كلية المستقبل الجامعة قسم الفيزياء الطبية
المرحلة الثالثة

ANATOMY

The Nervous System 1

Dr Abdulhusein Mizhir Almaamuri

Introduction

The nervous system is a major communicating and control system within the body. It works with the **endocrine system** to control many body functions. The nervous system provides a rapid and short-acting response, and the endocrine system provides a slower but often more sustained response. The two systems work together to maintain homeostasis. The nervous system interacts with all of the systems of the body. This system is large and complex. In order to facilitate understanding of the nervous system it has to be divided into smaller functional and anatomical parts.

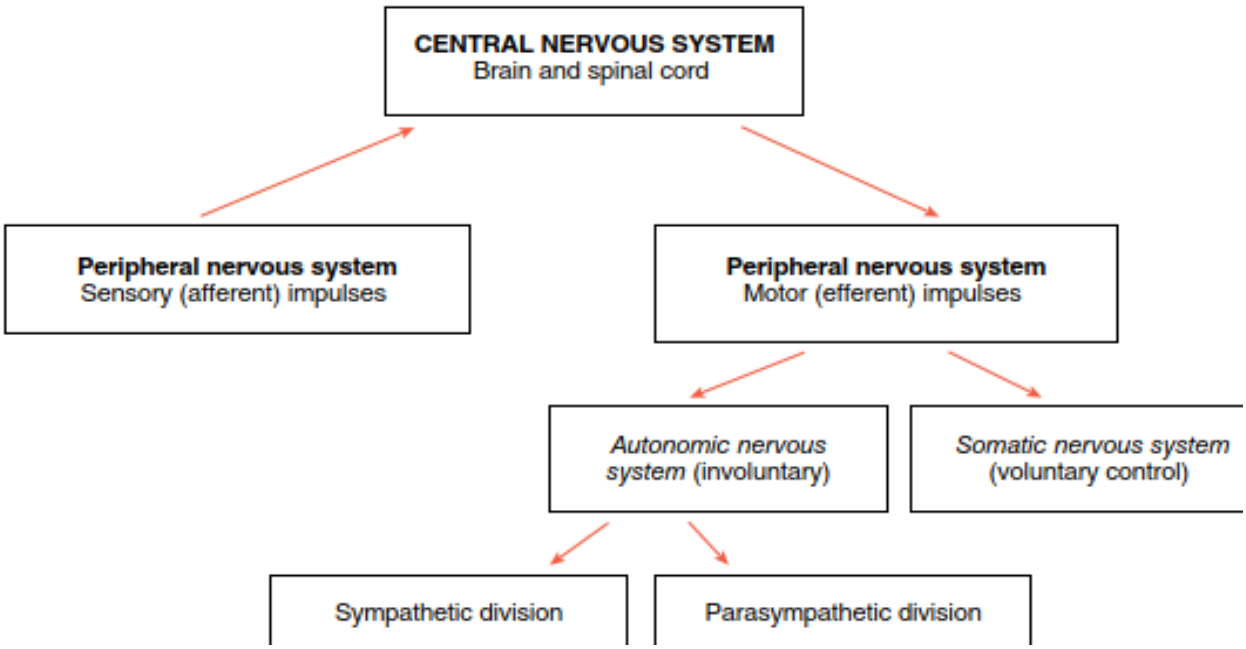
Organisation of the nervous system

The nervous system can be divided into two parts: the central nervous system CNS and the peripheral nervous system PNS. The central nervous system consists of the brain and spinal cord and is the control and integration centre for many body functions. The peripheral nervous system carries sensory information to the central nervous system and motor information out of the central nervous system. The direction of information flow to and from the nervous system is important and is shown in Figure.

Sensory division of the peripheral nervous system

Sensory information (stimuli) is gathered from both inside and outside of the body. This sensory input is delivered to the central nervous system via the peripheral nerves. Sensory nerve fibers are also called **afferent fibers**. Sensory information always travels from the peripheral nervous system towards the central nervous system. There are many different kinds of sensory information, including pain, pressure, temperature, chemical levels and more. Consider the maintenance of body temperature. As warm-blooded animals, it is important that body temperature is maintained between 36.5 and 37.5 °C. Temperature receptors in

the skin called thermoreceptors detect changes in temperature, and as temperature changes have the potential to cause damage to cells and tissues, this information must be relayed to the central nervous system and, if required, acted upon.



