Nervous system

The nervous system, together with the endocrine system, forms the body's internal communication system. The endocrine system uses a chemical message and the nervous system an electrical one (impulse).

The nervous system can be described in terms of reacting to external stimuli, such as sound, light, smell, taste and touch, all of which give the brain vital information in order to react to survive. The brain processes the information and decides on the appropriate action. These reactions can be in the form of muscle contraction in order to move away from danger, blinking for example closes the eye against foreign bodies, or may be an internal reaction such as the stimulation of a gland to produce a product, for example, the sweat glands may be stimulated to produce more sweat to cool the body as a result of the skin registering an increase in temperature. The functions of the nervous system are to:

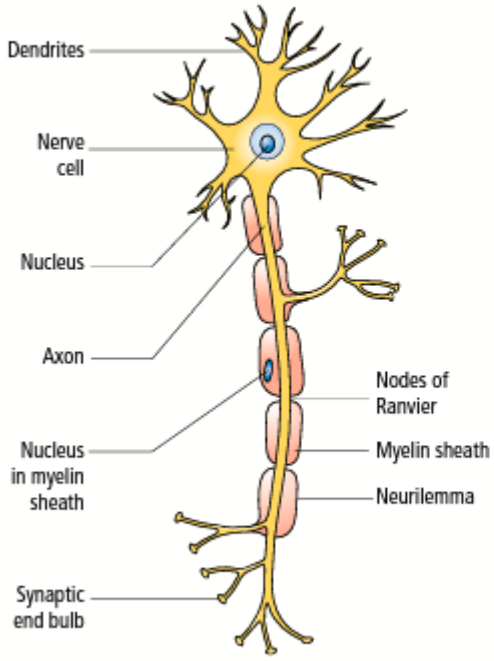
- sense change in the external environment outside of the body, for example temperature
- relay information from the external environment via sensory organs, for example sight and sounds
- sense change within the internal environment of the body
- interpret and respond to these changes and information in order to maintain the body's homeostasis (i.e. the ability of the body to adjust its physiological processes in order to maintain its eternal equilibrium).

The nervous system is organised into three major parts:

- the central nervous system (CNS): the brain and spinal cord
- the peripheral nervous system (PNS): made up of motor sensory and autonomic nerves
- the autonomic nervous system (ANS): made up of the autonomic nerves which have two functions – sympathetic and parasympathetic.

These systems are made from nerve tissue and nerve cells and are specialised for the transmission of electrical type messages or impulses.

Nerve tissue



△ Structure of a typical nerve cell

Nerve tissue is made up of nerve cells, known as **neurones**, which are capable of transmitting impulses which are like an electrical message. These impulses are created when there is a chemical change within the cell body caused by pressure, temperature change or other stimuli. Within the cell body are negatively charged potassium ions and outside the cell are positively charged sodium ions; when the chemical change occurs the membrane becomes permeable and the sodium ions leak into the cell body. The mix of the negatively and positively charged ions creates an electrical charge known as an impulse. Sodium and potassium ions are therefore known as neurotransmitters.

Each neurone joins along its length with the next, forming a junction or synapse, but one individual nerve cell can be up to a metre in length. The impulses are passed from one cell to the next from the brain and spinal cord to muscles to instigate contraction and to glands where they are stimulated to increase their activity, producing sweat for example. However, the most important function of the neurones is to take information from the external environment to the brain where it is considered and acted upon. There are three types of neurone, defined by their function:

Key terms

Neurone – nerve cell.

Impulse – an electrical message carried by nerve tissue.

Synapse – a junction or connection between neurones.

- **Sensory or afferent neurones** receive stimuli and take the impulses to the spinal cord and brain.
- **Motor or efferent neurones** carry impulses away from the spinal cord and brain to muscles and glands.
- **Association or internuncial neurones** bring about the distribution of the incoming and outgoing impulses.

