is the cation that is actively pumped out; hence there is more outside than inside. The sodium pumped is held out against its concentration gradient (using work and energy) by the sodium/potassium ATPase pump. (The fact that sodium is the main ion in the fluids outside the cells of the body is the same throughout the body and is the reason our blood tastes salty)
- Potassium is the primary intracellular cation. It is the same pump that pumps sodium **out** that pumps potassium **in**.

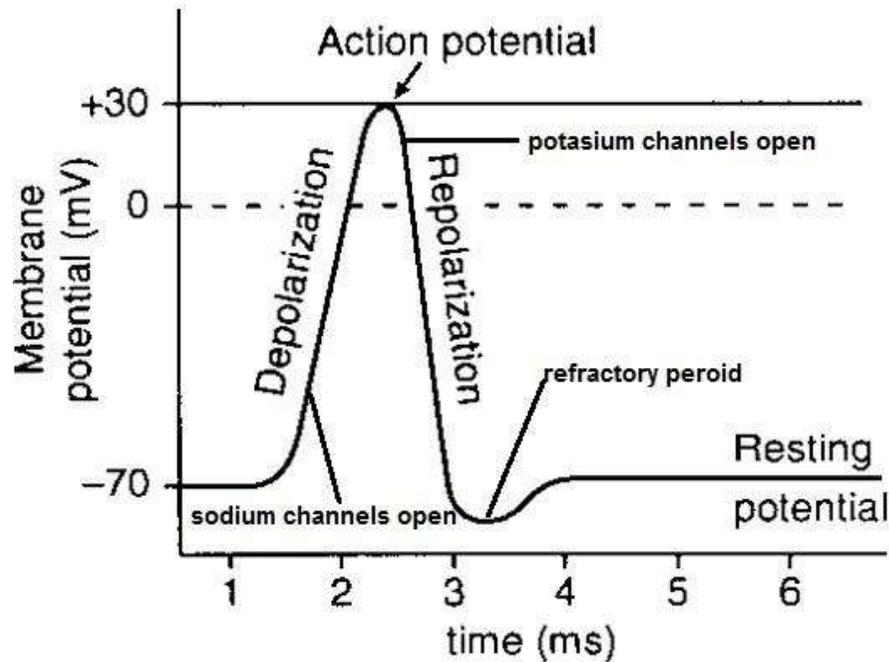


Figure 7 - Graph Showing Change In Polarity With And Action Potential

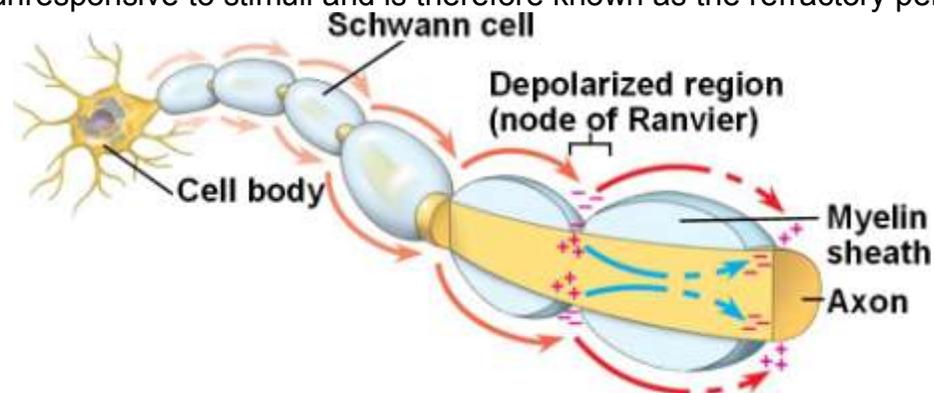
- When the nerve fibre is stimulated there is a change in the polarity of parts of the membrane. The membrane needs a minimum level of stimulation (liminal) for an action potential to be propagated, but when it is reached it precipitates a wave of electrical excitation along the fibre. This causes 'voltage gated' (i.e. electrically sensitive) sodium channels to open and sodium ions flow into the cell, taking an electrical current with them. During this brief phase of excitation, the polarity is neutralised (depolarisation). If it stayed like this, equilibrium would establish itself with equal concentrations of sodium inside and outside the cell.

- Following this, 'voltage gated' potassium channels open and potassium flows into the fibre, taking their electrical charge with them

- For the brief period that the action potential is there, the inside of the fibre changes from negative to positive but the sodium pump kicks in again and

pumps the sodium back out and the potassium back in. just after the area of depolarisation is a region of hyperpolarisation (just before 'normal polarisation is re-established) and non-responsive to an ordinary stimulation. So where the action potential is and the area of recovery, including the period of hyperpolarisation, the nerve is unresponsive to stimuli and is therefore known as the refractory period. It follows that the number of impulses along the nerve fibre is limited at ionic

- In myelinated fibres, the same principle applies except that the exchange **only** occurs at the sites of the **nodes of Ranvier**.



Saltatory conduction along a myelinated nerve fibre

Synapses

Figure 8 - A Synapse

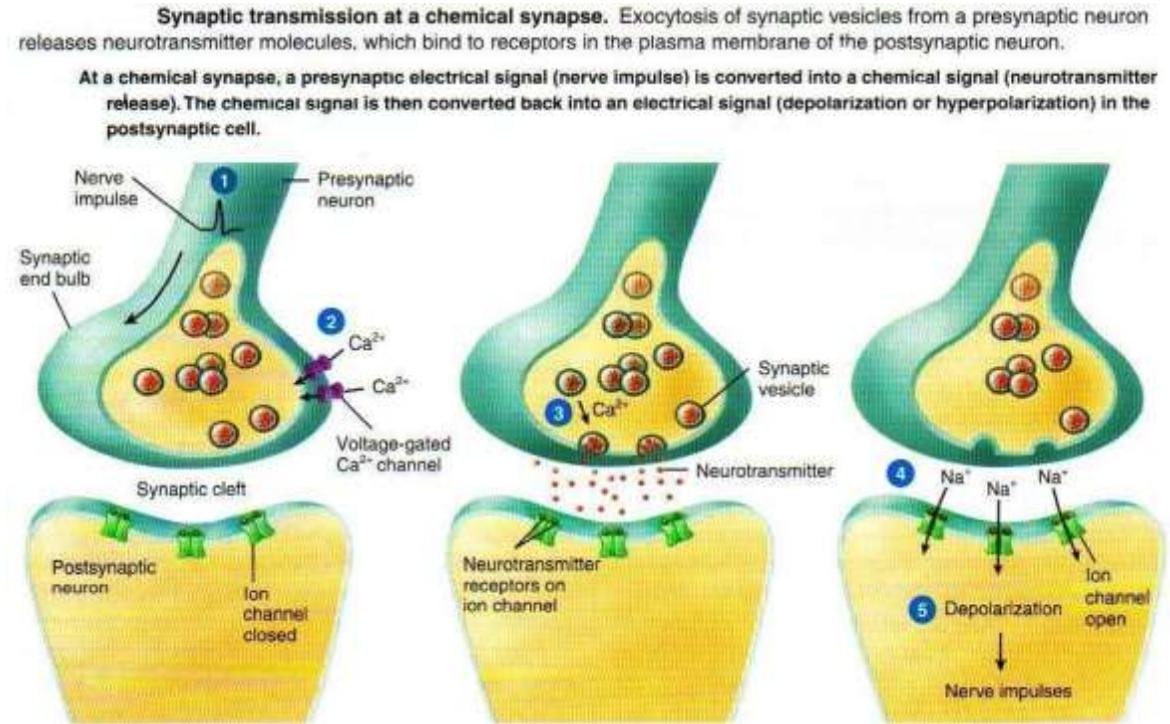
Nerve fibres do not attach directly to each other or to target tissues; they come into close apposition with them, but with a definite gap between the two called a synapse. The term synapse includes

- The end of the nerve fibre,
- The target tissue and
- The gap – the synaptic cleft.

1. When the action potential reaches the end of the axon, the pre-synaptic bouton, it affects the permeability of the membrane.
2. It then also stimulates the release of a chemical, a neurotransmitter substance from vesicles within the synaptic end bulb
3. This chemical diffuses across the synaptic cleft (the distance here is measured in thousandths of a millimetre)
4. The neurotransmitter then combines with receptor sites on the post-synaptic
5. membrane (they occur all over the post-synaptic cell, but are concentrated at the
6. synaptic sites)

The effects of neurotransmitter release:

- An **excitatory neurotransmitter** would cause stimulation of the post-synaptic membrane and contribute to precipitating an action potential there. Stimulation is dependent upon the temporal (frequency of impulses) and spatial (concentration of synapses) arrangement.
- An **inhibitory neurotransmitter** has the effect of hyperpolarizing the postsynaptic membrane and blocking excitation. Target tissues can have both types of nerve fibres converging on them (especially in the CNS) and it is the 'balance' of the two that results in the effect.



Neurotransmitters:

The neurotransmitters released at the synapses depend upon the target tissue

- Acetylcholine is released at muscle end plates, and parasympathetic nerve endings
- Nor-adrenaline is released at sympathetic nerve endings
- GABA (gamma-amino-butyric-acid) and dopamine are released primarily in the CNS
- 5-HT (serotonin) is released in the CNS and gut

After the neurotransmitter has been released, with its consequent effect, it needs to be removed from the synaptic cleft.

In cholinergic synapses, where **acetylcholine** (Ach) is the transmitter, there are enzymes near the post-synaptic membrane called cholinesterase, which break down the Ach after it has had its effect. By removing Ach from the post-synaptic membrane receptors, it makes more receptors available for the next batch of neurotransmitters in the next impulse; if the neurotransmitter is not removed, it effectively 'blocks' the receptor site and the next lot of neurotransmitter will have no effect.

In catecholamine synapses, the neurotransmitter could be **noradrenalin** (or dopamine or 5-HT). Here, the neurotransmitter is not broken down by post-synaptic enzymes, but is reabsorbed back into the synaptic bulb again and recycled.