Central nervous system

The central nervous system consists of the brain and spinal cord. The central nervous system processes and integrates sensory information. The received information has to be interpreted, it can be stored to be dealt with later or it can be acted upon immediately with one or more motor responses. For example, the sensation of temperature change would be received and interpreted by the hypothalamus (a structure of the central nervous system) and an appropriate action would be initiated.

Motor division of the peripheral nervous system

The motor division of the peripheral nervous system always carries impulses away from the central nervous system, usually to effector organs. Motor nerve fibres are also called **efferent** fibres. There are two types of motor information. Motor information to the somatic nervous system or to the autonomic nervous system.

Somatic nervous system

The somatic nervous system is under voluntary control, and the effector (tissue or organ responding to instruction from the central nervous system) is skeletal (voluntary) muscle. The central nervous system's response to sensory information may be to activate the somatic nervous system, eliciting a voluntary response involving skeletal muscle movement. So, from the example of temperature, if an increase in temperature is detected, then it might require the removal of a coat or the opening of a window – this is the motor response that involves the somatic nervous system. It is a voluntary activity that the person chooses to do.

Autonomic nervous system

The central nervous system's response to sensory information may be to activate the autonomic nervous system. This would lead to an involuntary action. The autonomic nervous system is responsible for involuntary motor responses. The effector may be smooth or cardiac muscle (both involuntary muscles) or a gland. In the example of increased temperature, the involuntary response is to lose heat through the skin – so warm blood is directed to the skin when peripheral blood vessels vasodilate. Vasodilatation is an example of an involuntary autonomic nervous system response. The indi- vidual cannot control this response.The autonomic nervous system is further divided into the sympathetic (fight or flight) and the parasympathetic (rest and digest) divisions. A fine balance between both of these divisions is required for the maintenance of homeostasis.

Neurons

The functional unit of the nervous system is the neuron or nerve cell. It has many features in common with other cells, including a nucleus and mitochondria, but because of its vital role it is well protected and has some specialist modifications. Two specialist

characteristics of neurons are:

- **irritability**, in response to a stimulus – the ability to initiate a nerve impulse.

- **conductivity** – the ability to conduct an impulse.

Neurons consist of an axon, dendrites and a cell body. Their function is to transmit nerve impulses. Nerve impulses only travel in one direction: from the receptive area – the dendrites – to the cell body, and down the length of the axon.

Axons bundled together are called **nerves**. Neurons rely on a constant supply of oxygen and glucose. Once the neurons of the brain and spinal cord have matured after birth they will not be replaced or regenerate if they become damaged. Peripheral neurons can regenerate if the cell body is not damaged and the alignment of the neuron is not disrupted.