Structures associated with nerve cells

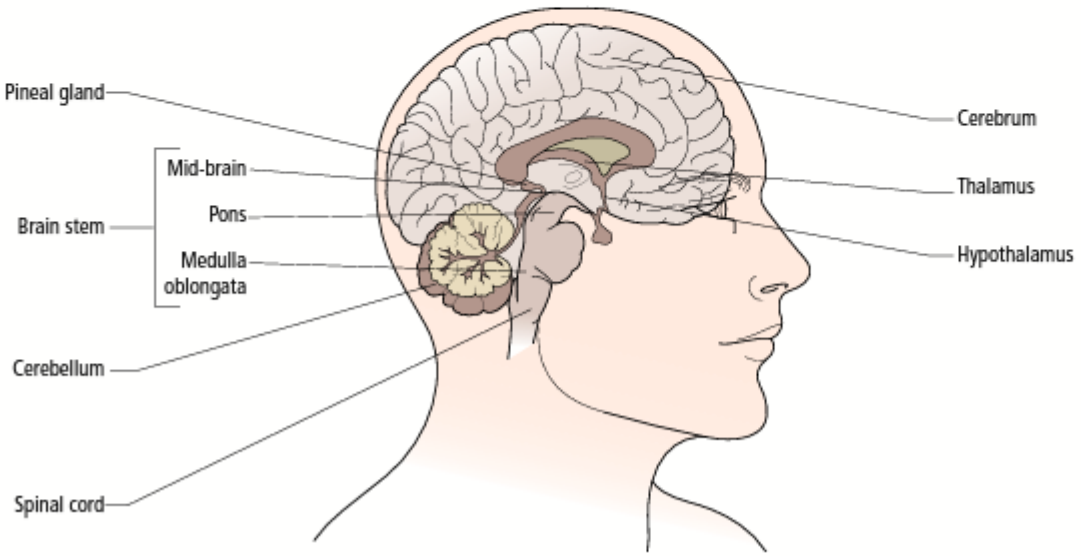
- Nerve cell body: contains the components of a typical cell such as the nucleus and mitochondria (see page 55 earlier in this chapter).
- Axon: carries impulses away from the cell body and can vary greatly in length from 1mm to over 1m.
- Dendrites: carry impulses to the cell body.
- Myelin sheath: a membrane that covers the axon of a nerve cell, it is made from fatty substances that insulate the nerve cell, ensuring the conduction of the impulse and increasing its speed.
- Nodes of Ranvier: gaps within the myelin sheath about 2–3mm in length that increase the rate of conduction of the impulse.
- Schwann cells: specialised **neuroglial** cells that exist outside of the CNS and are associated with sensory neurones. They wrap around the axon at intervals to protect and support the neurone.
- Neurilemma: the membrane that covers the Schwann cell.

Central nervous system (CNS)

The CNS consists of the brain and the spinal cord and is vital to the life and continued functioning of the body. It is considered to be the central area responsible for the assimilation and transmission of impulses to and from the external and internal body environments. It is protected by the skull (brain) and vertebrae of the spine (spinal cord) of the skeletal system.

Brain

The brain is the 'control centre' of the nervous system. Different areas of the brain specialise in the assimilation of different stimuli as shown in the diagram.



△ Areas of the brain

The brain is divided into three parts:

1. The cerebrum, which is divided into two hemispheres, which are further divided into lobes named after the skull bones under which they lie.
2. The cerebellum, or 'small brain', positioned under the cerebrum.
3. The brain stem, consisting of the hypothalamus, midbrain, pons and the medulla oblongata.

Cerebrum

The structure of the cerebrum has an outer layer made of folds of 'grey matter' consisting of nerve cell bodies. The inner layer of the cerebrum is made of 'white matter' or nerve fibres and it is these fibres that link the areas of the brain together so that the separate sections work together. This structure of the brain is responsible for controlling voluntary muscle contraction in movement and locomotion, the assimilation of conscious sensations such as pain, heat and cold and the control of mental activity such as reasoning and memory.

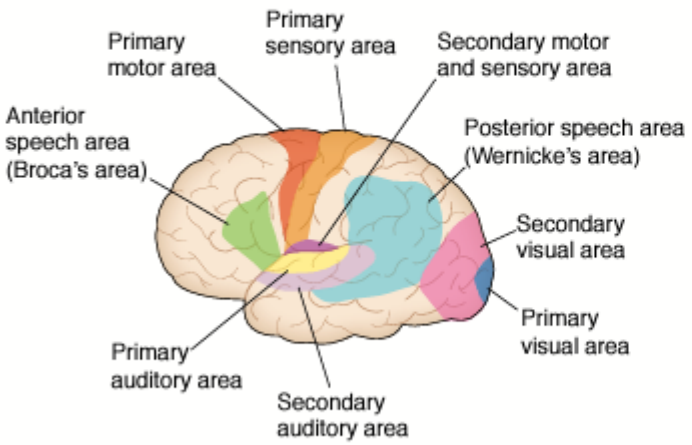
Cerebellum

The cerebellum sits under the cerebrum at the back of the skull and is divided into a left and right hemisphere; it has a similar structure with white matter on the inside surrounded by grey matter.