Summary of nerve impulses and synaptic transmission:

- All nervous tissue is excitable has the ability to respond to stimulus, creating an
- Excitation creating a nerve impulse, or an action potential
 - This excitation is electrical in nature
 - The membranes of nerve cells and their processes are maintained at a resting potential with sodium and potassium the main cations involved; sodium being pumped out, and potassium being pumped in
- With the arrival of the action potential, the cell membrane depolarises with sodium passing into the cell/fibre and potassium out; this action potential is propagated along the nerve fibre.
- Immediately after the action potential has passed, the sodium pump set in and pumps the sodium back out of the nerve fibre, and the potassium back in to re-establish the resting potential
- When the action potential reaches the synapse at its target tissue, it stimulates the release of a neurotransmitter which diffuses across the synaptic cleft; effecting a change on the post-synaptic membrane in terms of its stimulation or inhibition
- The overall effect on the post-synaptic membrane is a summation of temporal and spatial stimulation
- After the end effect at the post-synaptic membrane, the neurotransmitter is removed from the synaptic cleft by enzyme breakdown, or pre-synaptic reabsorption.

The Brain

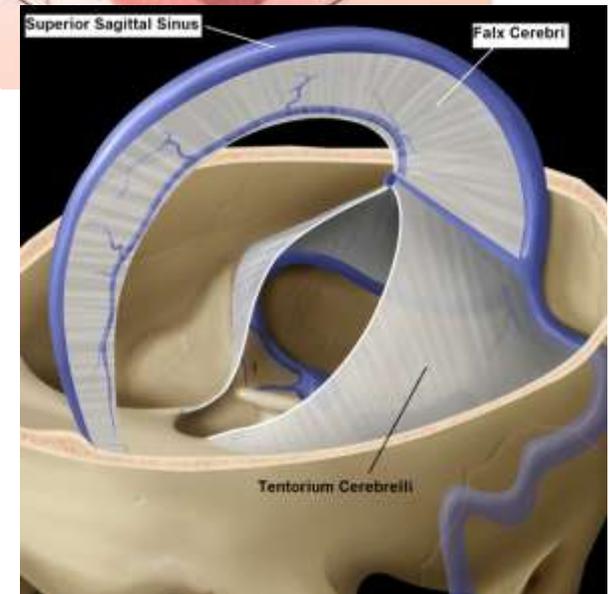
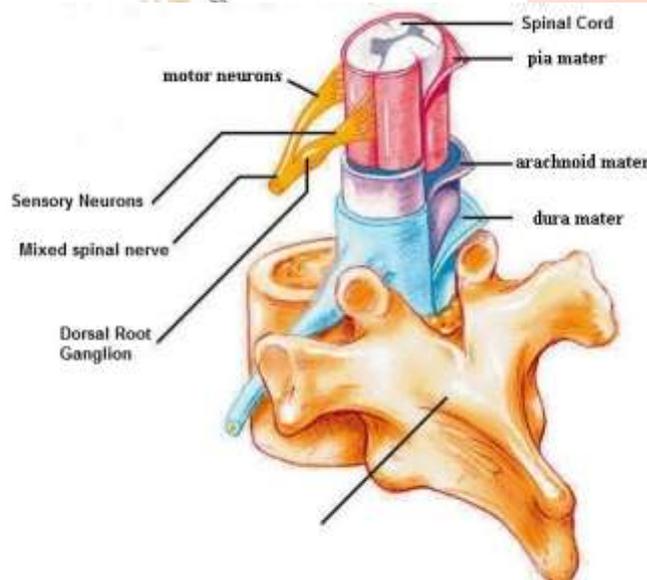
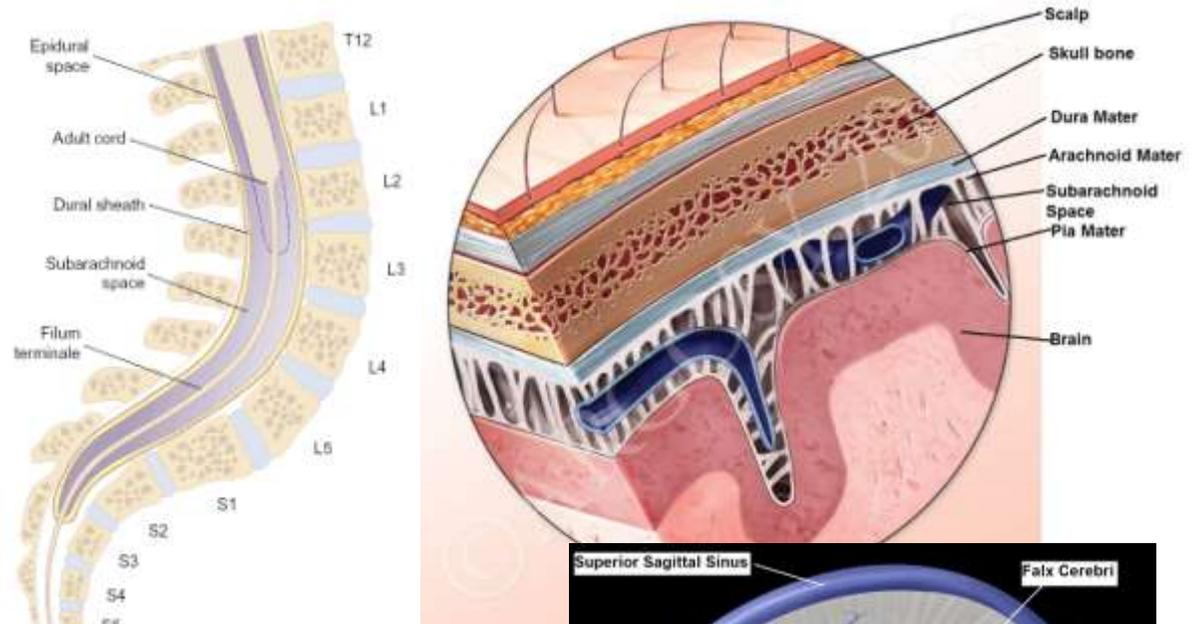
It is the centre of the nervous system. It is protected primarily by the skull, but also by the meninges :

- **Dura mater** (tough mother) – envelops the whole brain and spinal cord, It lies on and follows the anchoring it in the head and ending at S2
- **Arachnoid mater** (spider mother) – follows inside of dura and contains convolutions of the brain and spinal cord. It carries blood vessels
- **Pia mater** (soft mother) – very delicate. -collagen and elastic fibres Figure 9 - Meninges around Brain and Spinal Cord

Between the arachnoid mater and pia mater is the subarachnoid space, where the cerebral spinal fluid circulates.

Cerebrospinal Fluid

The CNS is hollow and it develops from an embryological neural tube in which a cavity persists. The brain requires Cerebral Spinal Fluid (CSF) (Fig 72 and 73) and this fluid is produced within the cavity. The place where the fluid is produced is the ventricles. The CSF is secreted by the Choroid Plexus which are situated along the whole length of the ventricles, but about 30% comes from the brain capillaries and seeps into the system by the extracellular fluid (i.e. it is not produced specifically as CSF, but becomes part of it). The total volume of CSF is about 130ml, of which 30ml is in the ventricles and 100ml is in the subarachnoid system (75ml in the spinal part, 25ml in the cranial part). The total production is about 500ml per day. The CSF is reabsorbed by the arachnoid villi; these are situated around the cerebrum and take the form of granulations; evaginations of the dura and arachnoid membranes into some, if not all, of the venous sinuses, where the CSF is returned to the blood circulation.



Upledger et al have put forward a 'pressurestat mechanism', where the choroid plexus produces CSF twice as fast as the arachnoid villi reabsorb it. This suggests a homeostatic mechanism, where the body 'knows' how much CSF and its pressure there should be there, and oscillates around an average volume. Hence, the choroid plexus produces the CSF up to a certain pressure, when production is 'turned off', and arachnoid reabsorption is on a continual basis.

Upledger has also described a 'telegraph system' in the monkey, where a single axon has been traced from the sagittal suture through the meningeal membranes to the third ventricle. A 'ball-valve mechanism' has been described in Gray's Anatomy (38th edition) where an arachnoid granulation body projects into the floor of the sinus, having a junction with the Great Cerebral Vein; if the arachnoid body contains a plexus of blood vessels which may become engorged and thus act like a 'ball valve', acting back on the choroid plexus. The pressure stat model of cranial movement is generally supported as compared to a contractile mechanism of the brain, which was once considered.

The function of CSF is to provide a buffer for the brain and spinal cord. The brain is essentially fat (in the cell membranes) and water, these making it very heavy – outside the skull; however the presence of the CSF creates a fluid environment in which the 'fluid' environment of the brain can 'float', thus reducing the 1500g weight of the brain to 50g. It also creates an important pathway for the removal of brain metabolites (there is a blood-brain barrier but no brain-CSF barrier).

Ventricles

These are spaces within the brain and are filled with cerebral spinal fluid (Fig. 38). These are two lateral ventricles passing down into the 3rd, thence to a 4th and then into the spinal cord and over the outside of the brain the pia and arachnoid mater.

