Histology of peripheral nervous system.

Dr Ashraf Sadek *PhD, MD, MRCPCH*

Assistant Professor of anatomy and embryology

1-Review the basic histology of neurons, glial cells and synaptic communications

2-Classify nerves.

3-Describe the structure of peripheral nerves.

4-Discuss myelination.

5-Describe the structure of ganglia (sensory and autonomic).

CELLS OF THE NERVOUS SYSTEM

I. Neuron = nerve cell

It is the building unit of the nervous system; it consists of:

1. *cell body* (*soma*) containing the nucleus and cell organelles

2. *processes:*

Many short *dendrites* (receiving inputs)

One long *axon* (conducting outputs) that terminates by making *synapses* with dendrites of other neurons. The axons are generally called nerve fibers.

Types of neurons:

According to the number of processes:

1. *Unipolar (pseudounipolar):* as in posterior root ganglion.

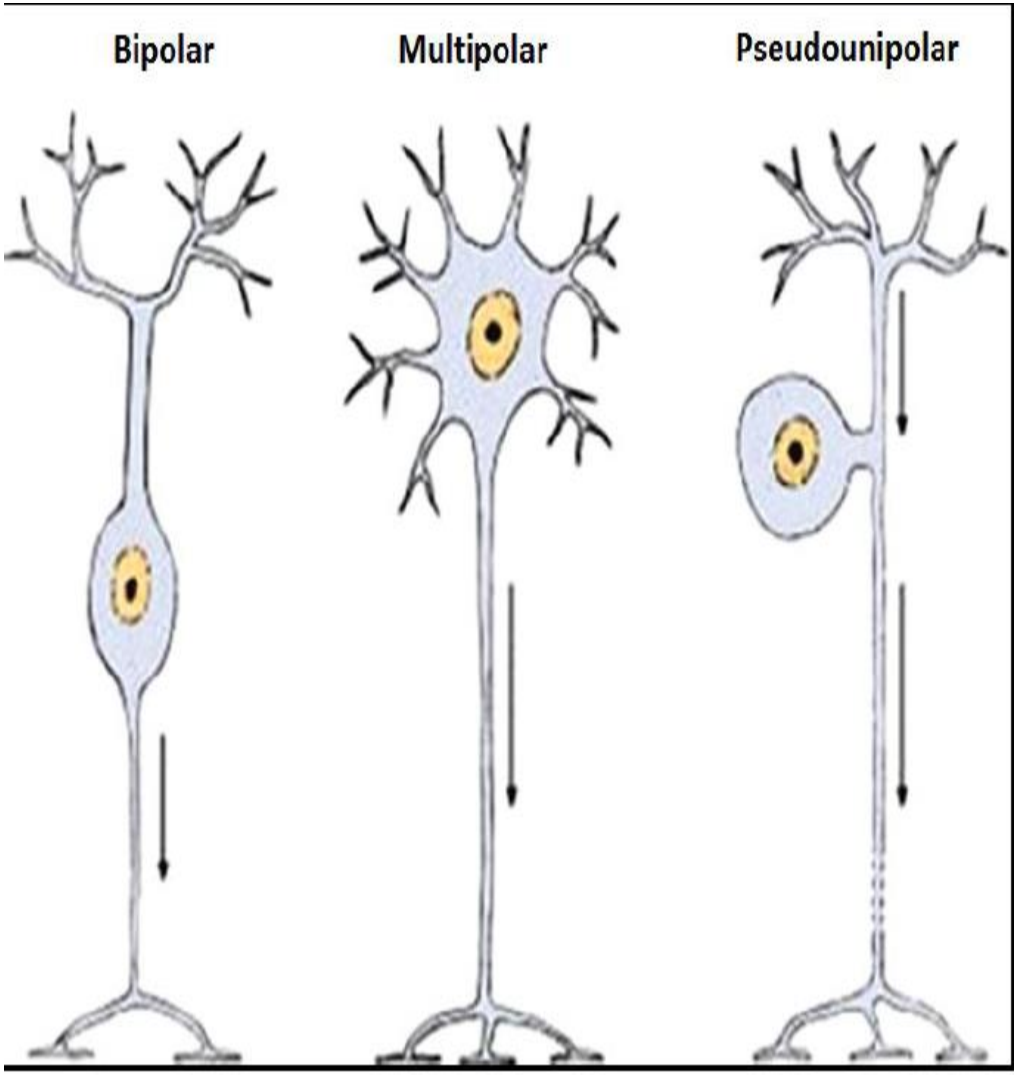
2. *Bipolar:* as in the retina, cochlear & vestibular ganglia

3. *Multipolar:* as in most parts of the brain & spinal cord.

According to the length of the axon:

1. Golgi type I neuron: of long axon as in long tracts of brain &spinal cord as in (*pyramidal cells of cerebral cortex, Purkinje cells of cerebellar cortex & motor cells of spinal cord).*

2. Golgi type II neuron: of short axon (*inhibitory in function),* numerous in all parts of the CNS.



Histological structure of the neuron

Nerve cell body (perikaryon)

