NEURO HISTOLOGY

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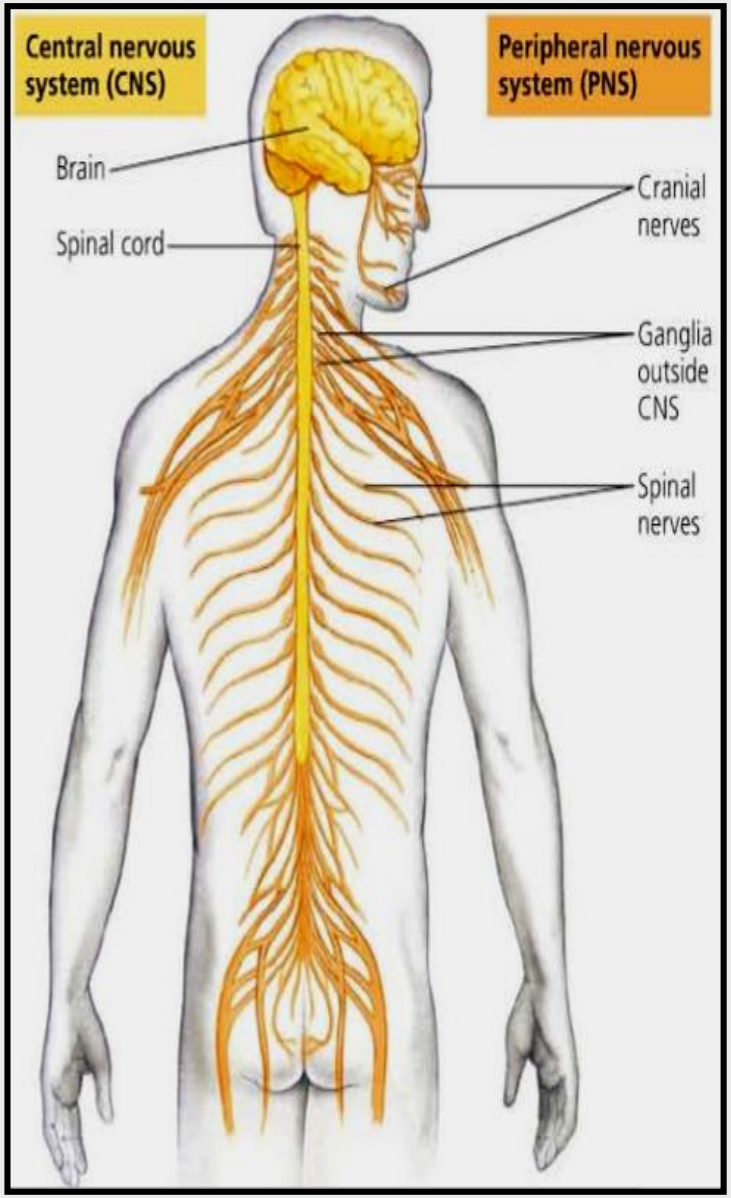
NERVOUS TISSUE

-Irritability and **conductivity**.

-derived from embryonic **neuroectoderm.**



The human nervous system is divided anatomically into:

=Central Nervous System (**CNS**), the brain (encephalon) and spinal cord.

=Peripheral Nervous System (**PNS**), consisting of **cranial** and **spinal** nerves (both motor and sensory), aggregates of nerve cells (**ganglia**) and **supporting** cells.

The part of PNS which regulates the function of internal organs (smooth muscles, cardiac muscle and glandular epithelium) is called **autonomic nervous system** (**ANS**)

-the human nervous system consists of at least 10 billion neurons.

Central Nervous System (CNS)
The brain and spinal cord are composed of **gray matter** and **white matter**.

Gray matter contains

-nerve **cell bodies** (**perikarya**)

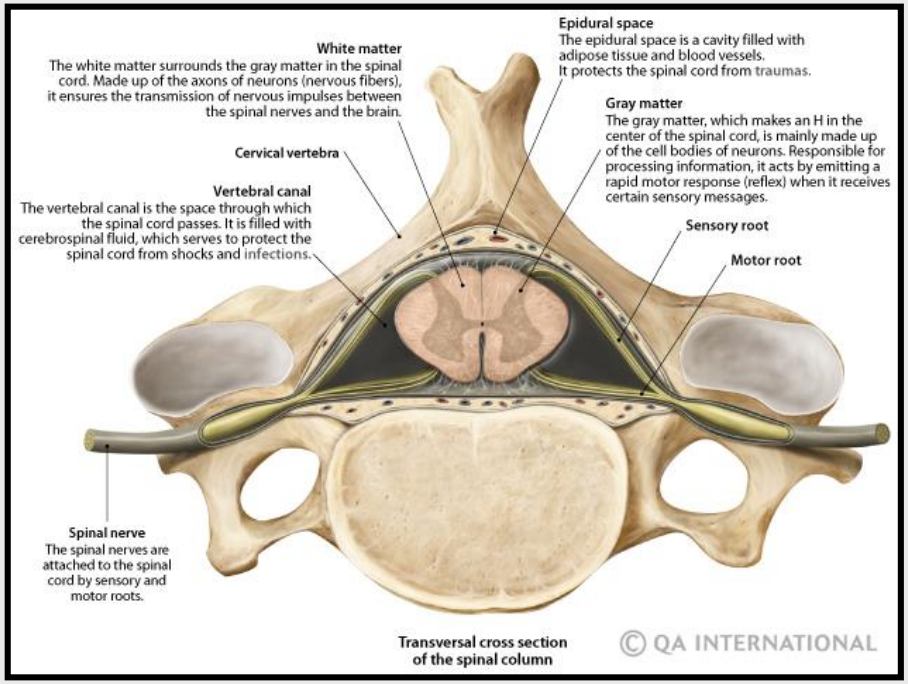
-**neuroglia** (supporting cells).

