Nervous Tissue (NT)

- highly specialized tissue
- forms, receives and sorts signals (irritability)
- transmits electrical impulses (conductivity)

Functions of Nerve Tissue

- Nervous tissue allows an organism to sense stimuli in both the internal and external environment.
- The stimuli are analysed and integrated to provide appropriate, co-ordinated responses in various organs.
- The afferent or sensory neurons conduct nerve impulses from the sense organs and receptors to the central nervous system.
- Internuncial or connector neurons supply the connection between the afferent and efferent neurons as well as different parts of the central nervous system.
- Efferent or somatic motor neurons transmit the impulse from the central nervous system to a muscle (the effector organ) which then react to the initial stimulus.
- Autonomic motor or efferent neurons transmit impulses to the involuntary muscles and glands.

- NT forms central and peripheral nerve system (CNS and PNS)
- NT consists of nerve cells = NEURONS and associated supporting cells = NEUROGLIA; neurons are specifically designed to transmit electrical impulses and to receive and process information; neuroglial cells are non-conducting cells that are in intimate physical contact with neurons. They provide physical support, electrical insulation and metabolic exchange with the vascular system.
- NT originates from ectoderm

NEURON

Nerve cells are very variable in appearance, shape and size, but all neurons have a cell body, also called soma or perikarion, and processes extending from the nerve cell to communicate with other cells. There are two types of processes: dendrites that receive impulses and axons (neurits) that transmit impulses. All nerve cells have one axon, which is usually the longest process that extends from the cell and one or more (hundreds) dendrites, these are generally shorter and thicker than the axon. The junction where a nerve cell communicates with another nerve cell or an effector cell (e.g. muscle fibre) is called a synapse, which can be chemical or electric. The terminal part of the axon with chemical synapses releases substances called a neurotransmitter which acts on the membrane of the other cell.
Cell body – **PERIKARION**: contains nucleus and most cytoplasm with organelles:

- nucleus – round or oval, very light, with prominent nucleolus
- rough ER (called Nissl’ substance) – involved in synthesis of proteins (neurotransmitters)
- other usual organelles (mitochondria, Golgi apparatus, lysosomes)
- neurofibrils – neurofilaments and neurotubules
- pigment lipofuscin

**DENDRITES** – input structure – receive signals; number of dendrites: one – several hundreds

- short, branched processes with structure similar to perikarion (cytoplasm + organelles + neurofibrils)
- incoming signals summate to initiate action potential highly branched tree structure
Classification of neurons according to number of processes (dendrites):

1. **Multipolar neuron** – several dendrites extend from body found in brain & spinal cord
2. **Bipolar neuron** – one dendrite and one axon (in retina of eye)
3. **Unipolar neuron** – one process only, link to axon (sensory neurons)
4. **Pseudounipolar neuron** – one short process divides later into dendrite and axon (spinal ganglia)

**AXON** – only one

- no protein synthesis here
- Trigger zone - where nerve impulses arise
- Axon hillock – the cone-shaped base of the axon, its cytoplasm is free of rER (Nissl substance)
- Axons terminal - end with fine branching with „terminal boutons“ – mitochondria and synaptic vesicles containing neurotransmitters
- Axon hillock and terminal are not covered with oligodendrocytes (in CNS) or Schwann cells (in PNS)
- Serves for impulses transmission and for axonal transport of neurotransmitters and nutrients

Classification of neurons according to length of axon:

1. **Golgi type I** – long axon (up to 1 m) – somatic motor neurons
2. **Golgi type II** - short axon (in μm)

Classification of neurons according to function:

1. sensitive neurons – (afferent) conduct informations from receptors to CNS
2. motor neurons – (efferent) conduct informations from CNS to effector cells: somatomotor to skeletal muscle and visceromotor to smooth muscle cells, cardiomyocytes or glandular cells
3. interneurons (97 %)
Sheaths of axons:

**Schwann sheath** *(neurilemma)* – Schwann cells surround the axon (gray fibers)

**Myelin sheath** – lipoprotein product of Schwann cells in PNS and oligodendrocytes in CNS
- electrically insulates axon
- increases speed of nerve impulse
- wraps around one axon many times and has a lamellar appearance

Many axons are wrapped in a lipid-rich covering called myelin. This *myelin sheath* insulates the axon from the surrounding extracellular component and increases the rate of electrical conduction. The myelin sheath is discontinuous at intervals called the *nodes of Ranvier*. The area covered with myelin is called *internodal area (internodium)*. In myelinated axons, the voltage reversal (that is, the impulse propagation) can occur only at the nodes, and the impulse "jumps" from node to node. This is called *saltatory conduction*. In unmyelinated axons, the impulse is conducted more slowly, moving as a wave of voltage reversal along the axon.

---

**Synapses**

- NEURON – NEURON

- Presynaptic neuron - conducts signal to a synapse // synaptic vesicles with neurotransmitter
- Synaptic cleft (20-30 nm thick)
- Postsynaptic neuron - conducts signal from a synapse // receptors on cell membrane
- Axodendritic (1)
- Axosomatic (2)
- A xoaxonal (3)
- Dendrodendritic synapses

**NEURON – EFFECTOR CELL**

Effector cells – muscle cells (in smooth muscle = **neuromuscular spindle**, in skeletal muscle = **motor-end-plate**), cardiomyocytes, glandular cells
Chemical Synapses

- Presynaptic cell releases neurotransmitters from synaptic vesicles
- Act on the postsynaptic cell (help initiate AP)
- Neurotransmitters can excite or inhibit
- Neurotransmitters (acetylcholine, serotonin, norepinephrine and epinephrin, dopamine, GABA, …)

- Neurotransmitter must be removed to prevent continual firing of neurons
- Enzymatically - acetylcholinesterase
- Many pharmaceuticals and drugs modulate this effect
- Cocaine block removal of dopamine

Electrical Synapses

- Without synaptic vesicles; synaptic cleft – only 2 nm thick
- Depolarizing wave continues from presynaptic to postsynaptic membrane
- Morphologically (in electron microscope) it looks like communicatin intercellular connection: gap junction (nexus)

**SUPPORT CELLS PLAY A VITAL ROLE**

Support cells are essential to the function and survival of nerve cells. The CNS and PNS each have their own specific types of support cells.

**Support cells in the CNS:**

The general term for support cells in the CNS is **glia** or **neuroglia** (glial cells, neuroglial cells). There are four types of neuroglial cells. (1) **Oligodendrocytes**, the myelin-secreting cells of the CNS. (2)
Astrocytes, which provide physical and metabolic support for nerve cells. (3) Microglia, (microglial cells), which are the phagocytes of the CNS. (4) Ependyma (ependymal cells) lining brain cavities and central canal in spinal cord.

Oligodendrocytes. As their name implies, oligodendrocytes have few processes. They are often found in rows between axons. The myelin sheath around axons is formed by concentric layers of oligodendrocytes plasma membrane. Each oligodendrocyte gives off several tongue-like processes that find their way to the axon, where each process wraps itself around a portion of the axon, forming an internodal segment of myelin. Each process appears to spiral around its segment of the axon in a centripetal manner, with the continued insinuation of the leading edge between the inner surface of newly formed myelin and the axon. One oligodendrocyte may myelinate one axon or several. The nucleus-containing region may be at some distance from the axon(s) it is myelinating. In the CNS, nodes of Ranvier (between myelinated regions) are larger than those of the PNS, and the larger amount of exposed axolemma makes saltatory conduction more efficient.

Unmyelinated axons in the CNS are truly bare, that is they are not embedded in any glial cell process. (In contrast to the situation in the PNS, described below.)
**Astrocytes.** Astrocytes are the largest of the neuroglial cells. They have elaborate processes that extend between neurons and blood vessels. The ends of the processes expand to form end feet, which cover large areas of the outer surface of the blood vessel or axolemma. Astrocytes are believed to play a role in the movement of metabolites and wastes to and from neurons, and in regulating ionic concentrations within the neurons. They may be involved in regulating the tight junctions in the capillaries that form the blood-brain barrier. Astrocytes also cover the bare areas of neurons, at nodes of Ranvier and synapses. They may act to confine neurotransmitters to the synaptic cleft and to remove excess neurotransmitters.