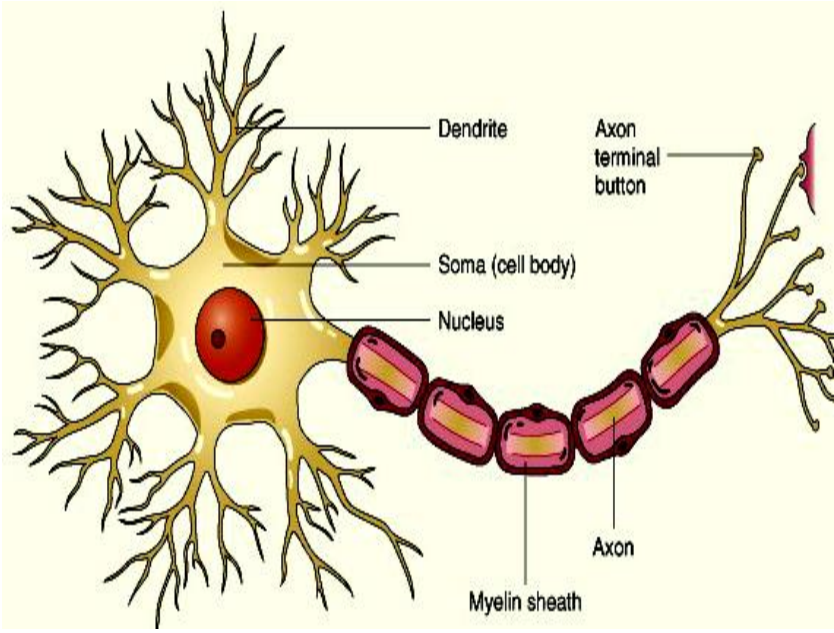
A. The nucleus

The nerve cell nucleus is spherical, large and open face or (vesicular).

It has prominent nucleolus.

It is usually central in position.

In autonomic ganglion cells and in Clarke's column, **the nucleus is not central, but is eccentric in position.**



B. The cytoplasm

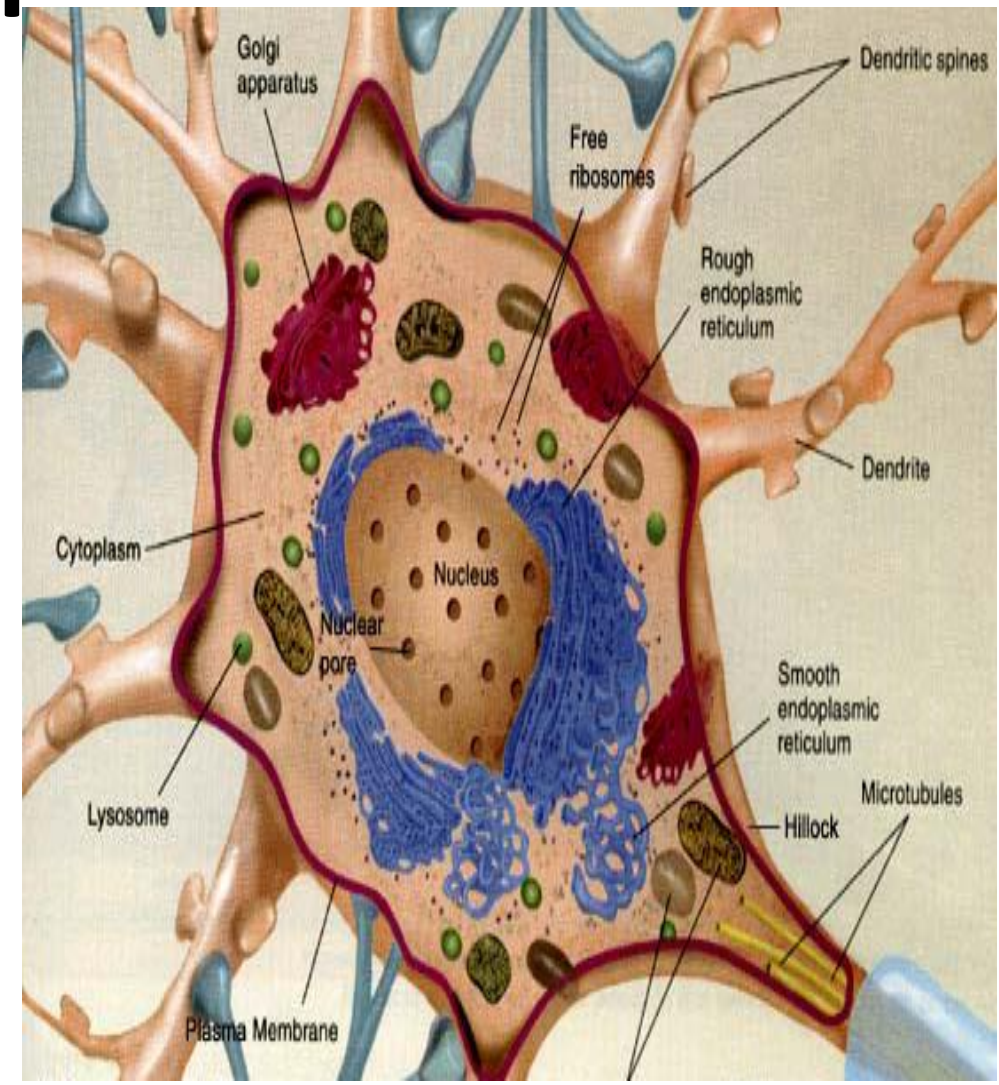
The cytoplasm contains the organelles and inclusions.

1. **<u>Organelles</u>**

a. Mitochondria: abundant in the cytoplasm and in the processes.

b. Golgi complex: is scattered all around the nucleus (perinuclear).

c. Lysosomes: are also present in the cytoplasm.



D. Nissl bodies or granules:

This is a characteristic feature of the nerve cell.

They are large basophilic granules or clumps of basophilic material present in the cytoplasm and dendrites, but absent from the axon and axon hillock.