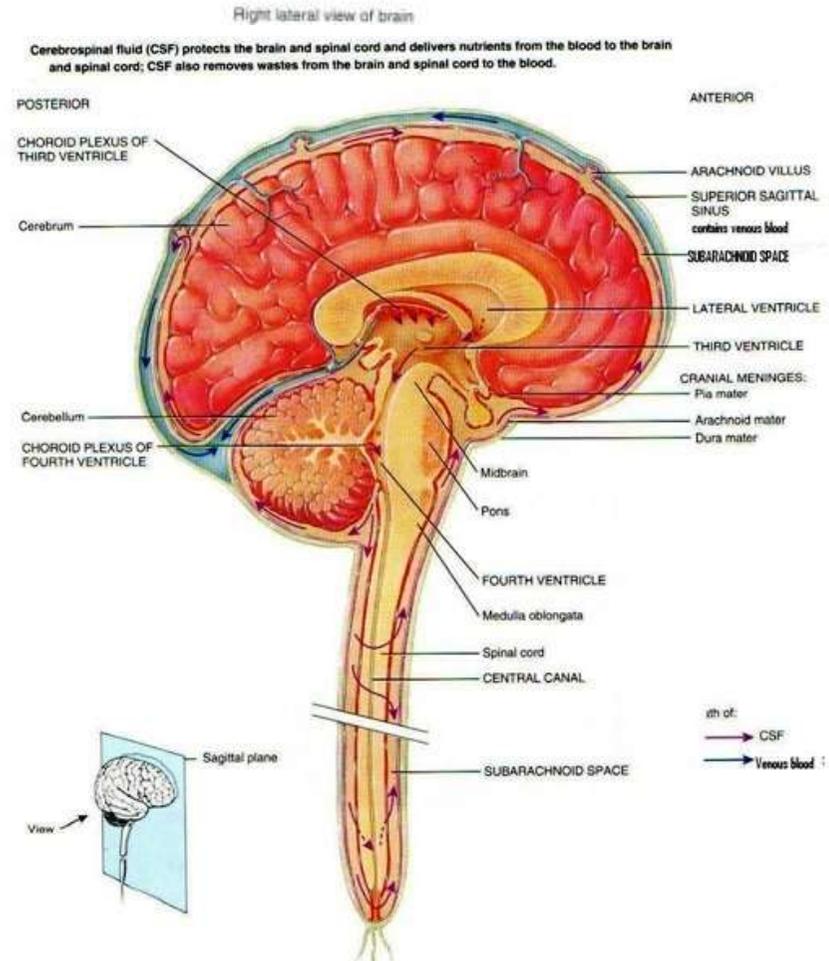
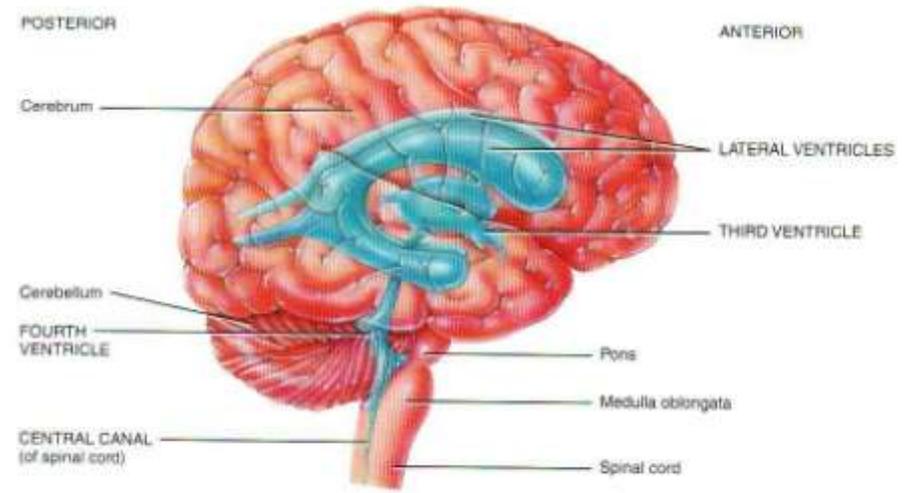


Figure 10 - Ventricles and Flow of CSF

The brain basically consists of three parts:

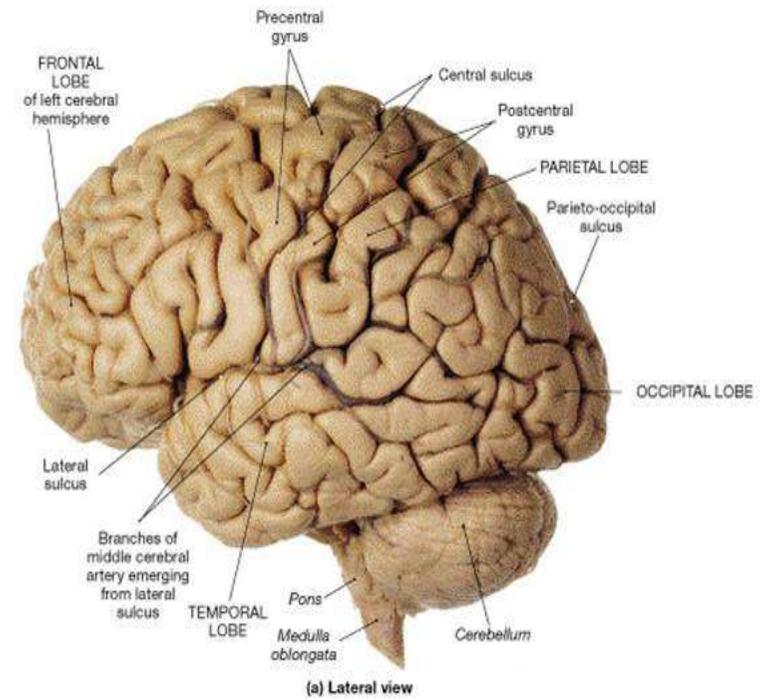
- **Cerebrum**
- **Cerebellum**
- **Brain stem**

Cerebrum

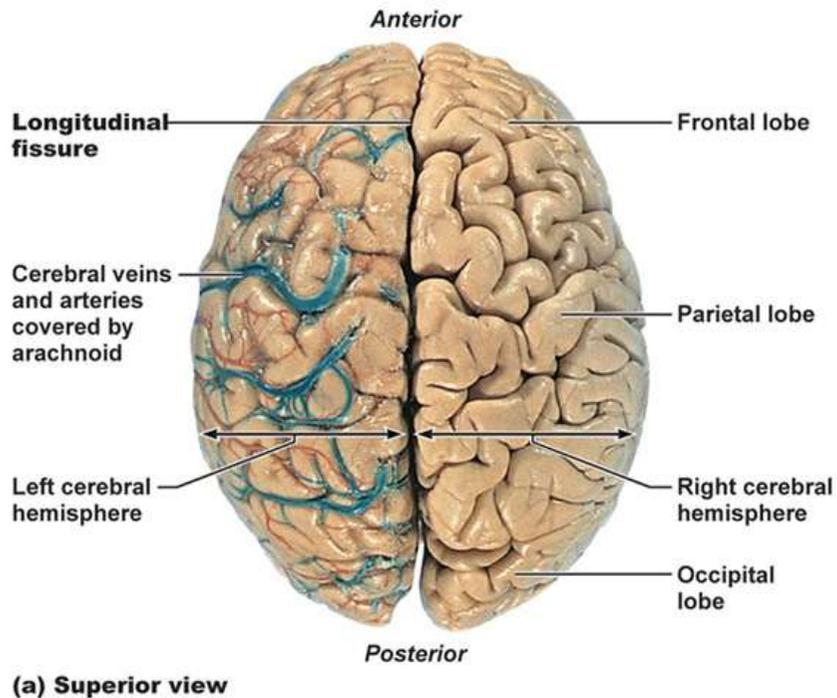
Two symmetrical hemispheres form the bulk of the brain. It consists of a surface layer of cortex (grey matter) with white matter underneath. During foetal growth, the grey matter grows faster than the white and folds over upon itself:

- Deep grooves (fissures)
- Shallow grooves (sulcus, or sulci)
- Folds (gyrus, or gyri)

Figure 11 - Views of the Brain from the Side and the Top



Cerebral Hemispheres



The functions of the cerebrum are:

- Origin of voluntary movement (motor)
- Receiving and interpreting information (sensory)
- The seat of higher functions: senses, memory, reasoning, intelligence, moral sense.

Functional areas of the cerebrum

Figure 12 - Functional Areas of the Brain

Cerebellum (little brain)

It is behind and below the cerebrum. Also it has grey matter over white matter.

Its function is coordination and balance.

Brain stem

It is at the base of the brain. It forms a connection with the spinal cord and between the left and right brain. It has three parts:

- **Mid brain** – has motor centres from the cerebellum to the spinal cord and sensory fibres from the medulla to the thalamus.
- **Pons** – (bridge) links left & right brain; it has some motor centres for cranial nerves V, VI, VII, and VIII, and has ascending and descending pathways.
- **Medulla oblongata** – conducts motor impulses, centres for heart, breathing, blood pressure etc.

In addition to these, much of the brain stem consists of clusters of grey matter, intermingled with small bundles of white matter, called the reticular formation. Part of this is called the reticular activating system (RAS), consisting of sensory fibres up to the cerebral cortex. When the RAS is stimulated, many impulses affect a widespread area of the cortex, resulting in wakefulness, or consciousness. Inactivation results in sleep.

