**08. The Nervous System**

The nervous system is a communication and instruction network. It is composed of the brain. spinal cord and nerves.

**The Nervous system**

The nervous system is the control and communication centre of the body. There are two parts: the central nervous system and the peripheral nervous system. The brain is the main unit and it is connected to the rest of the body by nerve cells which function as messengers, carrying information to, and instructions from the brain. They report back on pain, sensation and danger so that the body can respond and remain in what is known as homeostasis: a stable physiological state.

**DID YOU KNOW?**

The nervous system sends messages to the brain at 290 km per hour!

**TOPIC 1: STRUCTURE**

**WHAT IS THE NERVOUS SYSTEM MADE OF?**

Nervous tissue which is composed of:

* Nerve cells, known as neurones, with attached fibres which transmit nerve impulses
* Neuroglia, a connective tissue which supports the neurones; though only found in the nervous system, neuroglia does not transmit nerve impulses.

**WHAT IS A NERVE CELL?**

Nerve cells are the basic unit of the system on which everything else is built. Like all cells, they have a membrane containing a nucleus and a cytoplasm but they have a particular shape: long and narrow. Some are very long (up to a metre). Nerve cells are easily damaged by toxins and lack of oxygen. Unlike other cells in the body, they are not usually replaced when they die, however, current research suggests that some may have the ability to regenerate. The main parts of a nerve cell are:

* **Cell body:** the centre of the neurone, with a nucleus, cytoplasm and organelles such as mitochondria
* **Dendrites:** nerve fibres, like branches, which transmit nerve impulses to the cell body; most neurones have several dendrites
* **Axon:** a long single nerve fibre, which transmits nerve impulses away from the cell body; neurones generally have only one axon
* **Myelin sheath:** made of a white, fatty substance, this sheath covers the axon. It insulates the axon, protects it from pressure and helps speed up nerve conduction (the speed at which messages are transmitted)
* **Neurilemma:** a fine, delicate membrane which surrounds the myelin sheath and helps regenerate nerve cells; only found in peripheral nerves and not in the brain or spinal cord
* **Nodes of Ranvier:** these are gaps in the myelin sheath along the nerve. They speed up the passage of nerve impulses along the fibre
* **End feet/axon terminals:** the ends of the fibrils (tiny fibres) that make the axon are expanded and called end feet or axon terminals. They pass on the axon impulse to the dendrites of the next neurone
* **Synapse:** the point where one neurone meets another. A chemical messenger fills the gap between one neurone and the next, and enables the impulse to be transmitted

**TOPIC 2: FUNCTION**

**WHAT DOES A NERVE CELL DO?**

Nerve cells act as links in a chain, like relay runners, each one passing the 'baton' (information or instruction) to the next until it reaches the brain or the part of the body in question. The axon end feet of one cell are close to the dendrites of the next but they don't actually touch. The 'baton' of nerve impulses jumps across the gap via neuro-transmitters, chemicals released by the nerve endings.

**COLLECTIVE FUNCTION**

Individual neurones have the same function throughout the body, to transmit information, but collectively they make up five different types of nerves and nervous tissue which have specific functions:

* **Motor or efferent nerves:** carry impulses from the brain or spinal cord to muscles or glands which then act on the information/ instruction, producing movement or a secretion.
* **Sensory or afferent nerves:** carry impulses from all parts of the body to the brain.
* **Mixed:** carry both motor and sensory nerve fibres. The only place mixed nerves are found in the body is in the brain and spinal cord as cranial and spinal nerves.
* **White matter:** on the inside of the brain and the outside of the spinal cord; this is made of bundles of myelinated nerve fibres (i.e. with a sheath).
* **Grey matter:** on the outside of the brain and inside of the spinal cord - this is made of cell bodies and unmyelinated axons and dendrites.

**WHAT IS A NERVE IMPULSE?**

Nerve cells transmit and receive impulses throughout the body. Impulses do not continually run along each nerve but are created in response to internal or external stimuli - including changes in temperature, pressure or chemicals.

Positively charged sodium and potassium ions are present inside and outside the cell. In a resting axon, the concentration of sodium ions is lower inside the cell than in the tissue fluid outside, but the concentration of potassium ions is higher inside than outside. This is maintained by differences in membrane permeability to these ions, and the sodium-potassium pump. The overall result is that the inside of the cell has a more negative charge than the outside.