Dendrites

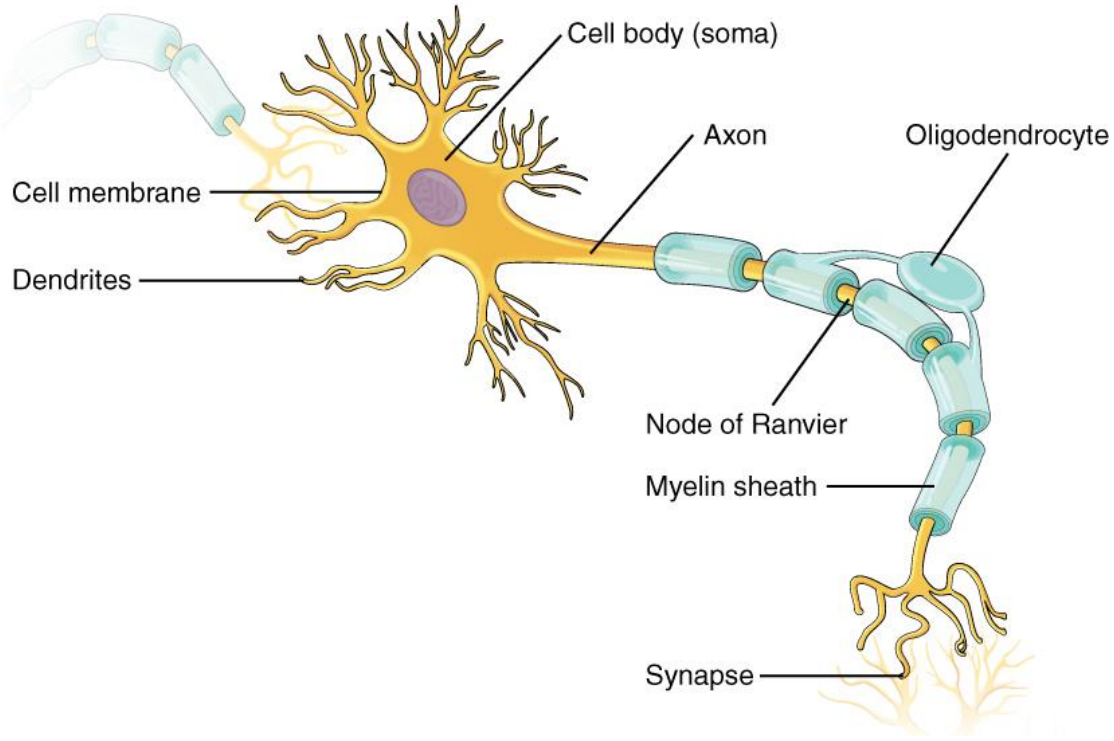
Dendrites are short branching processes that receive information and conduct it toward the cell body. Their branching processes provide a large surface area for this function. In sensory neurons the dendrites may form the part of the sensory receptors, and in motor neurons they can form part of the synapse between one neuron and the next.

Cell body

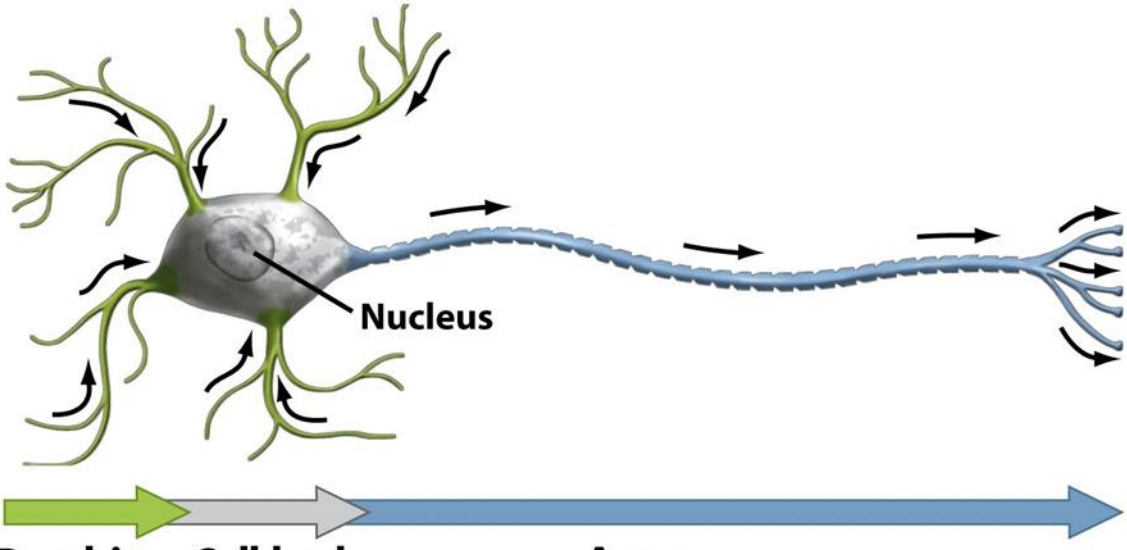
Most of the neuron cell bodies are located inside the central nervous system and form the grey matter. When clusters of cell bodies are grouped together in the central nervous system they are called nuclei. Cell bodies located in the peripheral nervous system are called ganglia.

Axons

Each neurone has only one axon that conducts information away from the cell body. The axon can branch to form an axon collateral. The axon will also branch at its terminal into many axon terminals. The axon delivers the impulse to another neuron or a gland or a muscle.The axon length can vary quite significantly from very short to 100 cm long.