Two kinds of astrocytes are identified, protoplasmic and fibrous astrocytes. Both types contain prominent bundles of intermediate filaments, but the filaments are more numerous in fibrous astrocytes. Fibrous astrocytes are more prevalent in white matter, protoplasmic ones in grey matter.

**Microglia.** These are the smallest of the glial cells, with short twisted processes. They are the phagocytes of the CNS, considered part of the mononuclear phagocytic system (see pg 110 in Ross et al.). They are believed to originate in bone marrow and enter the CNS from the blood. In the adult CNS, they are present only in small numbers, but proliferate and become actively phagocytic in disease and injury. Their alternate name, mesoglia, reflects their embryonic origin from mesoderm (the rest of the nervous system, including the other glial cells, is of neuroectodermal or neural crest origin).

**Ependymal cells.** Cuboidal to columnar cells in one layer lining the fluid-filled brain ventricles and central canal (canalis centralis) in spinal cord. Ependyma is involved in cerebrospinal fluid production in som regions (choroid plexus).

**Support cells in the PNS:**

The support cells of the PNS are called satellite cells and Schwann cells.

**Satellite cells.** Satellite cells surround the cell bodies of the neurons in ganglia (ganglion cells). These small cuboidal cells form a complete layer around the nerve cell body, but only their nuclei are visible.
in routine preparations. They help maintain a controlled microenvironment around the nerve cell body, providing electrical insulation and a pathway for metabolic exchange. In paravertebral and peripheral ganglia, nerve cell processes must penetrate between satellite cells to establish a synapse.

- Satellite cells – nutrition and isolation of neurons in ganglia

**Schwann cells.** Schwann cells are responsible for the myelination of axons in the PNS. A Schwann cell wraps itself, jelly roll-fashion, in a spiral around a short segment of an axon. During the wrapping, cytoplasm is squeezed out of the Schwann cell and the leaflets of plasma membrane of the concentric layers of the Schwann cell fuse, forming the layers of the myelin sheath. An axon's myelin sheath is segmented because it is formed by numerous Schwann cells arrayed in sequence along the axon. The junction where two Schwann cells meet has no myelin and is called the node of Ranvier (the areas covered by Schwann cells being the internodal regions).

![Diagram of a pseudounipolar neuron surrounded by satellite cells](image)

The lack of Schwann cell cytoplasm in the concentric rings of the myelin sheath is what makes it lipid-rich. Schwann cell cytoplasm is however found in several locations. There is an inner collar of Schwann cell cytoplasm between the axon and the myelin, and an outer collar around the myelin. The outer collar is also called the sheath of Schwann or neurilemma, and contains the nucleus and most of the organelles of the Schwann cell. The node of Ranvier is also covered with Schwann cell cytoplasm, and this is the area where the plasma membranes of adjacent Schwann cells meet. (These adjacent
plasma membranes are not tightly apposed at the node, so that extracellular fluid has free access to the neuronal plasma membrane.) Finally, small islands of Schwann cell cytoplasm persist within successive layers of the myelin sheath, these islands are called Schmidt-Lanterman clefts.

Myelination (development of myelin sheath):

Not all nerve fibres in the PNS are covered with myelin, some axons are unmyelinated. In contrast to the situation in the CNS, unmyelinated fibres in the PNS are not completely bare, but are enveloped in Schwann cell cytoplasm. The Schwann cells are elongated in parallel to the long axis of the axons, which fit into grooves on the surface of the Schwann cell. One axon or a group of axons may be enclosed in a single groove. Schwann cells may have only one or up to twenty grooves. Single grooves are more common in the autonomic nervous system.
Protocol:
Purkinje cell
Peripheral nerve – cross and longitudinal section