Stimuli are detected by sensory receptors. The axon membrane becomes temporarily more permeable to sodium ions which rush in, making the inside of the cell more positive (depolarisation). This electrochemical charge continues in waves along the length of the nerve cell - a nerve impulse. After it has passed the resting state is restored (repolarisation)

**USEFUL TIP**

How do you remember which are afferent and which are efferent nerves? Efferent exit the brain, afferent arrive in the brain.

**HOW DO NERVE CELLS COMMUNICATE?**

Nerve impulses only travel in one direction. So the movement of nerve impulses in a single neurone is as follows: the impulse crosses the synapse from the end feet of cell A into the dendrites of cell B. The impulse travels from the dendrites to the cell body and then out again along the axon to cell B's end feet. It then jumps across the synapse, helped by the chemical messengers. This process continues until the impulse reaches either the brain or the muscle/organ concerned.

**TOPIC 3: DIVISIONS OF THE NERVOUS SYSTEM**

The nervous system is divided into two main parts - the Central Nervous System (CNS) and the Peripheral Nervous System (PNS). The PNS acts as the lines of communication between the CNS and the rest of the body, and is further subdivided into the Somatic and Autonomic nervous systems.

**TOPIC 3: THE CENTRAL NERVOUS SYSTEM**

**The brain**

The brain is the organ that fills the cranium (skull). It stops developing in the 15th year of life. It is the main mass exercising control over the body and mind and it has three different sections:

* The cerebrum (also known as cerebral hemispheres)
* The cerebellum
* The brain stem.

**The cerebrum**

**Structure:** this is the largest part of the brain and is divided into two cerebral hemispheres, one on the right and one on the left. The outer layer is made of folds of grey matter (i.e. cell bodies). The folds increase the brain's surface area and thus the number of cell bodies. Inside the grey matter is white matter (i.e. nerve fibres). These fibres connect different parts of the brain together.

**Functions:**

* Controlling voluntary movement (i.e. the movements we choose to make)
* Interpreting and perceiving conscious sensations like pain, heat and cold
* Controlling mental activity, like memory, intelligence and reasoning.

**The cerebellum**

**Structure:** the cerebellum is also known as the 'small brain'. Positioned in the posterior cranial fossa, behind the pons Varolii, below the cerebrum and over the medulla oblongata, it also consists of two hemispheres, grey matter on the surface and white matter within.

**Functions:**

* Co-ordinating muscular activity, making sure movements are smooth and precise (damage to the cerebellum results in clumsy, uncoordinated movements).
* Subconsciously controlling and maintaining muscle tone and posture.
* Maintaining balance and equilibrium of body.

**Hypothalamus**

**Structure:** situated deep within the cerebrum at the top of the brainstem with the pituitary gland attached to its base.

**Function:** helps with the regulation of body temperature, water balance and metabolism. Centre for drives and emotions such as thirst, appetite, sex, pain and pleasure. It also regulates the pituitary gland thereby forming the main link between the nervous and endocrine systems. It secretes oxytocin and Antidiuretic Hormone (ADH) for storage in the posterior pituitary.

**The brain stem**

The brain stem consists of three parts, the midbrain, pons Varolii and the medulla oblongata.

**Midbrain**

**Structure:** lies between cerebrum and cerebellum and above the pons Varolii.

It is about 2cm long and consists of nerve cells and fibres.

**Function:** the relay station of the brain, transmitting messages to and from the spinal cord, the cerebrum and the cerebellum.

**Pons Varolii**

**Structure:** situated in front of the cerebellum, below the midbrain and above the medulla oblongata. It consists of nerve fibres, which bridge (hence pons, which means bridge in Latin) the gap between the two hemispheres of the cerebellum.

**Function:** like the midbrain, transmits messages to and from the spinal cord and cerebrum.

**Medulla oblongata**

**Structure:** lowest part of the brain stem, situated above the spinal cord and below the pons Varolii. Its construction is different from the cerebrum and cerebellum with white matter on the surface and grey matter in the centre. It is known as a vital centre because it controls the actions of the heart and lungs (respectively the centres of the vascular and respiratory systems). It has four centres.

**Functions:**

* **Cardiac centre:** controls rate and force of heart contraction
* **Respiratory centre:** controls rate and depth of breathing
* **Vasomotor centre:** controls constriction and dilation of blood vessels
* **Reflex centre:** responds to irritants thus controls vomiting, coughing, sneezing and swallowing.

**THE SPINAL CORD**

The spinal cord is the other main part of the central nervous system.

**Structure:** the spinal cord extends from the medulla oblongata through the spinal vertebrae ending at the first lumbar vertebra. It consists of white matter on the surface and grey matter inside branching off into 31 pairs of spinal nerves and part of one cranial nerve.