Information flow through neurons



Dendrites
Collect electrical signals

Cell body
Integrates incoming signals and generates outgoing signal to axon

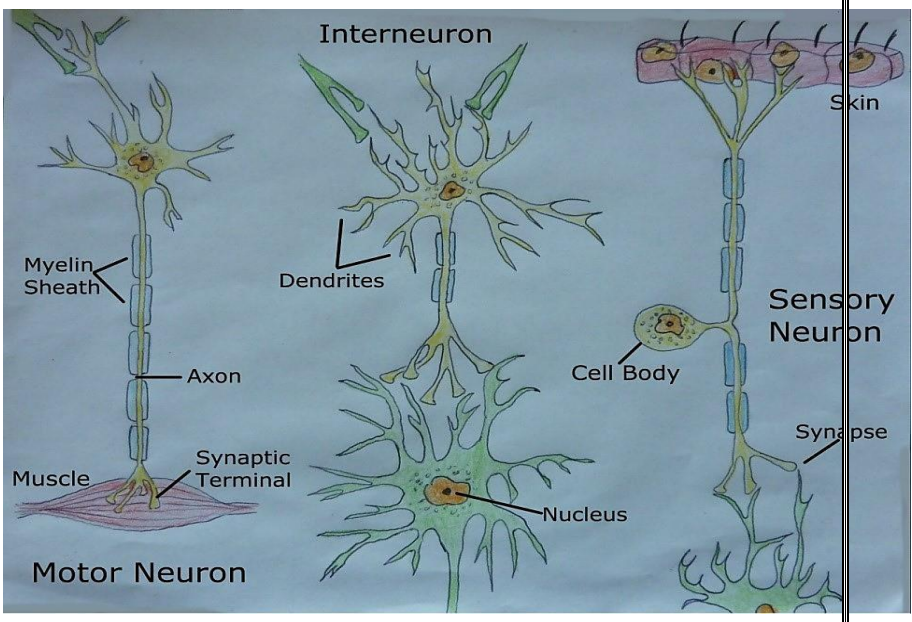
Axon
Passes electrical signals to dendrites of another cell or to an effector cell

Figure 45-2b Biological Science, 2/e

Classification of neurons according to their connections (function);

Sensory Neurons: Neurites connected to sensory surfaces of the body (e.g. Skin, retina, etc)

Motor Neurons: Connected to muscles.



Interneurons: Connectes to other neural cells

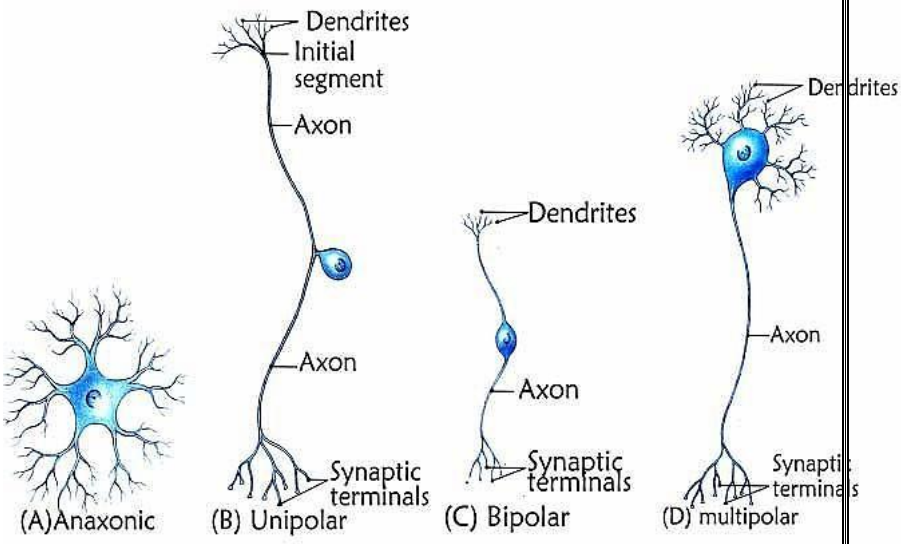
Classification of neurons according to their number of neurites;

Unipolar Neurons: a unipolar neuron has one axon with two branches attached to its soma. Most sensory neurons are unipolar

Bipolar Neurons: a bipolar neuron has one axon and one dendrite attached to its soma § Many interneurons are bipolar

Multipolar Neurons: a multipolar neuron has one axon and many dendrites attached to its soma.