On top of the brain stem is the Diencephalon: the Thalamus and the hypothalamus

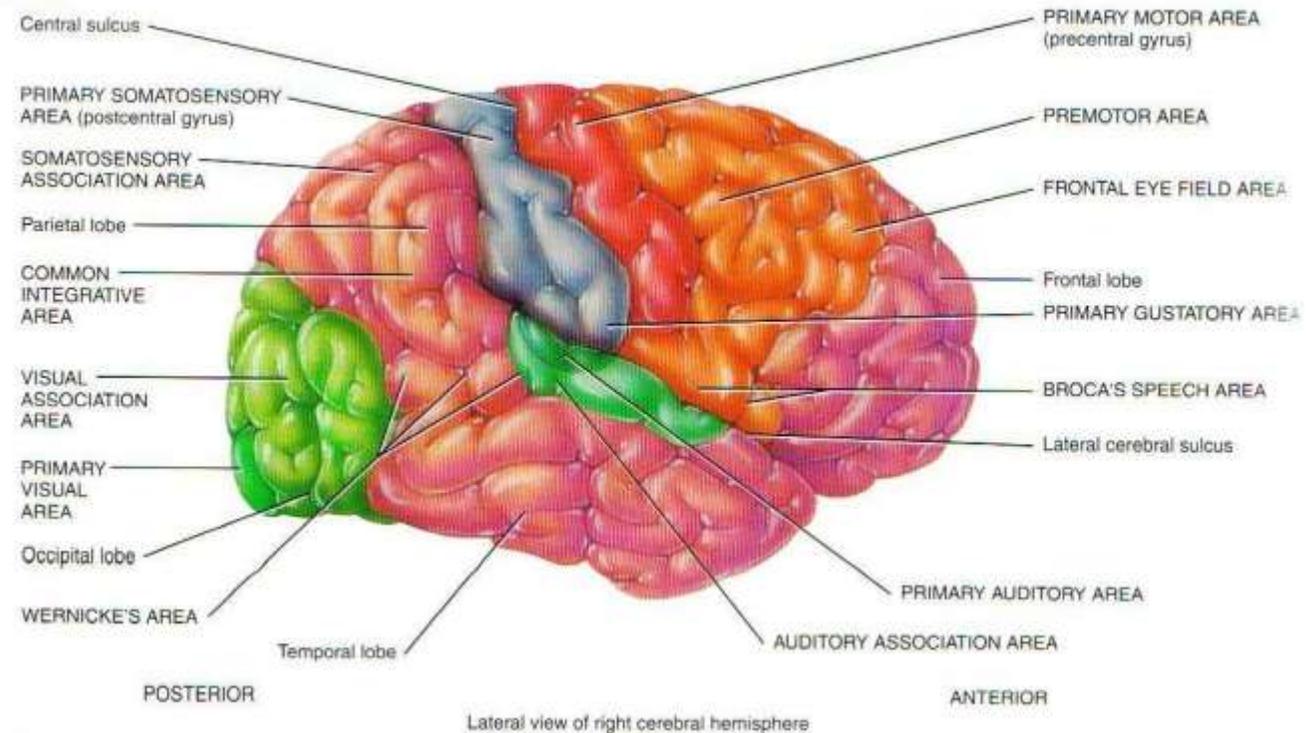
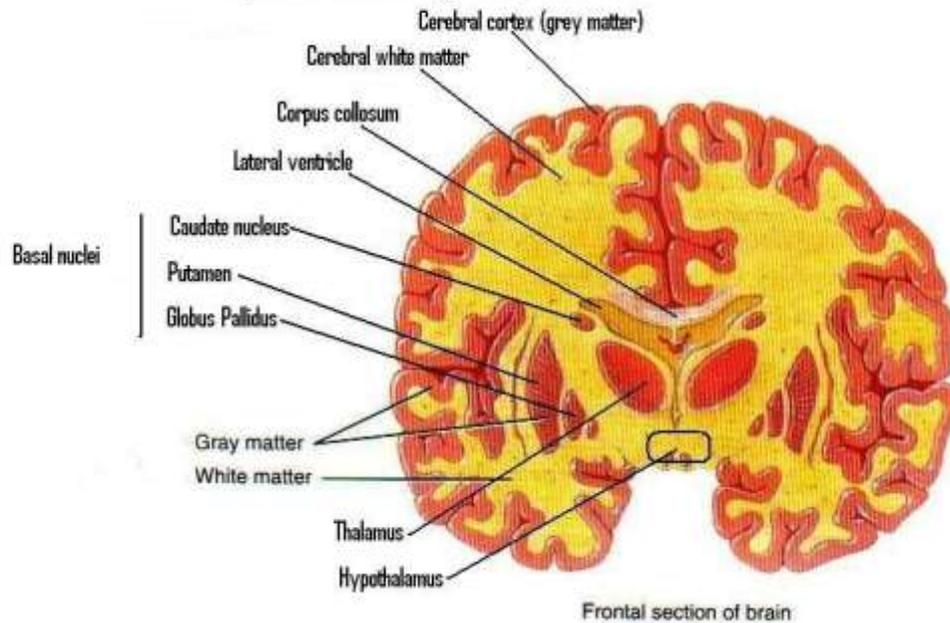


Figure 13 - Coronal Section Through Brain Showing Corpus Collosum

Diencephalon: thalamus and hypothalamus. Also shown as the basal nuclei - the caudate nucleus, the putamen and the globus pallidus



The Thalamus (inner chamber)

The thalamus consists of several paired masses of grey matter within white, the nuclei being important relay stations for sensory impulses. It also plays an important role in the acquisition of knowledge, or cognition (cogni – to get to know). It also contributes to motor functions through transmitting information from the cerebellum and basal nuclei to the cerebral cortex; hence it is very important in coordination.

The Hypothalamus

The hypothalamus (hypo-under) (Fig 119) lies under the thalamus and over the pituitary. Even though it is small, it controls many important bodily functions, many related to homeostasis.

Its main functions are:

1. Control of the autonomic nervous system (ANS). It regulates contraction of smooth and cardiac muscle and the secretions of many glands. Through the ANS it regulates heart rate, the movement of food through the gut and contraction of the urinary bladder.
2. Control of the pituitary gland. It controls the release of hormones from the pituitary gland and serves as a connection between the nervous and endocrine systems.
3. Regulation of emotional and behavioural patterns. Together with the limbic system, it regulates feeling of rage, aggression, pain and pleasure, and behavioural patterns related to sexual arousal.
4. Regulation of eating and drinking. It regulates eating and has a thirst centre
5. Control of body temperature.
6. Regulation of circadian rhythms and states of consciousness, i.e. wakefulness and our daily schedules

Pituitary gland

This is covered in the endocrine system.

The Spinal Cord

The spinal cord begins at the brain stem and ends at the level of L1. Below this, in the spinal canal, there are only nerves-known as the cauda equina (horse's tail).

Figure 14 - Spinal Cord

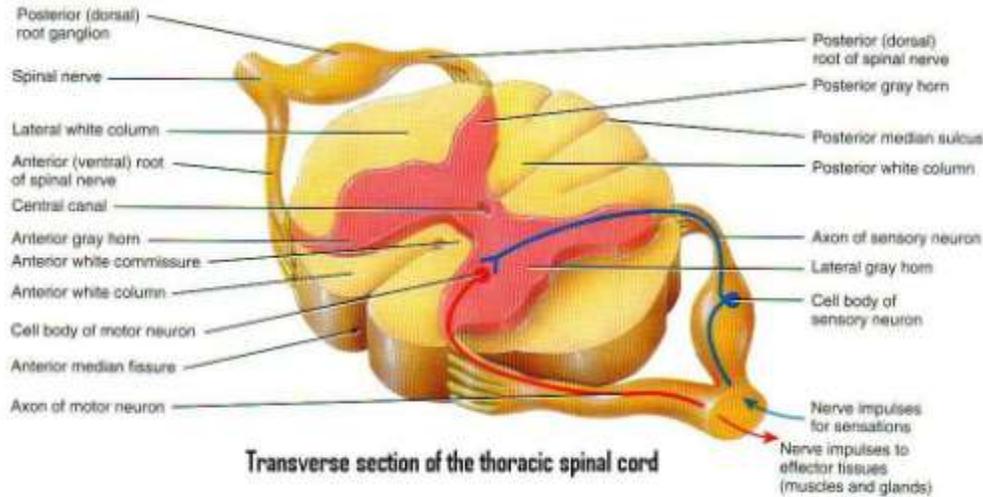


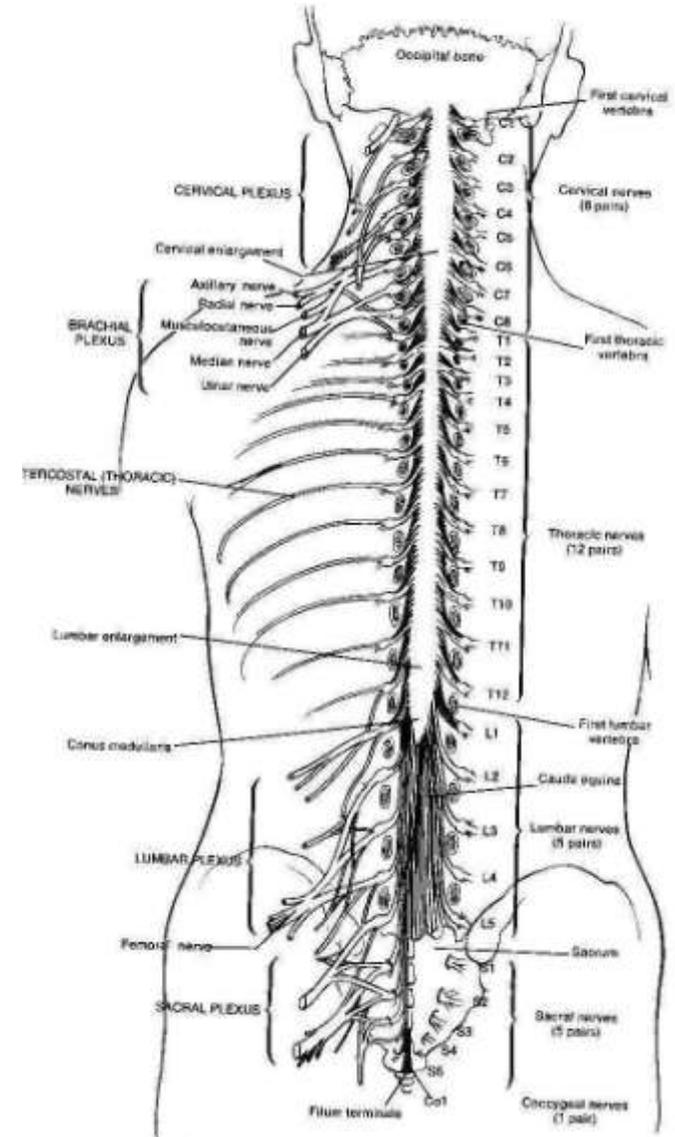
Figure 15 - Section Through Spinal Cord

There are afferent (sensory) and efferent (motor) roots passing in and out at every level of the spine(except above C1 in the cervical spine which is only a motor nerve):

- **Anterior roots** (ventral) carry motor fibres.
- **Posterior roots** (dorsal) carry sensory fibres.

