<u>Nervous System</u>

Neurons are the primary components of the nervous system, along with the glial cells that give them structural and metabolic support. The nervous system is made up of the central nervous system, which includes the brain and spinal cord, and the peripheral nervous system, which includes the autonomic, enteric and somatic nervous systems. In vertebrates, the majority of neurons belong to the central nervous system, but some reside in peripheral ganglia, and many sensory neurons are situated in sensory organs such as the retina and cochlea.

Axons may bundle into nerve fascicles that make up the nerves in the peripheral nervous system (like strands of wire that make up a cable). In the central nervous system bundles of axons are called nerve tracts.

<u>Structure of Neuron</u>

A **neuron** (American English), **neurone** (British English),[1] or **nerve cell**, is an excitable cell that fires electric signals called action potentials across a neural network in the nervous system. They are located in the nervous system and help to receive and conduct impulses. Neurons communicate with other cells via synapses, which are specialized connections that commonly use minute amounts of chemical neurotransmitters to pass the electric signal from the presynaptic neuron to the target cell through the synaptic gap.

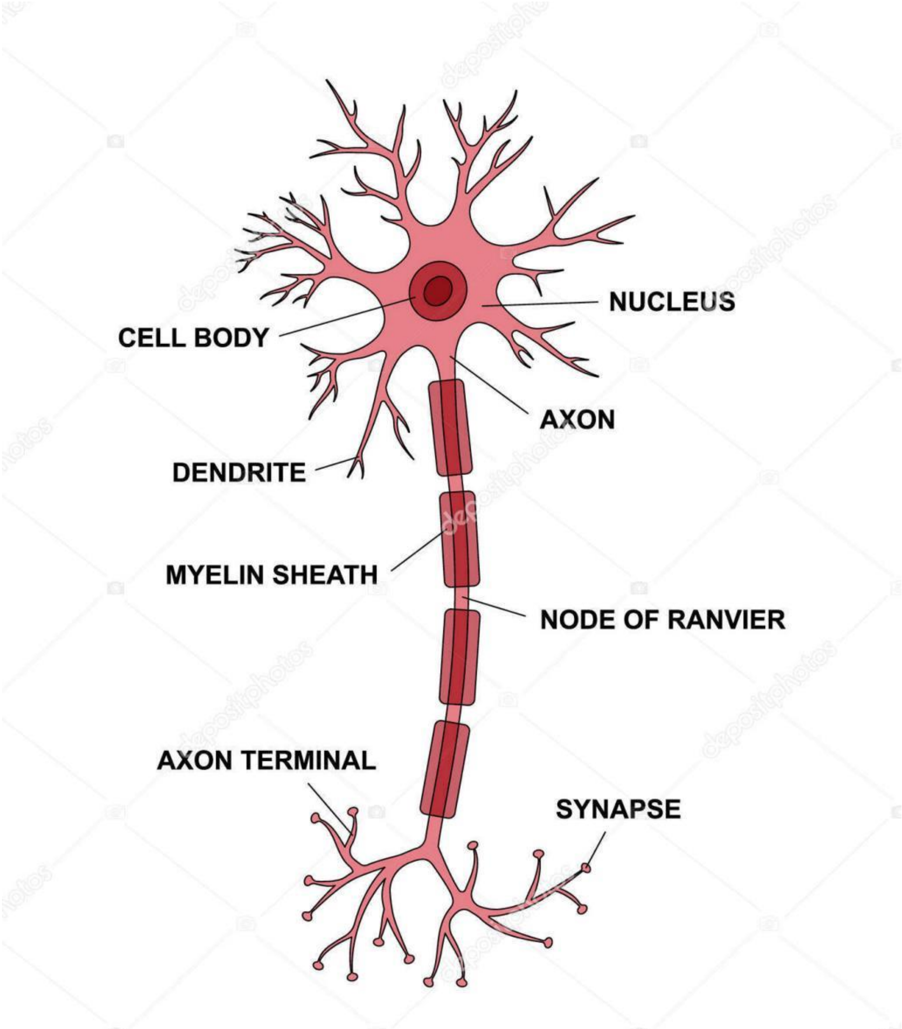
Neurons are the main components of nervous tissue in all animals except sponges and placozoans. Plants and fungi do not have nerve cells. Molecular evidence suggests that the ability to generate electric signals first appeared in evolution some 700 to 800 million years ago, during the Tonian period. Predecessors of neurons were the peptidergic secretory cells. They eventually gained new gene modules which enabled cells to create post-synaptic scaffolds and ion channels that generate fast electrical signals. The ability to generate electric signals was a key innovation in the evolution of the nervous system.[2]