These are the most common. Most motor neurons as well as many interneurons are multipolar



Anaxonic: Lacks axon.

Basic parts of a neuron

1.Soma or cell body

2.Neurites

Dendrites
(afferent)

Axon
(efferent)

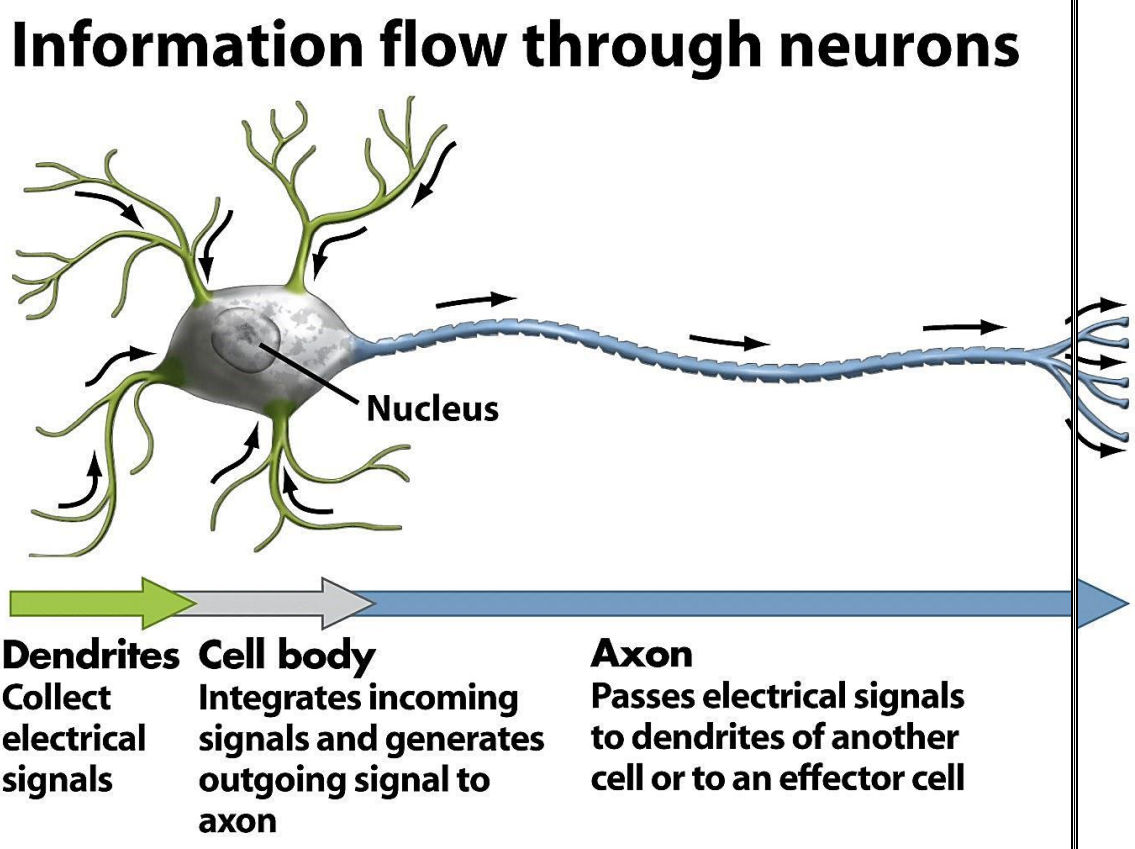
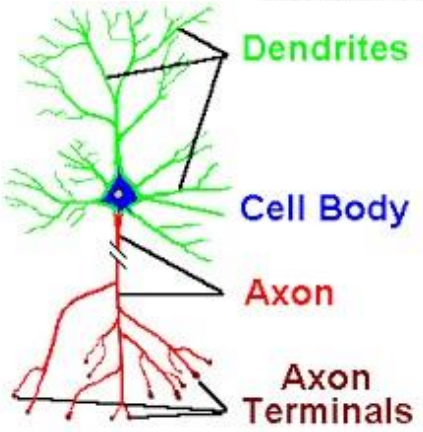
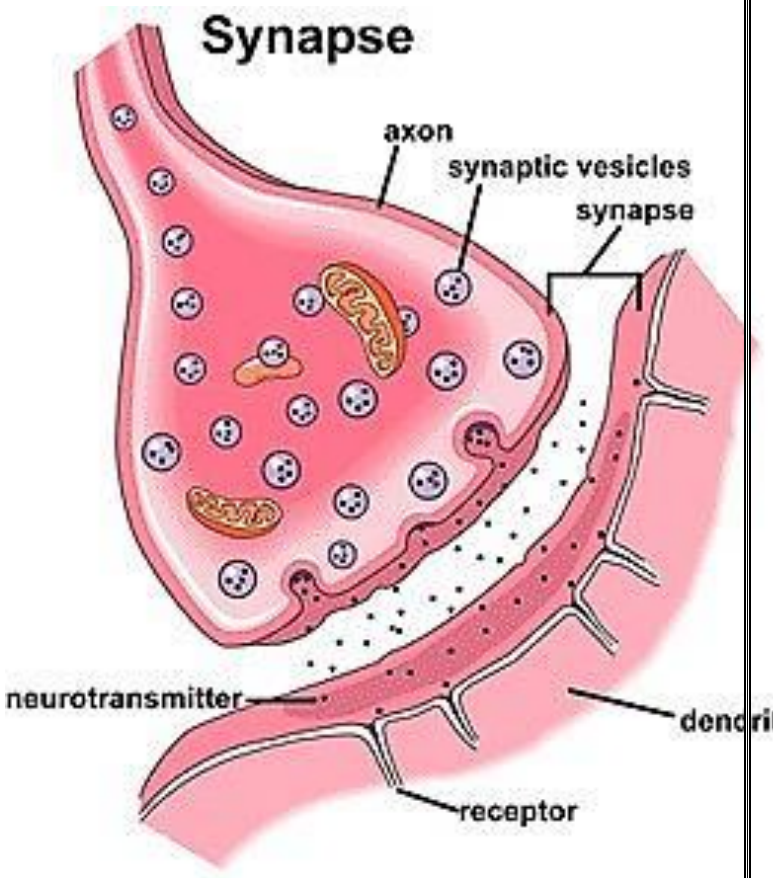