**Function:** the spinal cord carries motor and sensory nerve fibres along its length, sending messages to and from the body and brain.

**TOPIC 3: OTHER IMPORTANT PARTS OF THE CENTRAL NERVOUS SYSTEM**

**The meninges**

The meninges are membranes which protect the whole of the central nervous system. There are three different layers -

* **Dura mater, or outer membrane:**

a double layer of tough, fibrous membrane: the outer layer forms the periosteum ('skin') of the skull while the inner layer, the first protective covering of the brain, continues as the spinal dura mater as far down as the sacrum.

* **Arachnoid mater:** a delicate membrane positioned immediately under the dura and above the pia mater. It merges with the dura mater and thus covers the spinal cord as far as the sacrum. It connects to the sub-arachnoid space, situated between the arachnoid mater and the pia mater and is filled with cerebrospinal fluid (see below).
* **Pia mater:** a thin, vascular membrane which closely covers the brain, dipping into the various surface folds of the cerebrum and cerebellum, and continues along the length of the spinal cord. It supplies blood to the brain and spinal cord.

**DID YOU KNOW?**

There are more than 10 billion nerve cells in the spinal cord.

**Ventricles and cerebrospinal fluid**

There are four cavities inside the brain called ventricles, all containing cerebrospinal fluid. Two of these ventricles lie laterally within the cerebrum, a third lies deep inside the brain whereas the fourth, also deep inside the brain, opens into the subarachnoid space.

**Cerebrospinal fluid**

**Structure:** this is clear, colourless fluid, formed in special cells within choroid plexuses that are situated in the lining of the ventricles. It resembles blood plasma in composition, containing protein, glucose, salts, and other substances. It is secreted into the ventricles from where it circulates around the whole brain and spinal cord and is then reabsorbed into the venous sinuses of the body through the arachnoid mater.

**Functions:**

* Protects the brain and spinal cord, forming a cushion between the bony cavities and the nerves and acting as a shock absorber
* Keeps the pressure around the brain and spinal cord constant
* Transports nutrients and removes waste and toxic substances.

**TOPIC 3: THE PERIPHERAL NERVOUS SYSTEM**

**WHAT IS THE PERIPHERAL NERVOUS SYSTEM?**

The peripheral nervous system concerns all the nervous system outside the central nervous system and contains motor and sensory nerves which transmit information to and from the body and brain. It consists of 12 pairs of cranial nerves and 31 pairs of spinal nerves.

**CRANIAL NERVES**

Cranial nerves are divided into 12 pairs and include sensory, motor and mixed nerves. Examples of these are:

**5TH TRIGEMINAL**

**Opthalmic -** sensory nerves supplying the lacrimal glands, conjuctiva of the eyes, eye lids, forehead, anterior part of the scalp and mucous membrane of the nose

**Maxillary -** sensory nerves supplying the lower eye lids, upper gums, upper teeth and cheeks

**Mandibular -** sensory and motor nerves. Supplying the teeth and gums of the lower jaw, ear and tongue. Motor supplying the muscles of mastication

**7TH FACIAL**

Motor supply the muscles of facial expression and sensory supply nerves of taste from the anterior part of the tongue

**11TH ACCESSORY**

There are two parts, cranial and spinal.

Cranial branches joining the vagus nerve to supply the pharynx and larynx

Spinal branches supplying the trapezius and sternocleido mastoid

**SPINAL NERVES**

These nerves begin in the spinal cord and supply all parts of the body not covered by the cranial nerves. They are all mixed nerves. Spinal nerves are divided into 31 pairs:

* **Cervical**: 8 pairs
* **Thoracic:** 12 pairs
* **Lumbar:** 5 pairs
* **Sacral:** 5 pairs
* **Coccygeal:** 1 pair

The cervical and thoracic nerves are named after the vertebrae at the level at which they exit the spinal cord. The lumbar, sacral and coccygeal nerves leave the spinal cord at the level of the first lumbar vertebra and extend downwards inside the vertebral canal exiting the canal at different levels depending on their destination.

All spinal nerves except the 2nd to 12th thoracic nerves branch out and regroup to form plexuses which supply different parts of the body:

**THE CERVICAL PLEXUS**

This contains the first four cervical nerves and supplies the muscles of the neck, shoulder and skin and includes the phrenic nerve, which sends nerve impulses to the diaphragm telling it to contract.

**THE BRACHIAL PLEXUS**

This group includes the lower four cervical nerves and the first thoracic nerve. It branches out to supply the muscles from the base of the neck to the fingertips and skin.