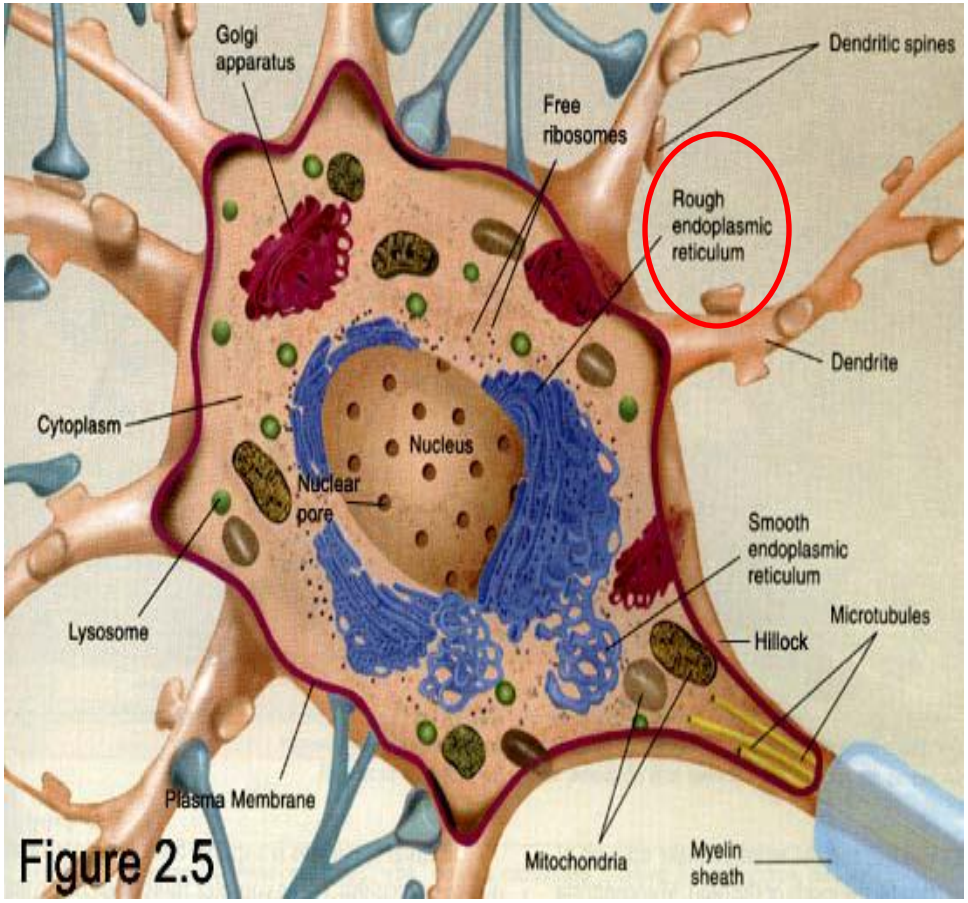
By EM they **are formed of cisternae of rER, free ribosomes and polysomes scattered between adjacent cisternae.**

Nissl bodies, also called **"chromatophilic substances",** are large and prominent in motor than in sensory neurons.

Injury to the nerve cell body or of the axon causes disintegration or temporary

Disappearance of Nissl *granules which is known as* ***chromatolysis****.*

Function of ribosomes: they synthesize new cytoplasmic proteins.



e. Neurofilaments

They are intermediate filaments, 10 nm in diameter present in the nerve cell body and its processes.

Neurofilaments of the axon are associated with a system of cross linkers to connect them with microtubules, axolemma.

The neurofilaments provide internal support for the nerve cell.

Bundles of neurofilaments form the neurofibrils that are seen by the LM in nerve cells stained by silver.

f. Neurotubules are found among the neurofilaments. They keep the shape of the cell and its processes and help in the transport of materials within the cell.

g. Centrioles are also found in adult cells, although they do not divide. They have an important role in the maintenance of microtubules.

2. Inclusions

a. Lipofuscin pigment: This is a yellow brown pigment which increases with age

b. Melanin pigment: This is present in the substantia nigra of midbrain.

► **Medical application:**

Immature nerve cells may produce tumors (medulloblastomas) but adult neurons do not produce tumors because they do not divide.

II. The nerve cell processes

They include the axon and the dendrites.