Figure 45-2b Biological Science, 2/e
© 2005 Pearson Prentice Hall, Inc.



- **Synapses are the gaps between adjacent neurons across which chemical signals are transmitted.**



Synaptic vesicles: small spherical membranes that store neurotransmitter molecules and release them into synaptic cleft.

Neurotransmitters

Neurons do not come into contact with one another. Where one neuron ends and another begins, there is a space called the synapse. In order for communication to occur between neurones or between the neurone and a muscle or gland, a chemical messenger called a **neurotransmitter** is secreted by the neurone into the extracellular space at the synapse.
Some examples of neurotransmitters are:

- acetylcholine,
- norepinephrine,
- dopamine,

Neuroglia of the nervous system

The neuroglia, or glial cells (gr. glia = glue), are the second most important components of the PNS and CNS. These cells are crucial to the functioning of the nervous system. They **are involved in all transport processes**, contribute to the

alimentation of the nerve cells, and serve as protection and insulation. Unlike the neurons, the glial cells do not initiate or transmit action potentials. In a mature nervous system, **glial cells reproduce and divide**. Particularly in the case of injuries or diseases, they reproduce in order to fill up the space that was formerly occupied by neurons.

For every nerve cell, there exist about 10 glial cells. Still, the glial cells only make up half of the total volume of the nervous system since glial cells **are much smaller than nerve cells**. The glial cells in the CNS and PNS differ from each other structurally and functionally.