All the spinal nerves emerge through the intervertebral foraminae (the holes between the vertebrae), as a mixed nerve (it contains both sensory and motor roots). Up to their point of exit, the nerve roots are covered in dura mater, but this continues as Perineurium. A short distance after leaving the intervertebral foramina, the spinal nerve divides into several branches. Frequently they form networks by joining with axons from adjacent nerves, forming a plexus, e.g. the cervical plexus is formed by cervical roots C4 – T1 and supply the arm and L2 – S3 supply the leg (see below).

Spinal cord and nerves



Spinal nerves: (i.e. peripheral nerves)

There are 31 pairs:

- 8 cervical (even with 7 vertebrae)
- 12 thoracic
- 5 lumbar
- 5 sacral
- 1 coccygeal

These nerves supply sensory to skin, muscle and joints and motor to the skeletal muscles.

The arm has 4 main nerves supplying it:

- **Musculocutaneous** – flexors to elbow
- **Median** – flexors to fingers and Thenar eminence
- **Radial** – extensors to elbow, extensors to finger
- **Ulnar** – medial wrist flexors and extensors, hypothenar eminence

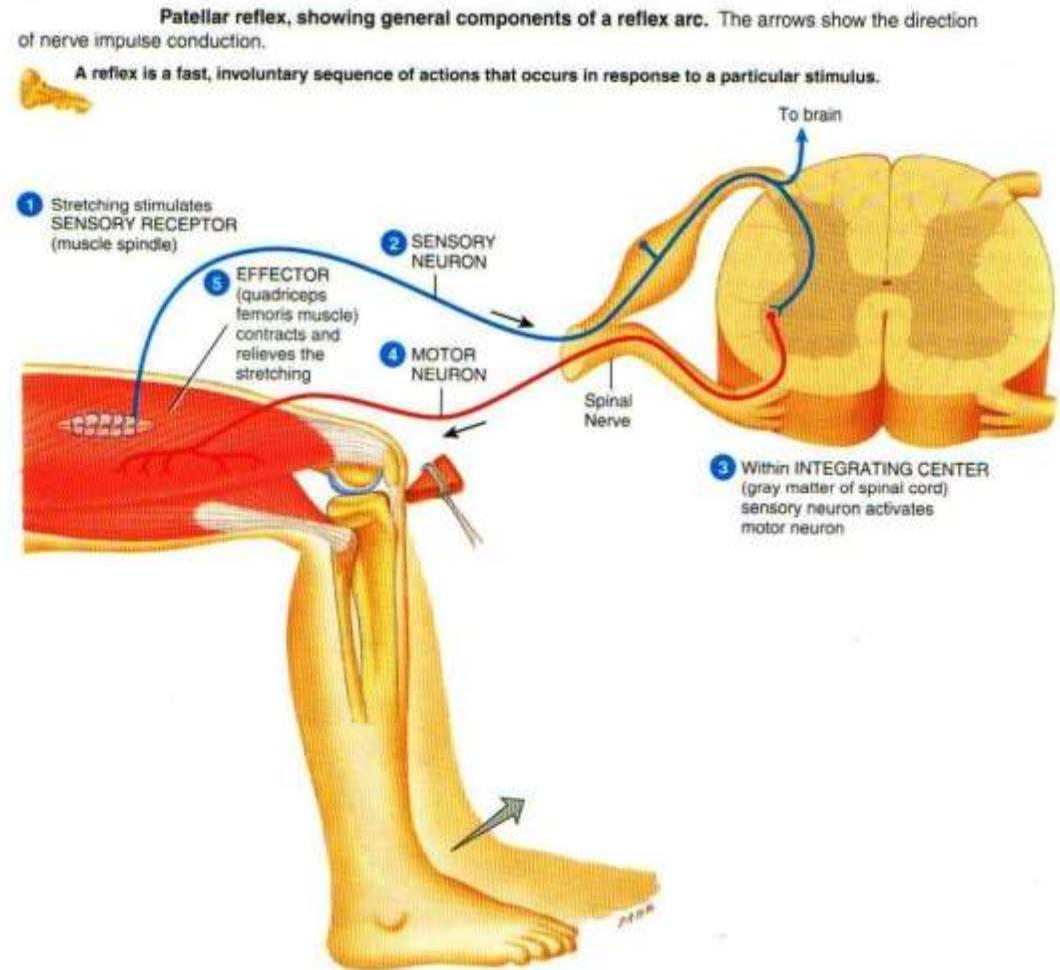
The leg has 3 main trunks: Femoral, Obturator, Sciatic

- **Femoral** – knee extensors (quadriceps)
- **Obturator** – thigh adductor group
- **Sciatic** – knee flexors and all groups below the knee

Reflexes

Reflexes are fast (usually), automatic, predictable responses to changes in the environment (Fig 78). A stimulus i.e. one which passes up the sensory (afferent, posterior, dorsal) nerve to the spinal cord, synapses with a motor neuron, causing the muscle to contract, e.g. tapping the patellar tendon stretches the quadriceps muscle. This will result in the quadriceps contracting. This would be a monosynaptic reflex, a simple reflex arc. They can be more than complex e.g. putting your hand in a flame – taking the hand out requires a number of muscles, and is thus more complex.

Figure 16 - Reflex Arc



Cranial nerves: come directly from the brain. There are 12 pairs:

- I. **Olfactory**-sense of smell.
- II. **Optic**-sense of sight.
- III. **Oculomotor**-motor to external eye muscles.
- IV. **Trochlear**-motor to external eye muscles.
- V. **Trigeminal**-sensory to face, motor for muscles of mastication.
- VI. **Abducens**-motor to external eye muscles.
- VII. **Facial**-motor for muscles of facial expression.
- VIII. **Vestibulocochlear**-sense of hearing and balance.
- IX. **Glossopharyngeal**-sense of taste, motor to the tongue.
- X. **Vagus**-sensory and motor to the heart, lungs and gut.
- XI. **Accessory**-motor to trapezius and sternocleidomastoid.
- XII. **Hypoglossal**-motor to the tongue

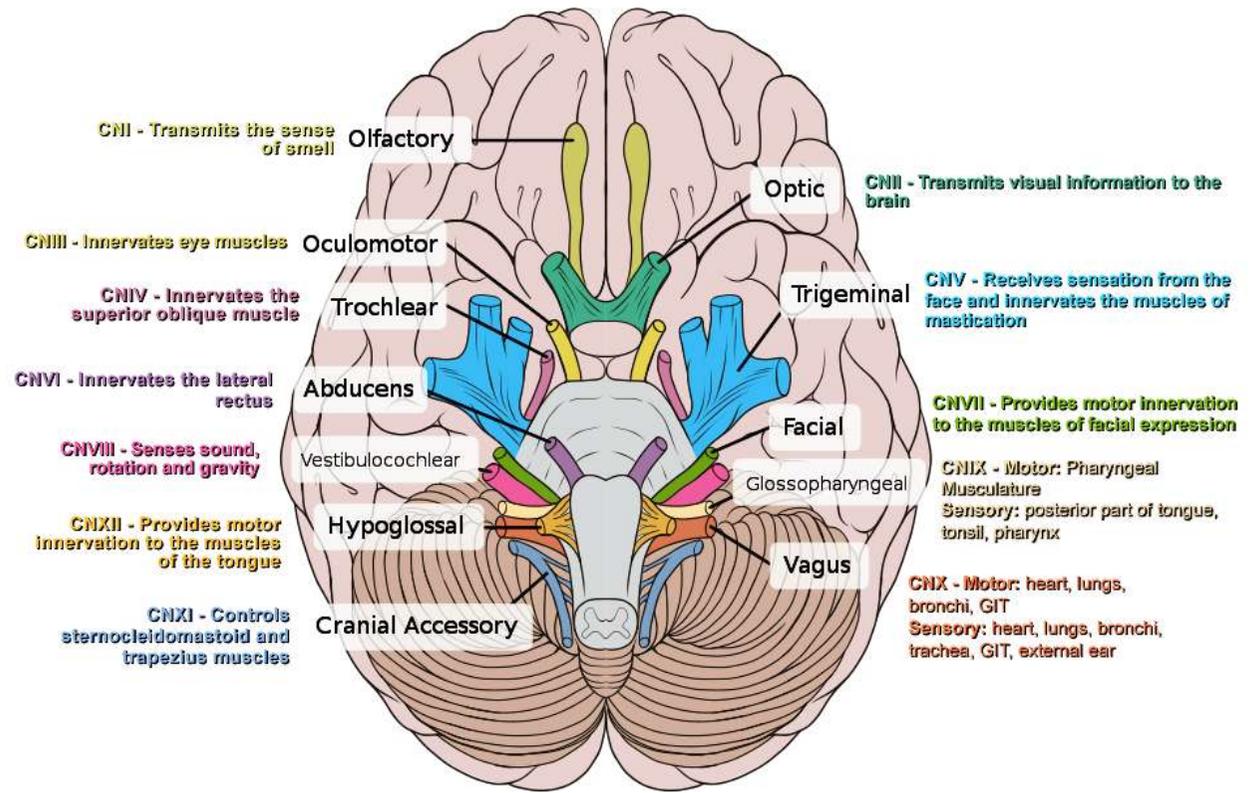


Figure 17 - Cranial Nerve Roots as They Emerge from the Underside of the Brain

Autonomic nervous system:

The autonomic nervous system (ANS) (Auto-self; nomus-law) regulates bodily functions not under conscious control. Examples of its activity display itself in the diameter of the pupil, and constriction of blood vessels; it also controls all internal organs, glands and skin.

It is divided into two parts:

- **Sympathetic**
- **Parasympathetic**

Figure 18 - Autonomic Nerves and their Differences

Generally speaking, it can be seen that the two balance each other out; when there is an increase of activity in one, there is a commensurate decrease in the other. Typically the hypothalamus turns up sympathetic tone at the same time as it turns down parasympathetic.