The functions of the cerebellum are more subconscious and include the coordination of muscular activity for the maintenance of muscle tone, posture and balance.

Brain stem

- The hypothalamus forms the uppermost part of the brain stem and is situated within the hemispheres of the cerebrum. Its function is to control the body's metabolism, water balance and body temperature. Emotions such as thirst, sex drive, pain and pleasure are elicited here and it is in close contact with the pituitary gland, the master gland of the endocrine system, forming a link between the two systems.
- The midbrain lies between the cerebrum and cerebellum and is made up of nerve cells and fibres. Its function is to relay information to and from the spinal cord and cerebrum and cerebellum.
- The pons sits in front of the cerebellum and bridges the gap between its two hemispheres. Its function is the same as that of the midbrain, to relay information.
- The medulla oblongata forms the lower part of the brain stem and is connected to the spinal cord. It forms a major role in the control of the body's functions. There are four control centres: 1) the cardiac centre, which controls the rate and force of the heart contractions, 2) the respiratory centre, which controls the rate and depth of breathing, 3) the vasomotor centre, which controls the constriction and dilation of the blood vessels and 4) the reflex centre, which controls vomiting, coughing, sneezing and swallowing.



△ Areas of the brain in terms of their function

Spinal cord

In connection and in continuation with the medulla oblongata, the spinal cord forms part of the central nervous system, stretching down the central back from the brain to the lumbar vertebrae. It is encased within the vertebrae of the spine and the arrangement of these bones allow for flexibility and protection. The spinal cord is made of grey matter encased by white matter with the nerve fibres running along its length. Its function is to relay messages sent to and from the peripheral nervous system and the brain.

Cerebrospinal fluid

This is a clear, colourless fluid that resembles blood plasma and is formed by specialist cells within the CNS. Its function is to:

- protect the brain and spinal cord by acting as a 'shock absorber' between these delicate organs and the bony structures that surround them
- maintain a constant pressure around the brain and spinal cord
- act as 'tissue fluid' in that it allows the flow of nutrients and the removal of waste products in and out of the CNS.

Meninges

The CNS is surrounded by three membranes or meninges which have a protective function. They are called:

- The dura mater – outermost layer
- The arachnoid mater – situated immediately below the dura mater.
- The pia mater – a vascular membrane which closely covers the brain and along the length of the spinal cord.

Peripheral nervous system (PNS)

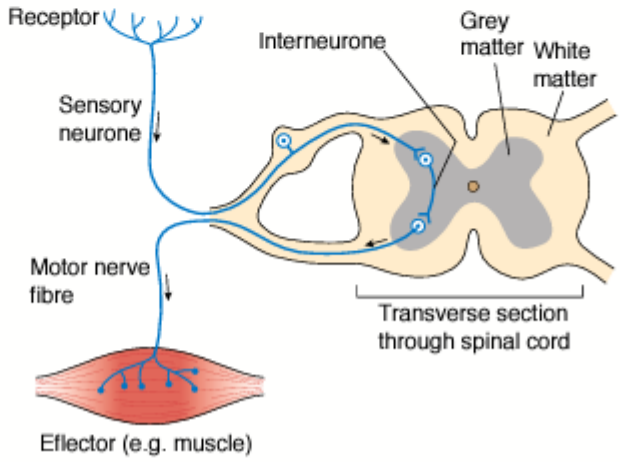
The PNS is a network of sensory and motor nerve fibres that relay the electrical impulses to and from the CNS to the extremities and organs of the body. Sensory nerve fibres carry messages from the external environment to the CNS for assimilation and recognition. This gives the body details of its surroundings so that it can react in an appropriate or possibly even life-saving manner. The responses to these stimuli are transmitted to muscles, organs and glands via the motor nerves to bring about the necessary action. The PNS consists of pairs of nerves, one from the left and the other from the right side of the body:

- Twelve pairs of cranial nerves that emanate from the brain. Many of these have a purely sensory function, such as the optic nerve, or a purely motor function, such as the facial nerve that provides stimulus for the movement of facial muscles for expression, while others are a mix of both sensory and motor functions.
- Thirty-one pairs of spinal nerves that emanate from the spinal cord, eight from the cervical region of the spine, twelve from the thoracic, five each from the lumbar and sacral regions and one

pair from the coccygeal. The spinal nerves are mixed with both sensory and motor functions and serve the specific areas of the body associated with the particular area of the spinal cord from which they leave through channels within the vertebrae.