Functions of the glial cells in the central nervous system

Astrocytes (macroglia):

- Exchange of substances
- Storage of glycogen and providing adjacent neurons with glucose
- Building the blood-brain-barrier
- Phagocytosis of dead synapses
- Forming glial scar tissue in the CNS, e.g., following a stroke or multiple sclerosis

Oligodendrocytes: **Microglia (Hortega cells):**

Ependymal cells:

Functions of the glial cells of the peripheral nervous system

The **Schwann cells** are responsible for myelination in the PNS. The **satellite cells** serve as helpers for the neurons and substitute cerebral astrocytes in the peripheral ganglia.

Myelin sheath

Peripheral nerve axons and long or large axons are covered in a myelin sheath. Myelin is a

fatty material whose purpose is to protect the neuron and to electrically insulate it, speeding up impulse transmission. Within the peripheral nervous system Schwann cells wrapped in layers around the neuron form the myelin sheath. The outermost part of the Schwann cell is its plasma membrane, and this is called the neurilemma. There is a regular gap (about 1 mm) between adjacent Schwann cells. The gaps are called the nodes of Ranvier. Collateral axons can occur at the node. Some nerve fibres are unmyelinated, and this makes nerve impulse transmission significantly slower.

Sensory (afferent) nerves

The dendrites of sensory neurons are often sensory receptors, and when they are stimulated the impulse generated travels towards the spinal cord and brain. There are different types of sensory receptors:

- special senses;
- somatic sensory receptors, located in the skin, such as touch, temperature and pain;
- autonomic nervous system receptors, located throughout the body, such as baroreceptors monitoring blood pressure, chemoreceptors monitoring blood pH and visceral pain receptors.

Motor (efferent) nerves

Information from the central nervous system is delivered to the peripheral nervous system via the motor nerves. Information transmitted through a voluntary somatic nerve may result in skeletal muscle contraction or the information may be autonomic in nature, not under voluntary control, and may lead to smooth muscle contraction or the release of the products of a gland.

The action potential

The nervous system is a vast communicating network sending information from the internal and external environment to the central nervous system and from the central nervous system to the muscles and glands. The way that the functional unit, the neurone, achieves this is by the generation and conduction of impulses or action

potentials. Generation of the action potential occurs due to the movement of ions into and out of the neuron and the electrical charge associated with this movement.

Two principal ions are involved:

- sodium – normally found outside of the cell (principal extracellular cation);
- potassium – normally found inside the cell (principal intracellular cation).

To provide support and protection for the CNS, the body has several layers of defenses, including the bones of the skull and meninges.

Bones of the Skull

The human skull is a hard, unbending container that protects the delicate brain. The bones are very thick in some places, such as the occipital region, and very thin in others, like in the temporal, sinus region.

The bones of the skull are referred to as the cranium. It is the first mechanism in the protection of the brain.

Meninges

The meninges cover the brain and spinal cord and protect them as well. There are three meningeal layers. They are the dura mater, arachnoid mater, and pia mater.

Dura Mater	The dura mater is the outer, tough layer of the meninges. It lines the inside of the skull.
Arachnoid Mater	The arachnoid mater is the middle layer of meninges. It is a web-like structure that allows the passage of blood vessels through it. Between the arachnoid mater and the pia mater, is the subarachnoid space. Cerebral spinal fluid (CSF) flows freely here.
Pia Mater	The pia mater is the thin, translucent, inner layer of the meninges. It covers the surface of the brain. It is the most vascular layer.

Cerebrospinal fluid

CSF is produced by the **choroid plexus** in the ventricles of the brain. There is approximately 150 mL of CSF circulating around the brain, in the ventricles and around the spinal cord.

The CSF is replaced every 8 h. It is a thin fluid similar to plasma and has several important functions:

- it acts as a cushion, supporting the weight of the brain and protecting it from damage;
- it helps to maintain a uniform pressure around the brain and spinal cord;
- there is a limited exchange of nutrients and waste products between neurones and CSF.

Functions of the Nervous System

The basic purpose of the nervous system is to regulate and adapt the human body to changes in the environment and in the body itself. It is the system responsible for communication and control in the body. Anatomically, the nervous system has 2 main subdivisions:

- The **central nervous system (CNS)**
- The **peripheral nervous system (PNS).**

The nervous system performs many different tasks and enables the human being, for instance, to smell or speak. Through receptors, the nervous system receives and processes different stimuli, such as heat or light, that can come from outside or inside the body.