The Sympathetic reaction

Generally the sympathetic reaction manifests itself during physical emotional stress. It is the first stage of the “fight or flight” reaction, with dilatation of the pupils; bronchus, increases blood pressure and flow, and prepares the body for physical activity. At the same time it reduces body functions that favour storage of energy: reduction such as gut activity etc. Emotions such as fear, embarrassment and rage can stimulate the sympathetic division. You can remember these as the ‘E situations’: exercise, emergency, excitement and embarrassment.

Specifically, sympathetic stimulates:

1. Dilatation of the pupils
2. Heart rate, force of contraction and blood pressure increase
3. The airways dilate allowing freer flow of air
4. Blood vessels to non-essential organs like the kidneys and gut constrict, reducing flow there (i.e. not essential during exercise)
5. Blood vessels to organs used in exercise: muscles, heart, liver and fatty tissue, dilate, allowing greater flow to them
6. Glycogen is broken down into glucose in the liver, and fats are broken down also, to provide fuel for energy production
7. Glucose released by the liver increases blood glucose levels
8. Any processes not essential to this activity are slowed, or stopped, e.g. the gut activity

Anatomical Differences in Sympathetic and Parasympathetic Divisions

Come from different regions of the CNS

- **Sympathetic**—from the **thoracolumbar** region
- **Parasympathetic**—from the **craniosacral** region

Differing locations of ganglia

- Sympathetic – close to spinal cord in a chain

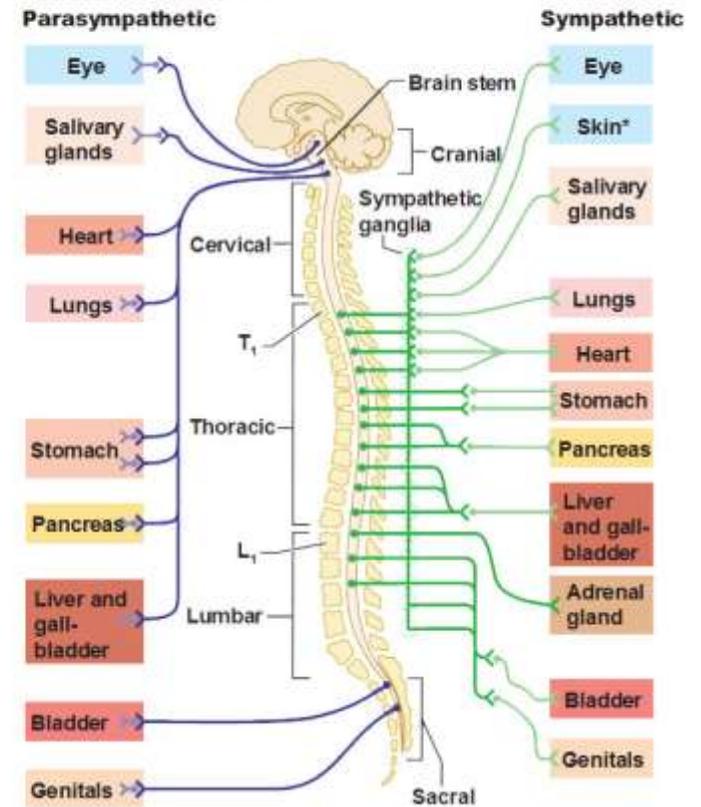
- Parasympathetic – close to target organs

Differing lengths of *postganglionic* fibers

- Sympathetic – Long
- Parasympathetic – Short

Postganglionic branching

- Sympathetic – lots, so that multiple organs can be mobilized at once
- Parasympathetic – very little branching



In contrast to this hive of activity, the parasympathetic system enhances 'rest and digest' activity, i.e. it controls basic vegetative functions and supports bodily functions that conserve and restore body energy during times of inactivity.

In general it

- It slows the heart,
- Constrict the pupils,
- Dilate blood vessels
- Stimulates activity in the gut, including secretions

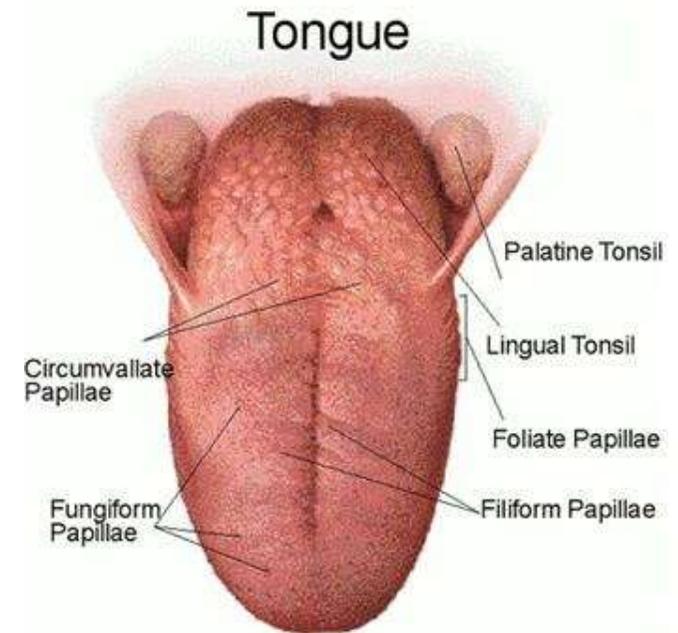
The Senses

Humans have 5 recognised senses which allow them to receive information about their environment. We tend to be more visually orientated but it is surprising how much information we receive in other ways and how important it is to our survival and emotional well being. The five senses are; taste, smell, touch, sight and hearing.

- **Taste**

- Taste buds are widely distributed over the tongue, soft palate, pharynx and epiglottis. They are small bundles of cells innervated by the 7th, 9th and 10th cranial nerves. There are small microvilli projecting from the cells into pores on the epithelium of the tongue etc. These are stimulated by various substances in solution in the saliva. Although we can taste many different substances some of this is due to a combination of smell and touch sensations with that of taste.
- The four basic taste are; sweet, salty(both perceived at the front of the tongue), sour (at the sides), and bitter at the back. Pungent tastes are due to a stimulation of sensory nerves. People's senses of taste differ and cause different preferences in food. Certain tastes stimulate specific physiological responses, for instance bitter tastes encourage the production of bile. Therefore eating bitter foods with fatty foods can aid their digestion. In Chinese medicine the different tastes are felt to correspond to different meridians and strong preferences or dislikes can indicate an imbalance in a specific area.

Figure 19 - Tongue Upper Surface



Smell

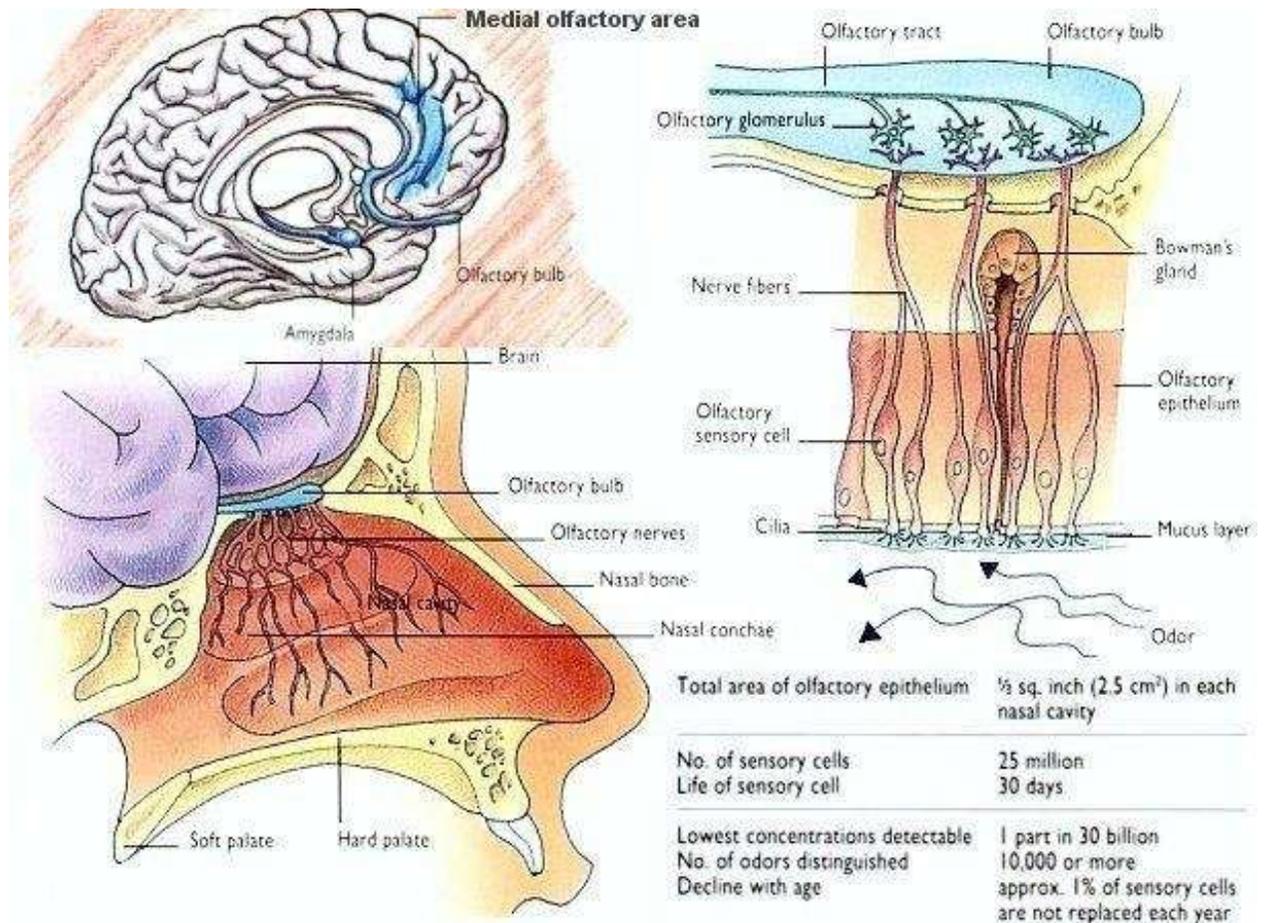
We inhale through the nose, but substances we inhale travel through to the lungs and can be absorbed into the blood in the alveoli. When air enters the nose, it is warmed, moistened, and filtered by the nasal hairs; also any molecules therein can come in contact with the olfactory cells. These are stimulated by either their shape or vibrational energy and send a message to the brain. The olfactory system is different from the others in that it doesn't have any synapses between them and the brain; the fibres passing up to the olfactory bulb through the cribriform plate. From here it has links with the limbic system, which is associated with emotions, sexual drive, appetite, intuition and memory. It also connects to the hypothalamus, which is concerned with homeostasis and the endocrine system.