Reflex arc

A reflex arc or action is the quick response to stimuli that could endanger or harm the body and serves as a means of protection. An example of this is when an object such as a flying insect comes too close to the eye. On seeing the insect, or at least being aware of it, the eye will blink and the muscles of the neck contract to move the head away quickly. This and other reflexes rely on the coordination of the sensory and motor neurones to and from the spinal cord with no impulse taken to the brain for assimilation and response. Instead the response is immediate, requiring no thought, and in this way the quickness of the response avoids the danger.



△ Typical reflex arc

Autonomic nervous system

The autonomic nervous system forms part of the peripheral nervous system but has an involuntary function. It is controlled by the hypothalamus within the brain and the nerve fibres arising from the medulla oblongata. The autonomic system is divided into two parts: the sympathetic and the parasympathetic.

Sympathetic

The function of the sympathetic part of the autonomic nervous system is to prepare the body for stressful situations, either excitement or 'fight or flight'. The nerve fibres arise from the thoracic and lumbar region of the spine and the neurones (nerve cells) release chemicals called hormones that bring about the following effects on the body:

- increased heart rate and force
- vasodilation of blood vessels in the heart and skeletal muscles
- vasoconstriction of blood vessels within the digestive system
- dilation of the bronchioles in the lungs, increasing lung capacity
- dilation of the pupils to increase the use of available light
- stimulation of the sweat glands to increase activity
- contraction of the arrector pili muscles in the skin to make hair 'stand on end'.

The nerve fibres arise from the brain and sacral region of the spine and their function is to maintain the body's normal functioning in non-stressful situations. The effects on the body are:

- decreased heart rate
- vasoconstriction of the coronary arteries of the heart
- vasodilation of the blood vessels in the digestive and urinary systems
- constriction of the bronchioles decreasing lung capacity.

Disorders of the nervous system

Disease/disorder	Cause	Description
Bell's palsy	Compression of the facial nerve as it runs through the temporal foramen leading to inflammation and swelling of the nerve	Paralysis of the muscles on the affected side of the face leading to a visual drooping of the features. The condition is temporary but recovery can take up to several months
Cerebral palsy	Damage to the CNS during pregnancy, birth or soon after as a result of bleeding or lack of oxygen	Signs and symptoms vary according to the part of the brain affected but include impaired speech, hearing or sight, muscle spasticity and poor coordination, muscle weakness and associated postural faults
Epilepsy	Reccurring seizures (fits) caused by abnormal and excessive neurological activity in the brain; causes are varied but can include trauma and/or infection	There are several grades of seizure, from a simple loss of awareness or recollection to unconscious, violent fitting
Multiple sclerosis (MS)	Degeneration of the myelin sheath that leads to the nerve tissue being exposed in the CNS. Cause is unknown but factors thought to contribute to its development include changes in environment and climate in particular, genetically abnormal myelin or viral infection	Symptoms vary depending on the affected site but usually muscle weakness, lack of coordination and disturbed sensations such as burning or 'pins and needles'

Disease/disorder	Cause	Description
Parkinson's disease	Destruction of neurones and lack of neurotransmitters; specific causes are as yet unknown, but may be a result of environmental factors, misuse of drugs and repeated trauma to the head such as occurs in boxing	Symptoms include lack of muscle coordination, fixed muscle tone, muscle tremor and progressive disability with no effect on the intellect
Meningitis	Inflammation of the meninges, the protective membranes covering the brain and spinal cord due to infection with bacteria, virus or other micro-organisms	Symptoms include headache, stiff neck, vomiting, fever, confusion and drowsiness; sometimes a rash is also seen
Migraine	Cause is unknown but common triggers have been identified including stress, hunger or thirst, fatigue, hormone disturbances during menstruation, pregnancy or menopause. Some attribute the condition to foodstuffs such as cheese and red wine but there is no confirmed evidence that this is so	Severe headache affecting usually one side of the head with accompanied visual disturbances, increased sensitivity to light and sometimes to sound, nausea and vomiting
Sciatica	Pressure or damage to the sciatic nerve as it appears from the lumbar region and travels down the back of the leg	Pain, weakness, tingling or numbness in the affected leg
Carpal tunnel	Pressure to the median nerve in the forearm and wrist	Leads to numbness, tingling, weakness or muscle damage in the hand and fingers