Our ability to remember things or to control our body movements as well as the regulation of our internal organs is governed by our nervous system. The **basic functions** responsible for accomplishing these activities include:

- **Sensory function**
- **Integrative function**
- **Motor function**

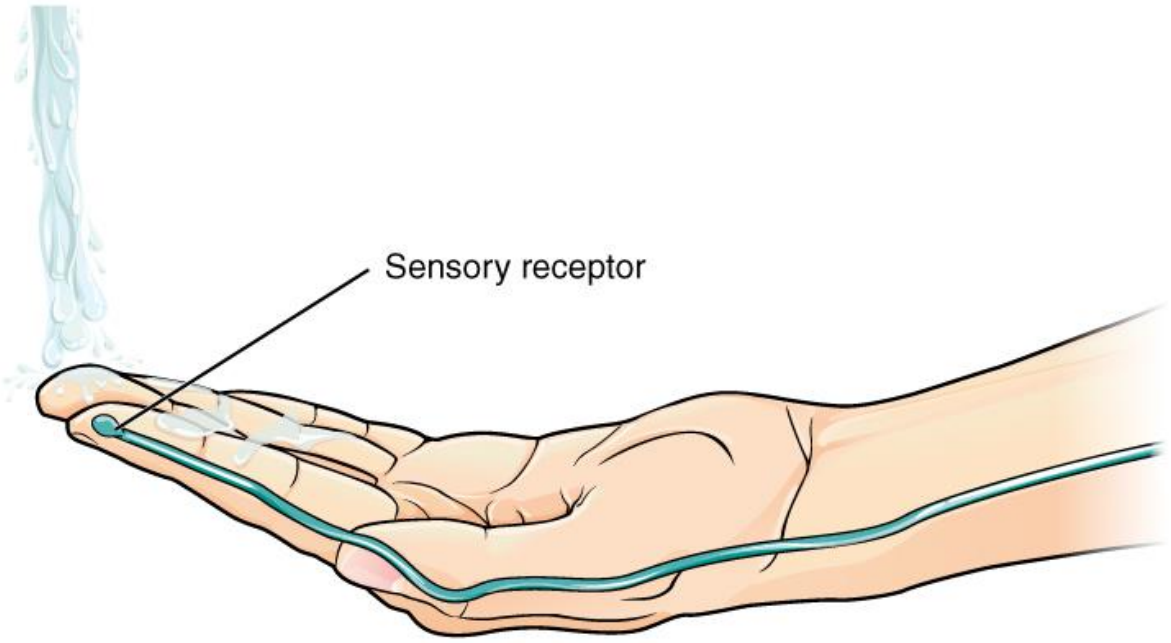


Image: Sensory Input. By: Phil Schatz. License: CC BY 4.0

Sensory function

In **sensory function,** certain sensors (or neurons) that serve as receptors for stimuli from inside the body (such as hunger or thirst) or from the environment (like the touching of a hotplate) translate such stimuli into an action potential.

These neurons are called **sensory or afferent neurons** (lat. af-/ad- = towards; ferre = to carry). They are responsible for transmitting these sensory signals via the cranial and spinal nerves to the brain and spinal cord.

Integrative function

The processing of the received sensory information constitutes the **integrative function** of the nervous system. This information is analyzed and memorized in preparation for a corresponding reaction. Perception is an important integrative function of the brain, where sensory signals are consciously identified.

In principle, the integration process is performed by **interneurons**. They represent the largest portion of all the neurons of the human body. They have short-distance axons that connect with neurons in the brain and spinal cord.

Motor function

When the sensory information has been processed, the nervous system can trigger a corresponding motor response. The **motor function** can take the form of a muscle contraction or glandular secretion.

The neurons responsible for this process are called **motor neurons or efferent neurons** (lat. ef-/ex- = out of, from). They carry the information from the brain through the cranial and spinal nerves to the spinal cord or from the brain and spinal cord to the effectors (muscles and glands).

The stimulation of the effectors by the motor neuron **causes muscle contractions and gland secretions**. Pulling away the hand after having touched a hotplate is a typical example of a motor response involving muscle contraction.