Neurons are typically classified into three types based on their function. Sensory neurons respond to stimuli such as touch, sound, or light that affect the cells of the sensory organs, and they send signals to the spinal cord and then to the sensorial area in the brain. Motor neurons receive signals from the brain and spinal cord to control everything from muscle contractions[3] to glandular output. Interneurons connect neurons to other neurons within the same region of the brain or spinal cord. When multiple neurons are functionally connected together, they form what is called a neural circuit.

A neuron contains all the structures of other cells such as a nucleus, mitochondria, and Golgi bodies but has additional unique structures such as an axon, and dendrites.

- The soma or cell body, is a compact structure, and the axon and dendrites are filaments extruding from the soma. Dendrites typically branch profusely and extend a few hundred micrometers from the soma.
- The axon leaves the soma at a swelling called the axon hillock and travels for as far as 1 meter in humans or more in other species. It branches but usually

maintains a constant diameter. At the farthest tip of the axon's branches are axon terminals, where the neuron can transmit a signal across the synapse to another cell. Neurons may lack dendrites or have no axons. The term neurite is used to describe either a dendrite or an axon, particularly when the cell is undifferentiated.



Neurons are highly specialized for the processing and transmission of cellular signals. Given the diversity of functions performed in different parts of the nervous system, there is a wide variety in their shape, size, and electrochemical properties. For instance, the soma of a neuron can vary from 4 to 100 micrometers in diameter.

- The **soma** is the body of the neuron. As it contains the nucleus, most protein synthesis occurs here. The nucleus can range from 3 to 18 micrometers in diameter.
- The **dendrites** of a neuron are cellular extensions with many branches. This overall shape and structure are referred to metaphorically as a dendritic tree. The branches form fractal patterns that repeat at multiple size scales. This fractal tree is where the majority of input to the neuron occurs via the dendritic spine.
- The **axon** is a finer, cable-like projection that can extend tens, hundreds, or even tens of thousands of times the diameter of the soma in length. The axon primarily

carries nerve signals away from the soma and carries some types of information back to it. Many neurons have only one axon, but this axon may—and usually will—undergo extensive branching, enabling communication with many target cells. The part of the axon where it emerges from the soma is called the **axon hillock**. Besides being an anatomical structure, the axon hillock also has the greatest density of voltage-dependent sodium channels. This makes it the most easily excited part of the neuron and the spike initiation zone for the axon. In electrophysiological terms, it has the most negative threshold potential.

  - While the axon and axon hillock are generally involved in information outflow, this region can also receive input from other neurons.
- The **axon terminal** is found at the end of the axon farthest from the soma and contains synapses. Synaptic boutons are specialized structures where neurotransmitter chemicals are released to communicate with target neurons. In addition to synaptic boutons at the axon terminal, a neuron may have en passant boutons, which are located along the length of the axon.

The accepted view of the neuron attributes dedicated functions to its various anatomical components; however, dendrites and axons often act in ways contrary to their so-called main function.

Axons and dendrites in the central nervous system are typically only about one micrometer thick, while some in the peripheral nervous system are much thicker. The soma is usually about 10–25 micrometers in diameter and often is not much larger than the cell nucleus it contains. The longest axon of a human motor neuron can be over a meter long, reaching from the base of the spine to the toes.