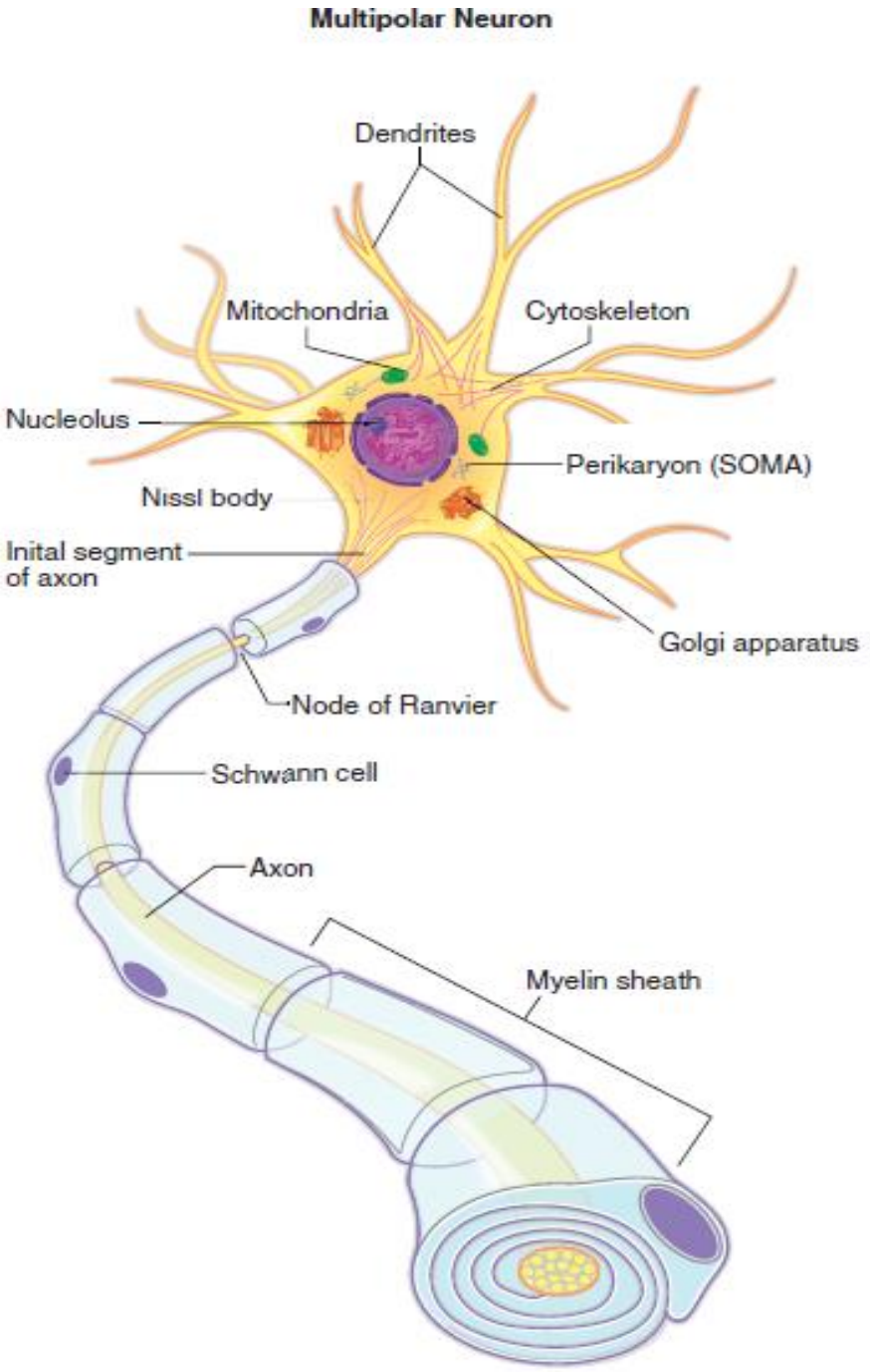
A. The axon It arises from the nerve **cell body at a region termed the axon hillock.**

Axon and axon **hillock lack of Nissl bodies.**

Axon contains

- thread-like mitochondria,
- abundant neurotubules, neurofilaments
- some elements of sER known as

axoplasmic reticulum.



The axon does not contain ribosomes.

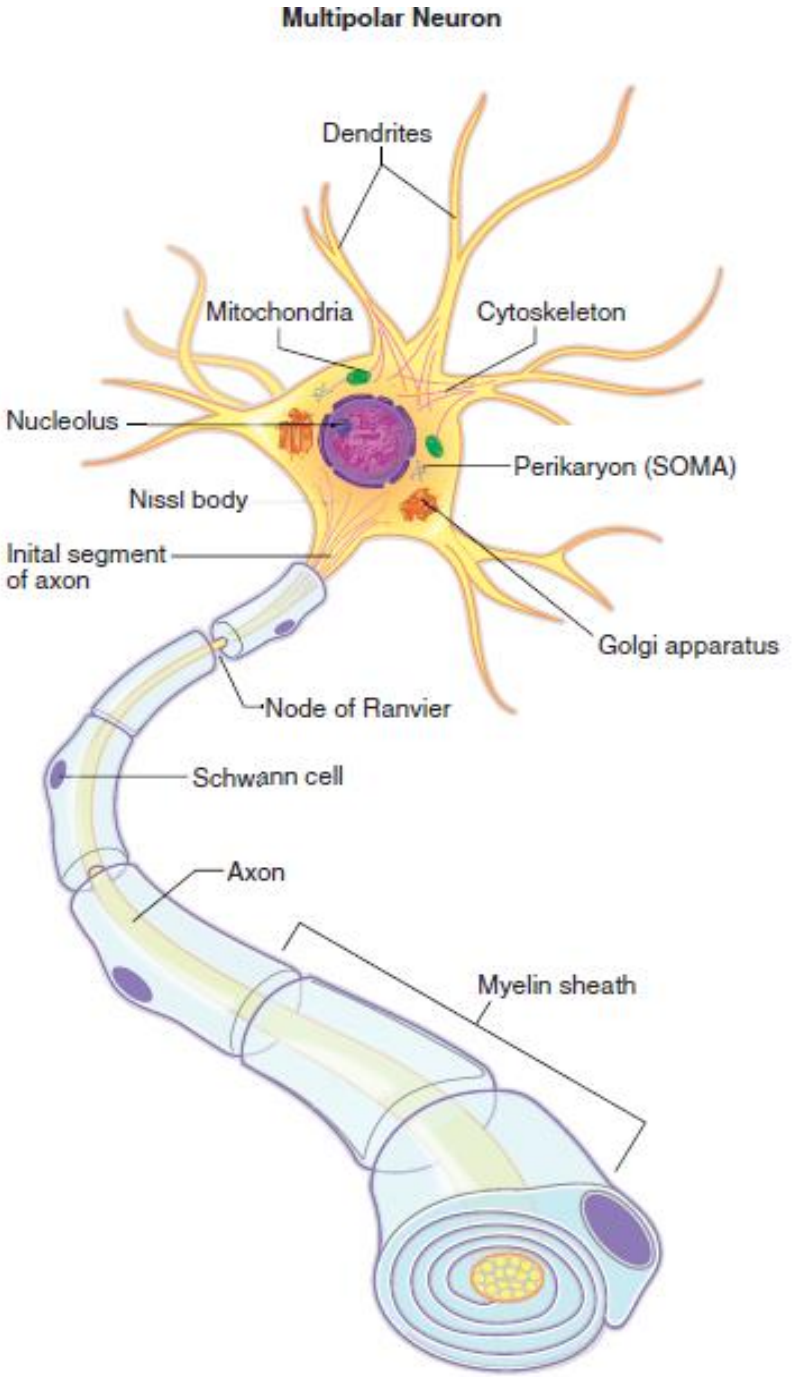
The cell membrane of the axon is called **axolemma**

its cytoplasm is called axoplasm.