**THE THORACIC (INTERCOSTAL) NERVES**

The thoracic nerves supply the chest muscles and the main part of the abdominal wall.

**THE LUMBAR PLEXUS**

This group includes the first three lumbar nerves and part of the fourth. It supplies the skin and muscles of the lower abdomen, thighs and groin.

**THE SACRAL PLEXUS**

This includes the fourth and fifth lumbar nerves and first four sacral nerves. It supplies the muscles and skin of the pelvic area. The main nerve is the sciatic nerve which supplies the hamstrings, before dividing above the knee into the tibial and common peroneal nerves to supply the lower leg.

**THE COCCYGEAL PLEXUS**

The coccygeal group forms a second small plexus on the back of the pelvic cavity, supplying the muscles and skin of the pelvic area such as the external sphincter of the anus, tissues of the perineum and the external genitalia.

**TOPIC 3: THE SOMATIC AND AUTONOMIC NERVOUS SYSTEM**

The motor division of the Peripheral Nervous System is divided into the Somatic Nervous System and the Autonomic Nervous System.

**WHAT IS THE SOMATIC NERVOUS SYSTEM?**

The Somatic Nervous System conducts impulses from the CNS to the skeletal muscle fibres. This is the voluntary branch of the PNS and allows conscious control over the contraction of skeletal muscles.

**WHAT IS THE AUTONOMIC NERVOUS SYSTEM?**

The Autonomic Nervous System conducts impulses from the CNS to cardiac and smooth muscles. This is an involuntary system controlled by the hypothalamus. Its nerves arise from the medulla oblongata. The Autonomic Nervous System is further divided into Sympathetic and Parasympathetic divisions. Every organ in the body has a sympathetic and parasympathetic nerve supply with one division generating the opposite effect to the other.

**SYMPATHETIC**

**Structure:** Consists of nerves that arise from the spinal cord at the thoracic and lumbar region, form ganglia (bundles of nerve fibres) just outside the CNS and then extend to the organ or tissue they supply.

**Functions:**

Prepares body for stressful situations such as excitement or physical activity (fight or flight system). Neurones release acetylcholine and noradrenaline which have the following effects:

* Accelerates action of heart, increasing rate and force of contraction.
* Vasodilation of coronary arteries, increasing blood supply to the heart muscle.
* Vasodilation of vessels supplying skeletal muscles, increasing oxygen and nutrient supply and waste removal.
* Causes sustained contraction of the spleen, thus increasing volume of blood circulating.
* Vasoconstriction of vessels that supply the digestive system and urinary system, increasing blood available for active muscles and brain.
* Dilation of bronchioles, increasing volume of air that can be inspired and expired.

**PARASYMPATHETIC**

**Structure:** Consists of nerves that arise from the brain and sacral region of the spinal cord, form ganglia near to or inside the organ or tissue they supply.

**Functions:**

predominant system in non-stressful situations and keeps normal body functions running when the body is at rest. Neurones release acetylcholine.

* Slows action of heart, decreasing rate and force of contraction
* Vasoconstriction of coronary arteries, decreasing blood supply to the heart muscle
* Vasodilation of vessels supplying the digestive system and urinary system with contraction of the bladder and rectal muscles, increasing digestion, nutrient absorption, micturition and defacation.
* Constriction of the bronchi, decreasing the volume of air inspired and expired

**WHAT ARE REFLEXES?**

A reflex is the automatic (not controlled by the brain) movement produced by a sensory stimulus. It is instant and involuntary e.g. a finger touching boiling hot water will immediately move away.

Several structures are involved in the production of a reflex and together they constitute the 'reflex arc':

* A sense organ, like the skin or the nerve endings in muscles, tendons or organs
* A sensory nerve travelling from the sensory organ
* the spinal cord
* A motor nerve starting in the spinal cord and travelling to the motor organ.

**Function:** reflexes are mostly protective and designed to stimulate the quickest motor responses (movements) possible. They are reflexes which are automatic and do not require supervision, like the secretion of gastric juices when food reaches the stomach.

**TOPIC 4: DISEASES AND DISORDERS (PATHOLOGIES)**

**NEURITIS**

Inflammation of a nerve, caused by infection, injury, poison, etc.