Figure 20 - Smell - Olfactory Apparatus

We normally notice a smell at about 1:1,000,000 concentration, but sometimes we can lose it over a certain concentration (e.g. hydrogen sulphide [bad egg gas] we cannot smell above 16:1,000,000 – it just becomes poisonous). Smelling can be both simple and complex; we become desensitised to a smell if it there all the time (you can't smell your own perfume after a while).

Our sense of smell affects us far more than most people realise. Smell is intricately tied up with our emotional responses and with our memory. People who lose their sense of smell report emotional disturbance, and we all know that smell is intricately involved with the stimulation of appetite as this often evaporates during a cold.

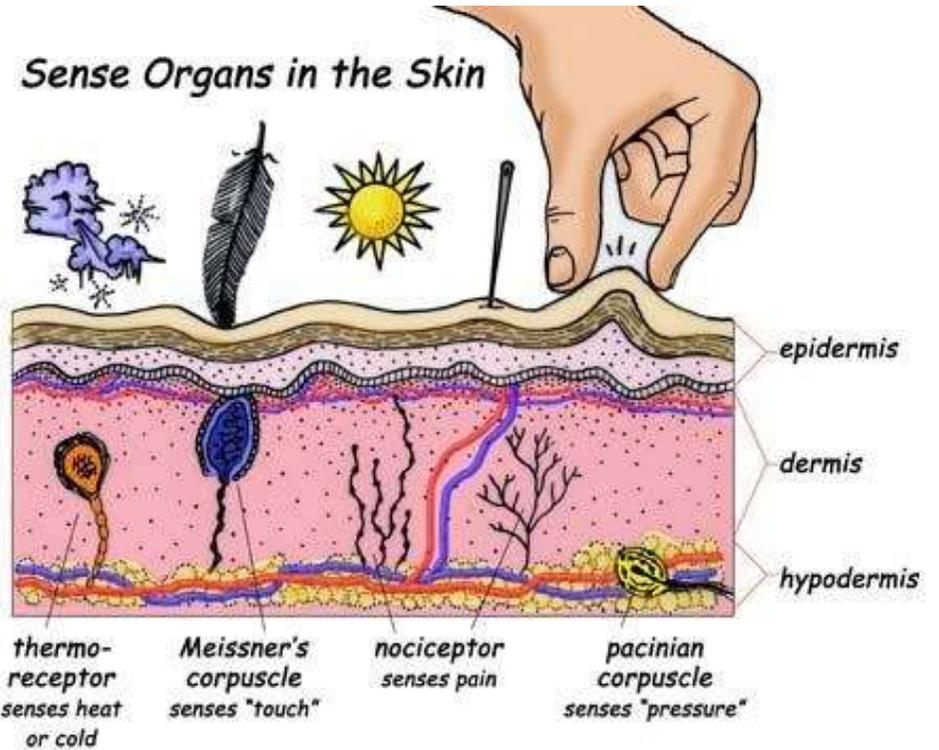
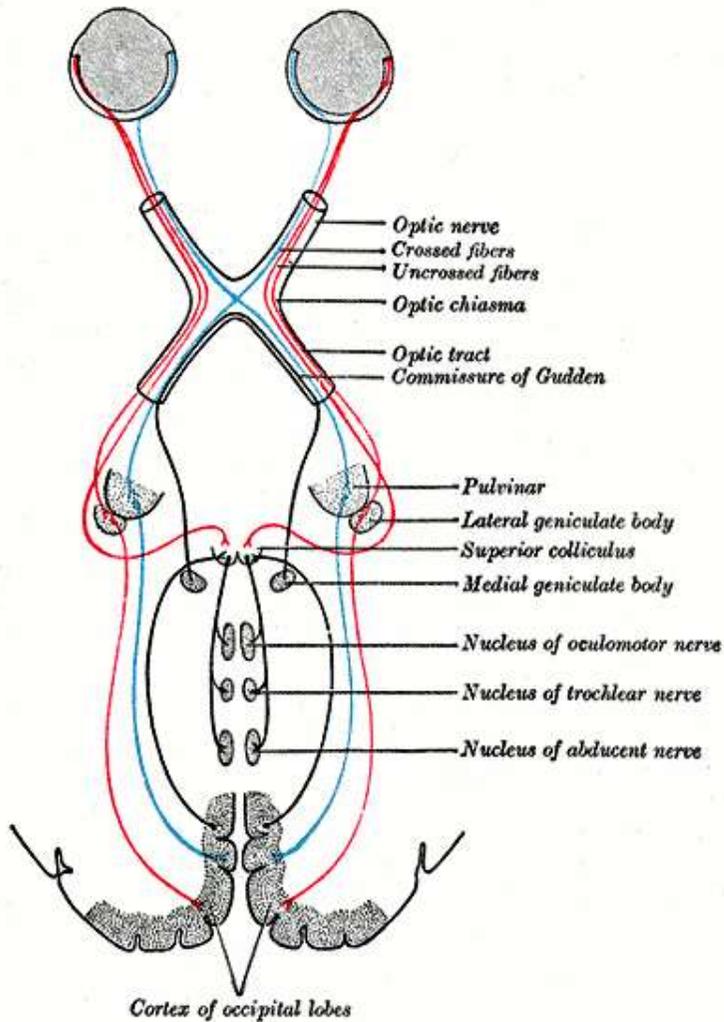
Smells are perceived by the olfactory nerves which lie at the top of the nasal cavity. These are connected directly to the brain via the olfactory bulb, and are the only nerves in the body which do not pass through synapses. In order to perceive a smell at least 42 molecules of the substance must stimulate the olfactory nerves. The exact mechanism is not known but it may be to do with the shape of receptors on the nerves or vibrational frequencies. This area is receiving much interest from research scientists and many books are written on the subject.



Touch

The sensory nerves throughout our body are able to perceive different stimuli; these are cold, heat, pain and touch.

Figure 21 - Skin - Different receptors in Skin



Sight

We see with our eyes. The following description is a gross simplification. The eyes are supplied by the 2nd cranial (optic) nerve, as regards sight.

Figure 22 - Sight - Pathways to Visual Cortex

Other cranial nerves (III, IV and VI: Oculomotor, Trochlear and Abducens) supply the muscles around the eye and enable them to move.

Special Senses

Sight

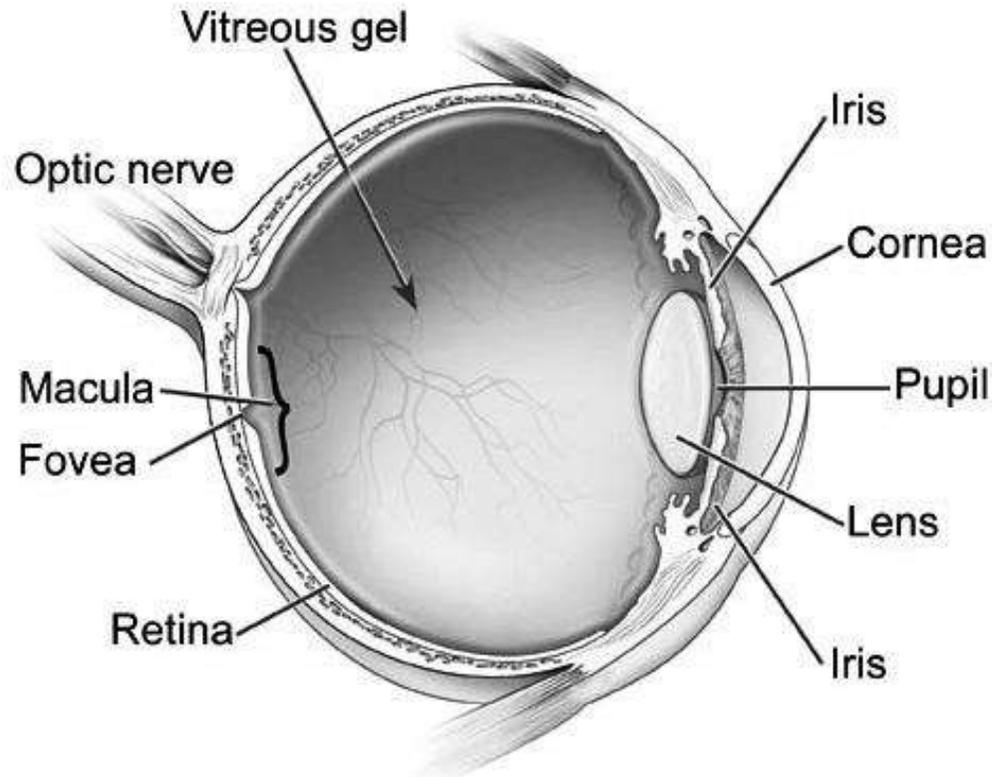


Figure 23 - Eye - Cross Section

The eyes are spherical structures. Although structurally separate, they function as a pair to allow us to see in three dimensions and judge distance (parallax).

The eye is made up of a fibrous layer which is divided into the sclera and the cornea.

The sclera is the white of the eye and becomes the transparent cornea in the centre of the eye to allow light through.