- The axon is single, of uniform diameter. It runs more or less a straight course, with a length varying from fraction of a millimeter to one meter or more.

- It branches at its end forming terminal arborizations.

- The surface of axon is smooth.
- The function of the axon is conduction of nerve impulses away from the cell body i.e. centrifugal.



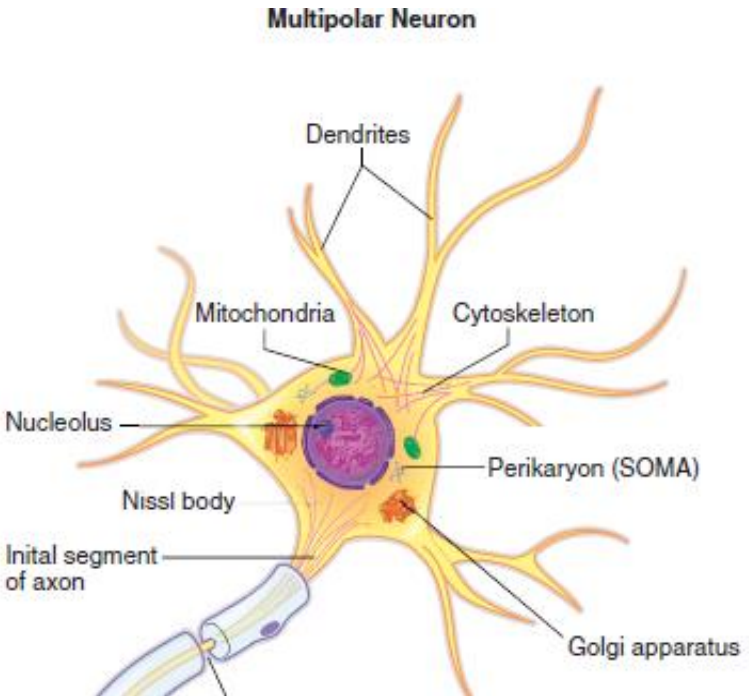
- **B. The dendrites**

These are usually thick and short with tapering ends.

They contain neurofilaments, neurofibrils, mitochondria and Nissl granules.

- They show extensive branching like a tree branching, which arise at acute angles.

- The surface of the dendrites is rough due to the presence of spines on the surface known as dendritic spines.
- The function: dendrites conduct nerve impulses towards the cell body i.e. centripetal conduction.



Axoplasmic transport (Axonal transport)

1. Anterograde transport:

Proteins, glycoproteins and some other macromolecules, together with certain organelles are **transported along the axon away from the cell body.**

2. Retrograde transport:

This takes place in the axon and dendrites to **transport some of the cytopasmic components to the cell body** so that they do not accumulate at the fiber terminal.

If the axon has become damaged, retrograde flow of substances that normally would not enter the axoplasm, is believed to signal to the cell body the need for axon regeneration.

Retrograde flow can also carry infective viruses as rabies and herpes' viruses, or toxins as tetanus toxins from the peripheral tissues to the CNS.

Dendritic transport

Certain proteins e.g. acetyl choline esterase, which destroys acetyl choline, are transported towards the dendritic terminals.

Differences between axon and dendrites

	Axon	Dendrites
Number	It is single	usually multiple
Shape	It is thin, long and cylindrical	They are short and tapering
Branches	It does not branch except its end.	It is branching
Surface	Smooth	Rough
Organelles	It does not contain Nissl granule granules	They contain Nissl granules
Function	It carries nerve impulses away from the cell body	It carries nerve impulses toward the cell body

The Nerve Fibers

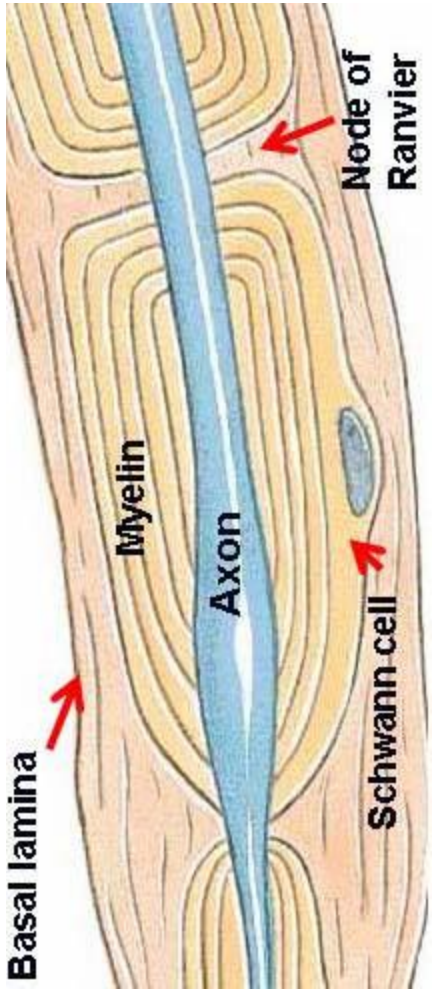
- **Definition**
- The nerve fiber is the nerve cell process usually the axon. It may be naked or sheathed.
- In PNS, nerve fibers could be sheathed by one or two types of nerve sheathes (the myelin sheath and or the neurolemma sheath)
- while in the CNS, the nerve fibers could be only sheathed by myelin sheath.