**Effect:** pain along the nerve's length and/or loss of use of the structures supplied by the nerve.

**BELL'S PALSY**

Injury or infection of the facial nerve which subsequently becomes inflamed

**Effect:** facial paralysis.

**NEURALGIA**

Various causes

**Effect:** bouts of burning or stabbing pain along the course of one or more nerves.

**SCIATICA**

Pressure on the roots of the sciatic nerve often caused by degeneration of an intervertebral disc

**Effect:** pain down the back and outside of the thigh, leg and foot

**PARKINSON'S DISEASE**

Progressive disease caused by damage to basal ganglia of the brain and resulting in loss of dopamine (neuro-transmitter).

**Effect:** causes tremor and rigidity in muscles, as well as difficulty and slowness with voluntary movement.

**MULTIPLE SCLEROSIS** (also known as disseminated sclerosis)

Loss of the protective myelin sheath from nerve fibres in the central nervous system.

**Effect:** causes muscular weakness, loss of muscular coordination, problems with skin sensation, speech and vision.

**CEREBRAL PALSY**

Damage to the brain, caused during birth or resulting from a pre-natal defect.

**Effect:** affects motor system control.

**MOTOR NEURONE DISEASE**

A rare progressive disorder, in which the motor neurones in the body gradually deteriorate

**Effect:** weakness and wasting of muscles

**MYALGIC ENCEPHALOMELITIS (ME)**

Also known as post-viral fatigue or chronic fatigue syndrome.

**Effect:** exhaustion, general aches and pains, headaches and dizziness, inflammation of the brain and spinal cord.

**STRESS**

Stress is any factor that affects mental or physical well-being. Emotions such as anxiety, fear and other negative feelings can affect the nervous system causing increased heart rate, breathing difficulties, sleep disturbances and stomach problems. All of these physical effects are caused by the nervous system over-working in response to stress.

**DEPRESSION**

Is a bipolar affective disorder - also known as manic depression, seasonal affective disorder (SAD) - also known as winter depression or winter blues, post-natal - is a form of clinical depression which can affect women, and less frequently men, after childbirth.

**EPILEPSY**

A disorder of the central nervous system characterized by loss of consciousness and convulsions.

**MIGRAINE**

A severe, disabling headache, usually affecting only one side of the head, and often accompanied by nausea, vomiting, photophobia and visual disturbances.

**STROKE**

A sudden loss of consciousness resulting when the rupture or occlusion of a blood vessel leads to a lack of oxygen in the brain.

**TRANSIENT ISCHAEMIC ATTACK (TIA)**

Sometimes called a mini-stroke: a temporary restriction of blood supply to the brain, which causes short-term symptoms such as temporary vision loss or impairment.

**ALZHEIMERS DISEASE**

The most common form of dementia in older people that affects many areas of cognitive function.

**CONCUSSION**

An injury to the brain caused by a blow; usually resulting in loss of consciousness.

**DEMENTIA**

The result of a brain injury, resulting in long-term decline in cognitive function due to damage or disease in the body beyond what might be expected from normal aging.

**MENINGITIS**

An infectious disease characterized by inflammation of the meninges (the tissues that surround the brain or spinal cord) usually caused by a bacterial infection; symptoms include headache, stiff neck, fever and nausea.

**MYASTHENIA GRAVIS**

A chronic progressive disease characterized by chronic fatigue and muscular weakness (especially in the face and neck).

**PARALYSIS**

A loss of the ability to move a body part.

**PERIPHERAL NEUROPATHY**

Is the term for damage to nerves of the peripheral nervous system, which may be caused either by diseases of the nerve or from the side-effects of systemic illness.

**POLIOMYELITIS**

An acute viral disease marked by inflammation of nerve cells of the brain stem and spinal cord.

**SPINAL CORD INJURY**

Is damage to white matter or myelinated fibre tracts that carry signals to and from the brain.

**SPINA BIFIDA**

Is a developmental birth defect involving the neural tube; a not uncommon congenital defect in which a vertebra is malformed and the backbone does not form properly.

**INTERRELATIONSHIPS**

**Nervous system links to:**

All systems: nerves from the central nervous system control and receive information from every body system.

**Muscular:** muscles require a nerve impulse to contract.

**Skeletal:** muscle contraction (caused by nerve impulses) produces movement in the skeleton.

**Circulatory:** nerves control the heart rate.

**Respiratory:** nerves control the process of respiration.

**Endocrine:** works closely with the endocrine system to maintain homeostasis - balance in the body.

**Skin:** the skin contains a variety of nerve endings, at different levels in the layers.

**Summary**

The nervous system

* Has two parts, the central and peripheral (including autonomic) nervous systems
* Informs and warns the body of environmental changes, sensations, pain and danger and initiates responses to stimuli.