There is a middle vascular layer made up of the choroid, ciliary body and iris. The choroid is very rich in blood vessels and its function is to absorb light after it has passed through the pupil and stimulated the retina. The ciliary body allows changes in the thickness of the optic lens. It is supplied by the 3rd cranial nerve. The iris is the pigmented part of the eye, with the pupil at its centre. It consists of two layers of muscle fibres, one circular and one radiating which control the aperture of the pupil. The lens lies directly behind the pupil and is a highly elastic biconvex structure. An inner layer of nervous tissue is known as the retina. It is specially adapted to be stimulated by light rays. The light

sensitive layer is made up of rods and cones; rods enable us to see in black and white and are used for night vision. Cones enable us to see in colour.

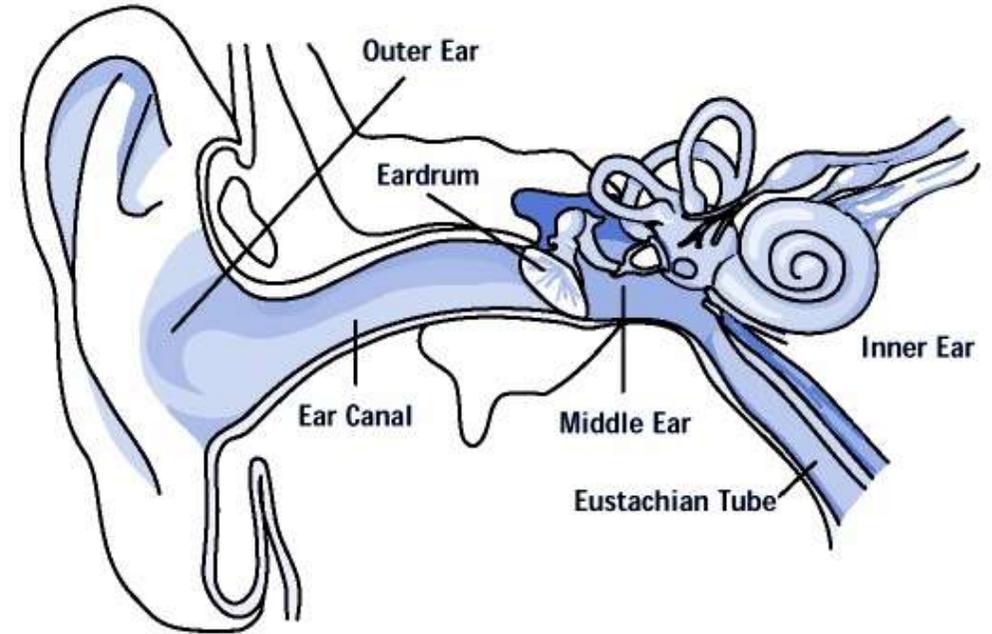
Hearing

The ears are the structures that enable us to hear.

Figure 24 - Ear - Structures of Outer, Middle and Inner Ear

They are divided into

- The external ear
 - The auricle or pinna is the ear lobe etc. This leads into the auditory canal which leads to the eardrum. This canal is lined with hairs and ceruminous glands that secrete wax to prevent dust and germs reaching the delicate ear drum. The eardrum or tympanic membrane separates the outer ear from the middle-ear.
- The middle ear–
 - This is also an air-filled space. Within this space three tiny bones known as the auditory ossicles. These are called the malleus, the incus and the stapes. The malleus is in contact with the ear drum. This articulates with the incus and then stapes is in contact with the oval window (foramen ovale), which is the membrane covering the entrance to the inner ear. There is also a canal connecting the middle ear with the palate, at the back of the mouth, and is called the Eustachian tube. The function of this is to allow the equalisation of pressure between the middle ear and the outside.
- **The inner ear**
 - This contains the vestibular system where can be found the semicircular canals (for balance) and the cochlea (which senses sound)

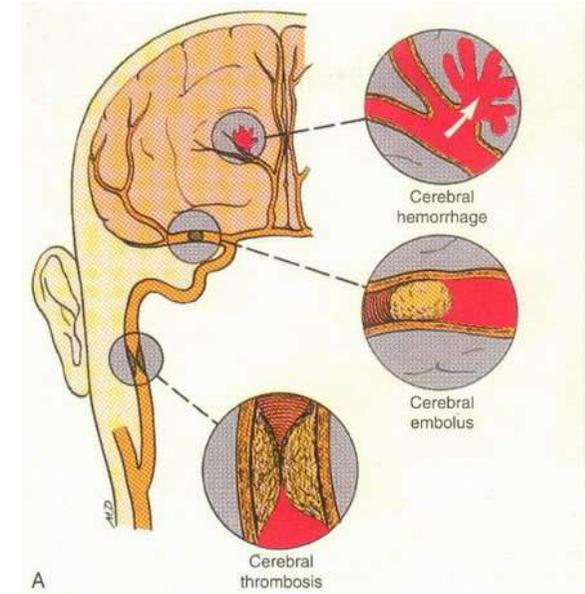


Disorders of the nervous system:

Sciatica—irritation of the sciatic nerve, causing pain down the back of the leg

CVA—cerebrovascular accident (CVA), or a stroke; sudden onset of neurological symptoms from a blood clot or bleed.

Figure 25 - Stroke - From Blockage or Bleed



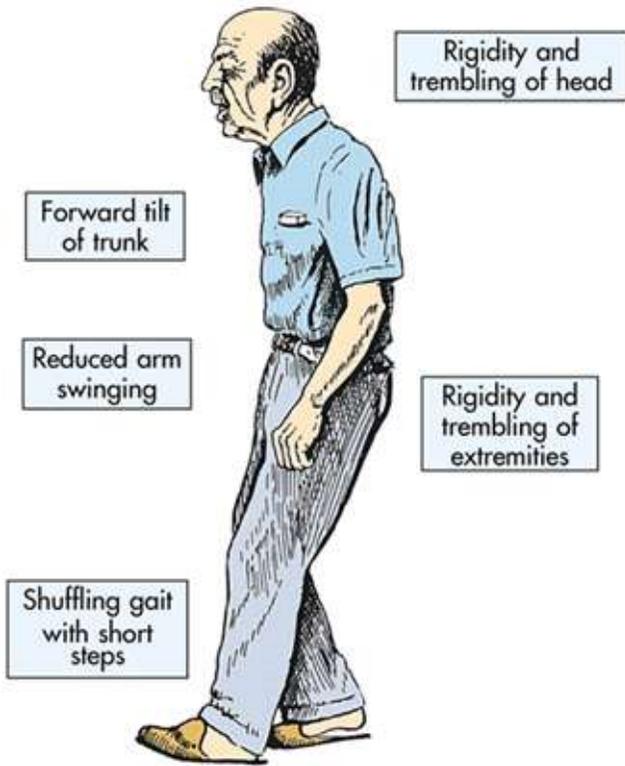
Shingles—herpes zoster: caused by chicken-pox virus. Causes rash and irritation along the course of the sensory nerve

Figure 26 - Shingles - Herpes Zoster

Poliomyelitis—causes destruction of motor cells in spinal cord, with paralysis

Figure 27 - Poliomyelitis

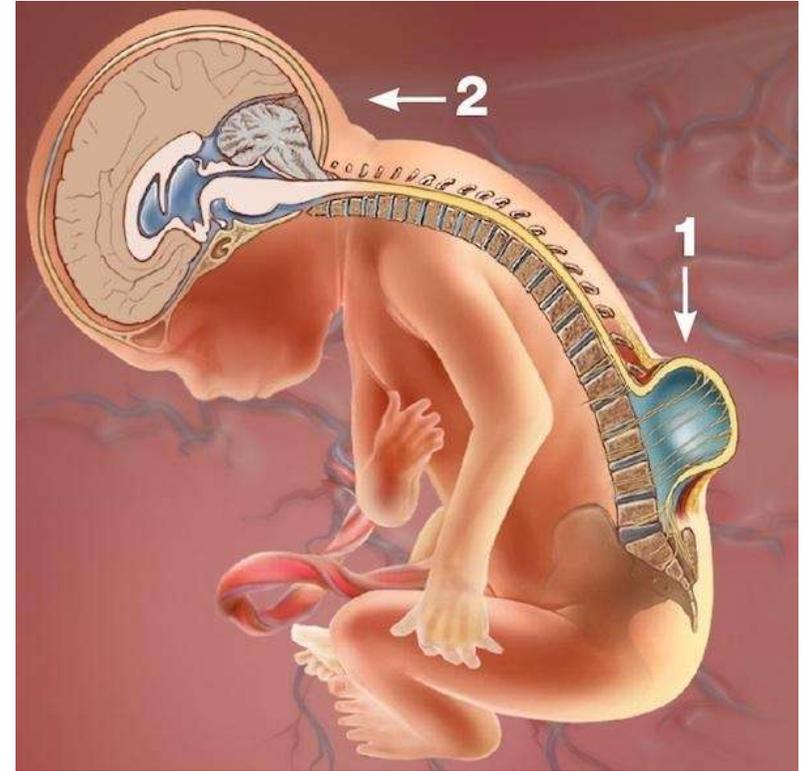




Parkinson's disease—progressive disease, affecting older people. Shows as tremor, shuffling gait, reduced motor function, expressionless face.

Spina Bifida—defective closure of the neural tube (spinal canal); usually occurs at the base of the spine (L-spine/sacrum). Occult form is hidden (i.e. skin is intact). Neural defects can also cause hydrocephalus (excess fluid on the brain)

Figure 28 - Spina Bifida



MS—multiple sclerosis. Results in destruction of myelin sheath. Causes progressive motor dysfunction. Fatal, but can last 7 –30 years.

Epilepsy—two main types: grand mal and temporal lobe. Causes fits, absences, and déjà vu experiences

Trigeminal neuralgia—pain along the trigeminal nerve, usually the cheek. Precipitated by touch, washing face, cold wind.

Vertigo—the subjective sensation of the environment moving. Can cause dizziness and vomiting

Alzheimer's—Is a progressive disease of no apparent reason. Its symptoms are short term memory loss and confusion.

Huntingdon's Chorea—(St. Vitus' dance) degenerative condition starting between 35-50; characterised by strange, involuntary, jerking movements and progressive intellectual impairment.