The myelin sheath or medullary sheath

This forms a tubular sheath covering the axon.
It is formed of lipoprotein complex material derived from the cell membrane of Schwann cell.

Multiple Schwann cells are needed to form myelin around a single peripheral nerve fiber.

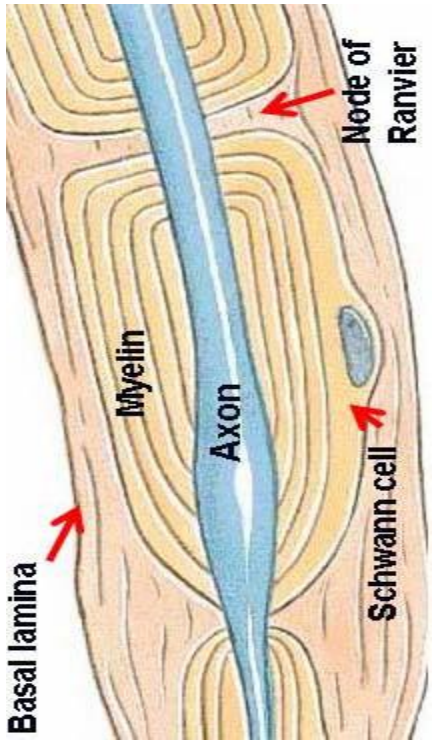
The lipid material usually dissolves in ordinary preparations ,leaving a network of protein material called neurokeratin.
The myelin can be stained black with osmic acid.



It is interrupted along its course by constrictions called **nodes of Ranvier**.

The part between 2 nodes is called the **internodal segment.**

Oblique clefts are seen in the myelin sheath as seen after osmic acid staining, called **Schmidt Lantermann clefts**. They may represent tapered cytoplasm between the rolling cell membranes.



Function

It is an electrical insulator. Conduction of impulses is faster in axons with large diameters and thicker myelin sheath.

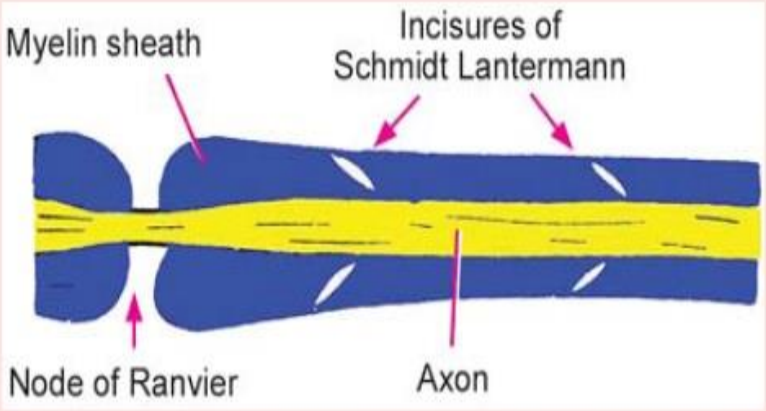
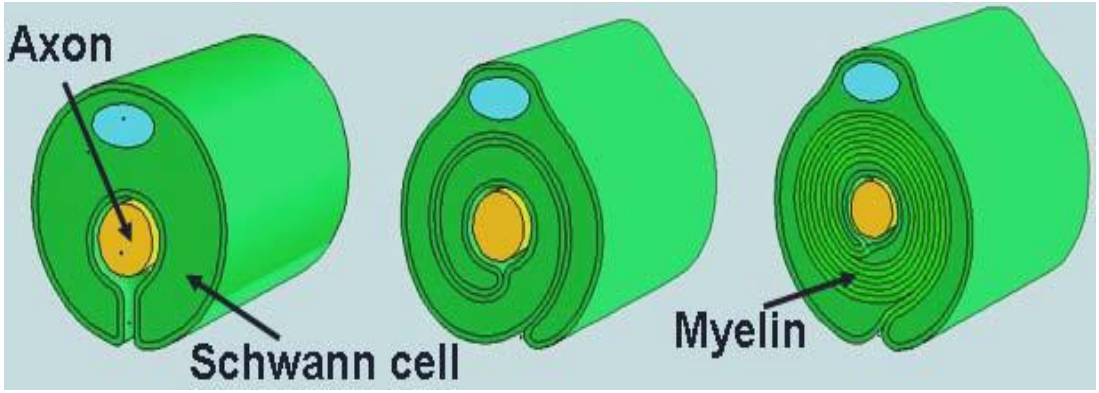


Fig. 1.17. Diagram to show the incisures of Schmidt Lanterman. Also see Fig. 1.1

Formation of myelin sheath in the peripheral nerve (The jelly-roll theory)

During development, Schwann cells become arranged along the axon.
Each cell wraps a part of the axon and turns around it.
The internal surface of the opposed regions of Schwann cell membrane comes in contact with each other, while the cytoplasm is squeezed away.
This leads to formation of several turns of the double cell membrane around the axon.

The remaining cytoplasm of Schwann cell forms an outer thin layer containing the nucleus representing the **neurolemmal sheath** of nerve fiber.



The neurolemmal or Schwann cell sheath

Function of neurolemma:

1. Formation of myelin.
2. Regeneration of damaged axon.
3. Insulation of nerve impulse.

- The cells forming sheathes around nerve fibers are ectodermal in origin and are called:

Schwann cell in PNS which can form myelin and or neurolemmal sheath.

Oligodendrocyte in CNS which can only form myelin sheath.

Types of nerve fibers

Nerve fibers are classified into types according to whether they are myelianted or not and if they are covered with neurlomma or not.