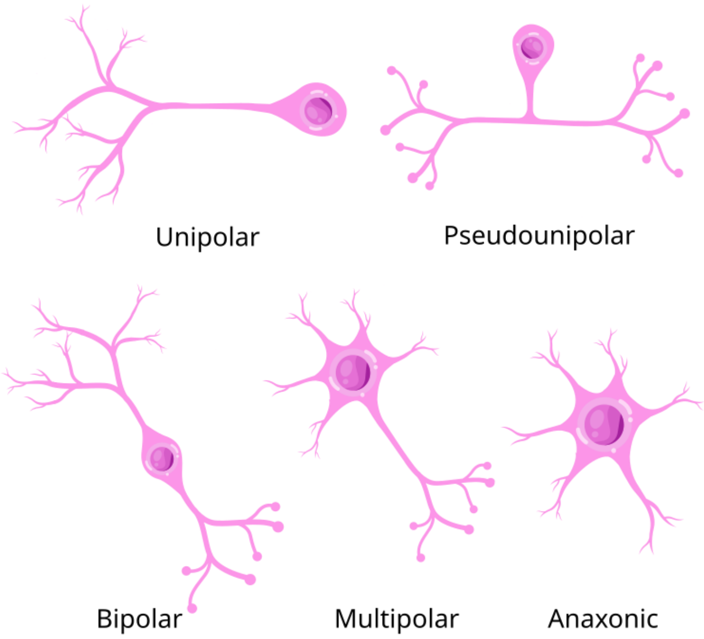
Sensory neurons can have axons that run from the toes to the posterior column of the spinal cord, over 1.5 meters in adults. Giraffes have single axons several meters in length running along the entire length of their necks. Much of what is known about axonal function comes from studying the squid giant axon, an ideal experimental preparation because of its relatively immense size (0.5–1 millimeter thick, several centimeters long).

Fully differentiated neurons are permanently postmitotic however, stem cells present in the adult brain may regenerate functional neurons throughout the life of an organism (see neurogenesis). Astrocytes are star-shaped glial cells that have been observed to turn into neurons by virtue of their stem cell-like characteristic of pluripotency.

Types of Neuron

Most neurons can be anatomically characterized as:

- **Unipolar**: single process. Unipolar cells are exclusively sensory neurons. Their dendrites receive sensory information, sometimes directly from the stimulus itself. The cell bodies of unipolar neurons are always found in ganglia. Sensory reception is a peripheral function, so the cell body is in the periphery, though closer to the CNS in a ganglion. The axon projects from the dendrite endings, past the cell body in a ganglion, and into the central nervous system.



- **Bipolar**: 1 axon and 1 dendrite. They are found mainly in the olfactory epithelium, and as part of the retina.
- **Multipolar**: 1 axon and 2 or more dendrites
  - Golgi I: neurons with long-projecting axonal processes; examples are pyramidal cells, Purkinje cells, and anterior horn cells
  - Golgi II: neurons whose axonal process projects locally; the best example is the granule cell
- **Anaxonic**: where the axon cannot be distinguished from the dendrite(s)
- **Pseudounipolar**: 1 process which then serves as both an axon and a dendrite

Synapse and Types

Our nervous system consists of billions of nerve cells that exchange signals between them and also transmit information to effector cells, so that the human body can function effectively. A synapse is defined **as the junction between two cells**, serving as the primary means of communication between a presynaptic neuron initiating the signal and a postsynaptic cell receiving the signal. This type of connection facilitates communication not only between two neurons, but also between a neuron and an effector cell, i.e. a muscle cell or gland cell.

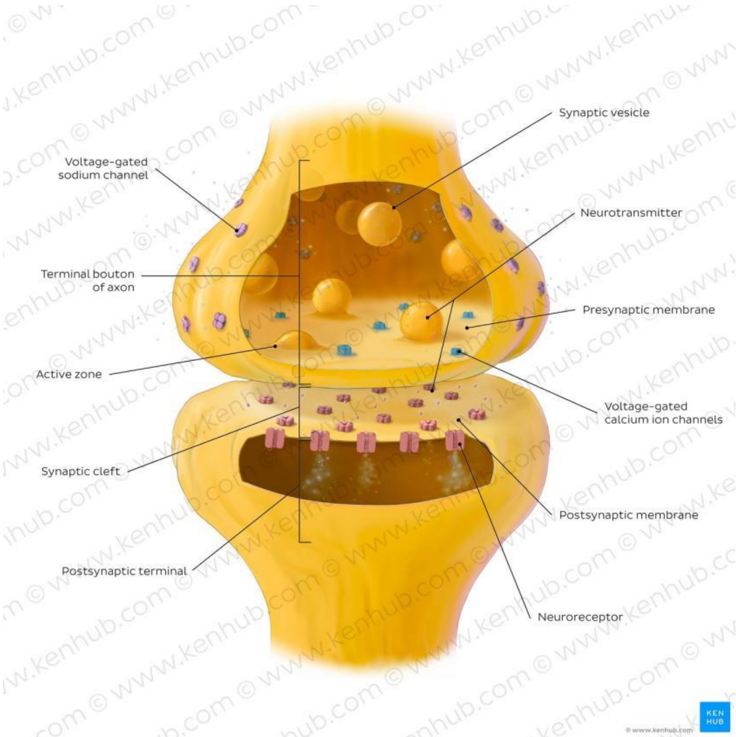
This article will discuss the types, structure and physiology of synapses.