1. Myelinated nerve fibers with neurolemma. These are commonly seen in peripheral nerves.

2. Myelinated nerve fibers without neurolemma, e.g. nerve fibers in the white matter of CNS.

3.Unmyelinated fibers with neurolemma, e.g. nerve fibers of autonomic nervous system and some peripheral nerve fibers.

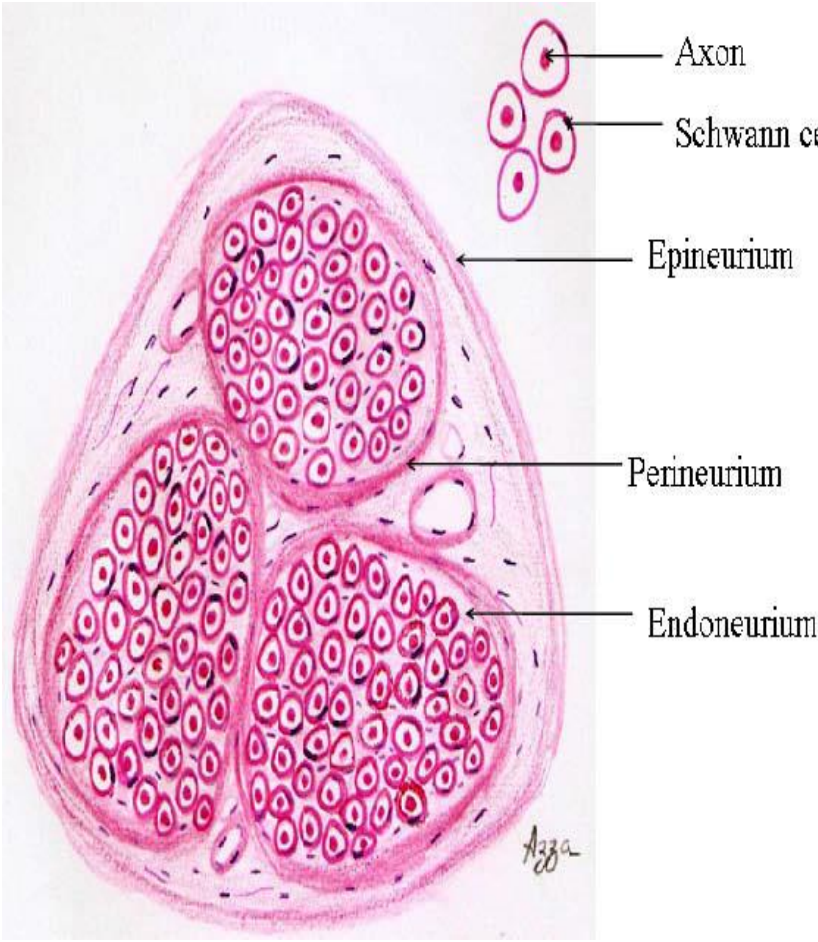
- Single Schwann cell can envelope several unmeylinated peripheral nerve fibers.
- The nerve fibers were seen to lie singly or in groups in deep longitudinal invaginations of a Schwann cell.
- The original line of invagination is called mesaxon

4. Unmyelinated fibers without neurolemma,as in

1- grey matter of CNS

2- nerve fibers at their origin or at the nerve terminals

Structure of Peripheral Nerve (Nerve trunk)



- It is formed of bundles of longitudinally
- arranged nerve fibers with a connective
- tissue covering.
- The nerve as a whole is surrounded by
- fibrous connective tissue sheath called **epineurium**.

Within the epineurium, nerve fibers form bundles (fascicles), each surrounded by **perineurium**.

- Each individual nerve fiber within the bundle is surrounded by a delicate sheath of vascular loose connective tissue called **endoneurium**.

Ganglia

- They are encapsulated ovoid structures containing aggregations of nerve fibers and nerve cell bodies outside the CNS. Ganglion cells and fibers are supported by connective tissue matrix and are surrounded by CT capsule.
- **►Types of ganglia**
- 1. Craniosomatic ganglia e.g spinal ganglia and trigeminal ganglia.
- 2. Autonomic ganglia (sympathetic and parasympathetic)

1. Spinal ganglia

- Spinal ganglia are fusiform swellings of the

  dorsal roots of spinal nerves.
- The nerve cells are pseudounipolar rounded in shape having one process which becomes

convoluted when leaving the cell, forming

branches. Both branches have the appearance of axons and are myelinated.

The nerve cells are relatively few in number

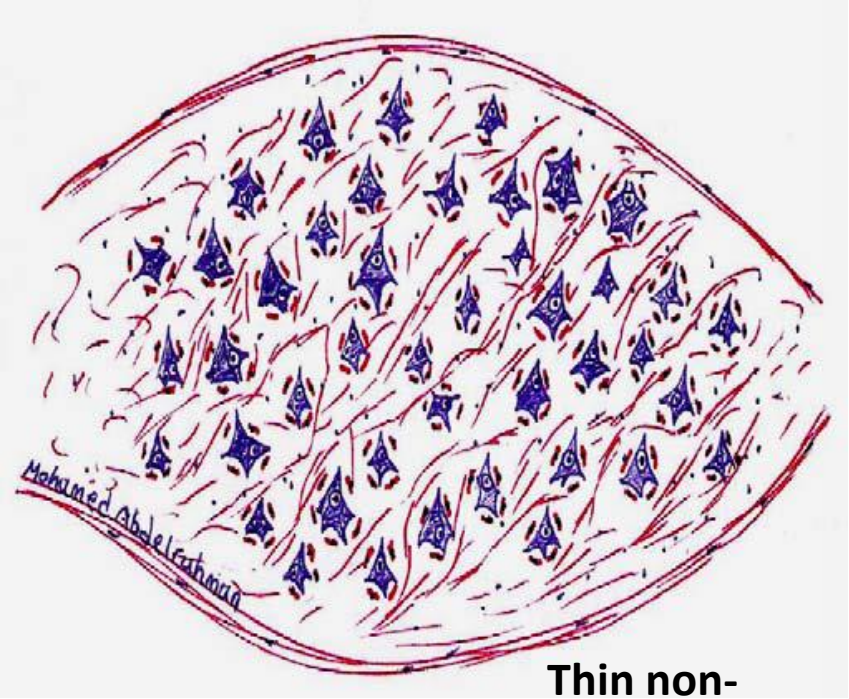
arranged in groups separated by bundles of **myelinated** nerve fibers.