Key facts about synapses	The site of interaction between a neuron (**presynaptic cell**) and another cell; neuron,

<u>Table quiz</u> Definition	muscle cell or gland cell (**postsynaptic cell**)
Function	**Signal transmission** between two cells
Classification	***Based on the way they function:*** - Chemical, communicating through chemical messengers - Electrical, communicating through direct ion flow between cells ***Based on the location of interaction:*** - Axodendritic - Axosomatic - Axoaxonic - Dendrodendritic - Dendrosomatic - Neuromuscular - Neuroglandular
Anatomy	***Chemical synapses*** - Synaptic knob (or presynaptic terminal or axon terminal) - Neurotransmitters, serving as chemical messengers - Synaptic cleft, a narrow gap between the presynaptic and postsynaptic membrane - Postsynaptic membrane, containing receptors that bind to neurotransmitters ***Electrical synapse*** - Gap junctions, providing direct communication between adjacent neurons - Connexons, hexameric protein complexes forming channels for the passage of ions and small molecules

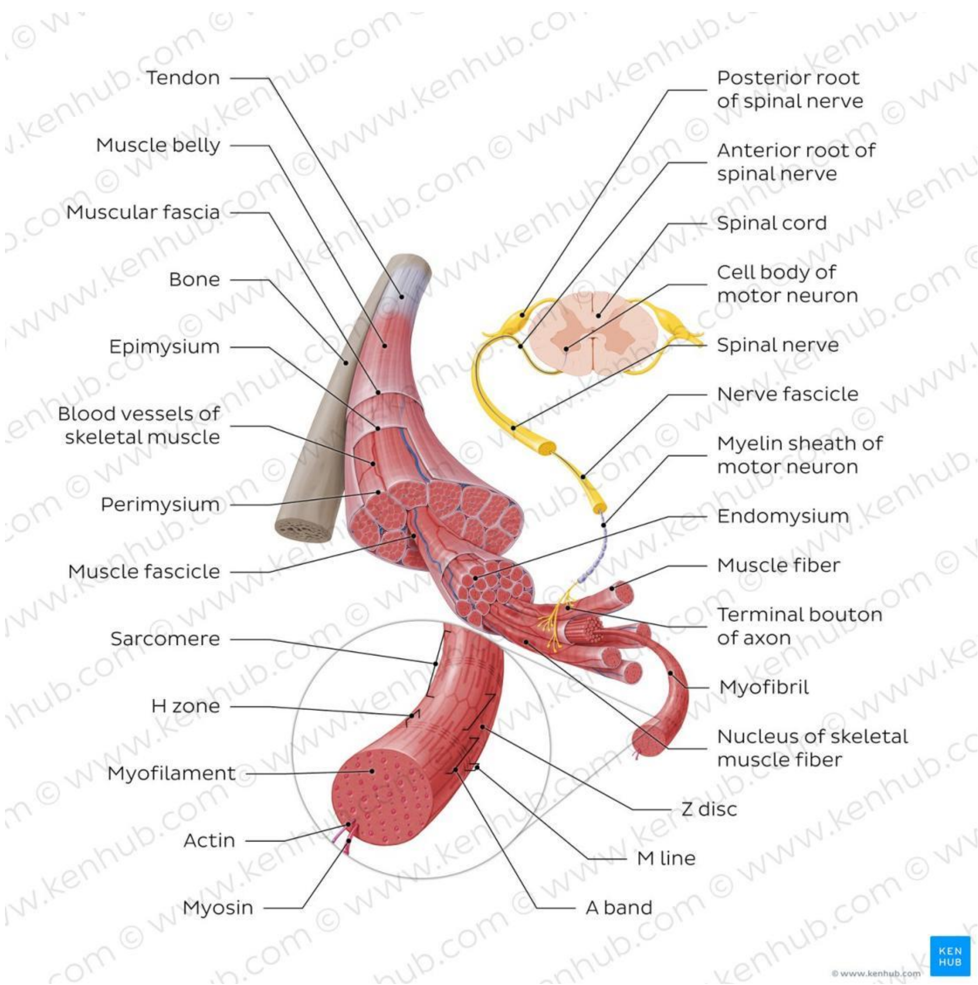
<u>Classification of synapses</u>

Synaptic transmission can be either **chemical** or **electrical**, and thus, synapses can be classified into two types based on the way they function: <u>chemical synapses</u>, the most common ones in the human nervous system, and electrical synapses, mainly found in non-mammals.



Depending on the location of interaction between the two cells involved, synapses can alternatively be categorized as:

- **Axodendritic**; an interaction between the axon terminal of the presynaptic neuron and the dendrite of the postsynaptic neuron.
- **Axosomatic**; an interaction between the axon terminal of the presynaptic neuron and the cell body (soma) of the postsynaptic neuron.
- **Axoaxonic**: an interaction between the axon terminal of one neuron and the axon of another neuron.
- **Dendrodendritic**; an interaction between the dendrites of two neurons.
- **Dendrosomatic**; an interaction between the dendrites of one neuron and the the cell body (soma) of another neuron.
- **Somatic**; an interaction directly between the cell bodies (somata) of two neurons.



Motor unit

Fig:-Anatomy of the synapse

1. **Terminal bouton** (or presynaptic terminal/knob or axon terminal), located at the end of the presynaptic neuron’s axon that houses synaptic vesicles (i.e., membrane-bound spheres which store neurotransmitters) and contain voltage-gated Ca2+ channels.
2. Neurotransmitters**:** chemical molecules serving as messengers for the transmission of information between the two cells involved in the chemical synapse. They can be characterized as excitatory or inhibitory, based on their effect on the postsynaptic neuron; excitatory neurotransmittors, such as glutamate, make it more likely for the postsynaptic neuron to generate an action potential, and inhibitory neurotransmittors, such as γ-aminobutyric acid (GABA), less likely.