- The ganglion cells have central large vesicular nuclei with prominent nucleoli (Owl's eye) and the cytoplasm contains prominent Nissl bodies.
- Each cell is surrounded by a single layer of flattened capsule cells or satellites, analogous to the neurolglia cells of CNS.

2. Autonomic ganglia

They are represented by sympathetic and parasympathetic ganglia. Sympathetic ganglia are swellings along the sympathetic chain.

The ganglion cells are stellate multipolar nerve cells with irregular outlines.
They are numerous and scattered throughout the ganglion **without** grouping and are separated by **unmyelinated** nerve fibers.



Thin non-myelinated nerve fibers

The nuclei of nerve cells are eccentric in position.
The ganglion cells are surrounded by discontinuous capsule of satellite cells.

The Synapse

- It is the site at which nerve impulses are transmitted from one neuron to another.

►**The synapse is formed of 3 parts:**

1. **The presynaptic terminal** is the part of the neuron that delivers impulses at the synapse. It is expanded to form the end bulb, end foot or terminal button.

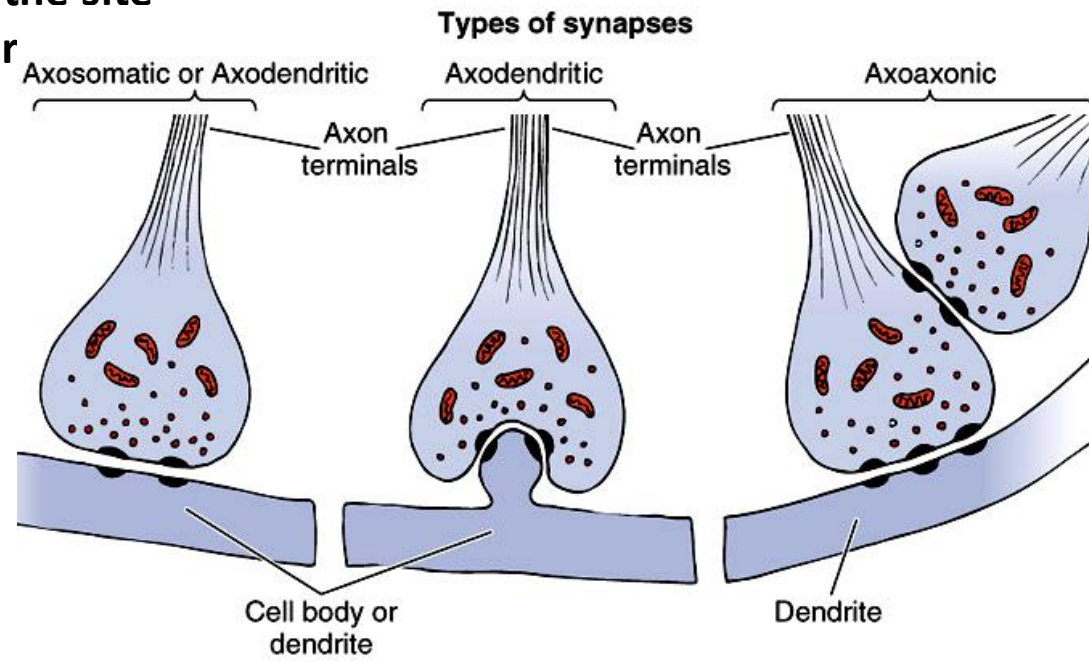
   The axolemma forms the presynaptic membrane.

2. The postsynaptic terminal is the part receiving impulses, and its membrane is the postsynaptic membrane.

3. The synaptic cleft is a narrow space separating the pre- and postsynaptic membranes, with is seen only with the EM.

Types of synapses

A. Synapses are classified according to the site of termination of the axon on the other neuron, into the following types:



1. Axodendritic: the axon of the first neuron makes synapse with the dendrites of the 2nd neuron.

2. Axosomatic: the axon of the first neuron makes synapse with the cell body of the second neuron.

3. Axoaxonic: the axon of the first neuron makes synapse with the axon of the second neuron.

Other types of synapses

Function of synapses

The arrival of a nerve impulse at the synapse leads to depolarization of the presynaptic membrane, which becomes permeable to calcium ions (calcium influx) which enter the cell.

This causes fusion of the synaptic vesicles with the presynaptic membrane, discharging their content of chemical transmitter into the synaptic cleft. This causes either a wave of depolarization of the postsynaptic membrane in excitatory synapses, or hyperpolarization of the postsynaptic membrane in inhibitory synapses

► **Medical application**

1. The myelin sheath may be damaged by an autoimmune mechanism
e..g .in **multiple sclerosis** where the **microglia** phagocyte the myelin debris by lysosomal activity.
This leads to various neurologic consequences.

2. The microglias may be infected by HIV-1 virus.
A number of cytokines, such as interleukin-1, activates and enhances HIV replication in the microglia.
3. Glial cells may produce tumors e.g **gliomas** and **schwannomas**

Thank you