3. **Synaptic cleft:** a narrow gap between the presynaptic and postsynaptic membranes across which neurotransmitters diffuse to reach the postsynaptic neuron.
4. **Postsynaptic membrane**, containing protein receptors that bind to neurotransmitters released by the presynaptic neuron. Receptors are usually ligand-gated channels (ionotropic receptors), or G-protein-coupled receptors activating ion channels through a signaling pathway (metabotropic receptors).

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Condition of action potential in neuron

An action potential occurs in a neuron when it receives enough excitatory input to reach its threshold potential, triggering a rapid electrical signal. This involves a rapid influx of sodium ions (Na+) causing depolarization, followed by a repolarization as potassium ions (K+) flow out, restoring the membrane's resting potential. This process propagates along the axon, allowing the neuron to transmit signals to other neurons.

The Conditions Required for an Action Potential:

Stimulus:

A stimulus, such as neurotransmitters from a previous neuron, causes the membrane to depolarize.

Threshold Potential:

The depolarization must reach a certain level, known as the threshold potential (around -55 mV), for an action potential to fire. If the threshold is not reached, the action potential will not occur.

Voltage-Gated Channels:

Reaching the threshold triggers the opening of voltage-gated sodium channels, allowing a rapid influx of Na+ into the cell.

Propagation:

The depolarization caused by the Na+ influx in one part of the axon triggers the voltage-gated sodium channels in the adjacent area to open, propagating the action potential down the axon.

The Phases of an Action Potential:

Depolarization:

Positively charged Na+ ions rush into the neuron, making the inside of the cell less negative and even positive.

Repolarization:

As the membrane potential rises, sodium channels close, and voltage-gated potassium channels open, allowing K+ to flow out of the cell. This outflow of positive charge makes the inside of the cell more negative again.

Hyperpolarization (Undershoot):

The membrane potential briefly becomes even more negative than the resting potential before returning to its normal resting state. This is due to the slow closing of potassium channels.

Refractory Period:

During and immediately after an action potential, the neuron enters a refractory period when it's difficult or impossible to trigger another action potential. This is mainly due to the inactivation of sodium channels.