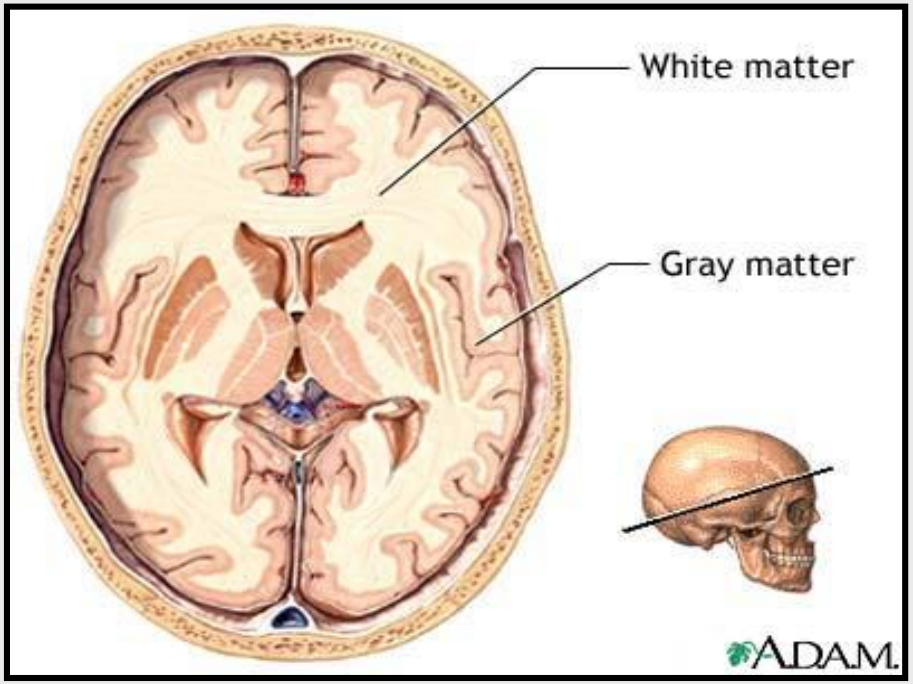
-**neuropil** (a complicated network of cell processes)

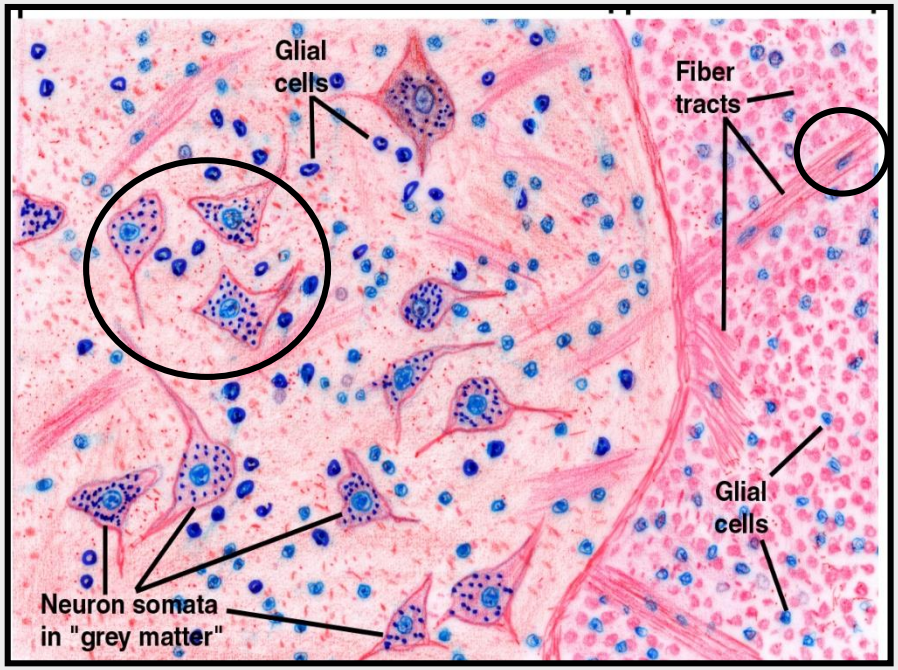
Functionally related groups of cell bodies in the **gray matter** are called ***nuclei*** i.e. ***nucleus*** means a cluster or group of neuronal cell bodies and neuroglia

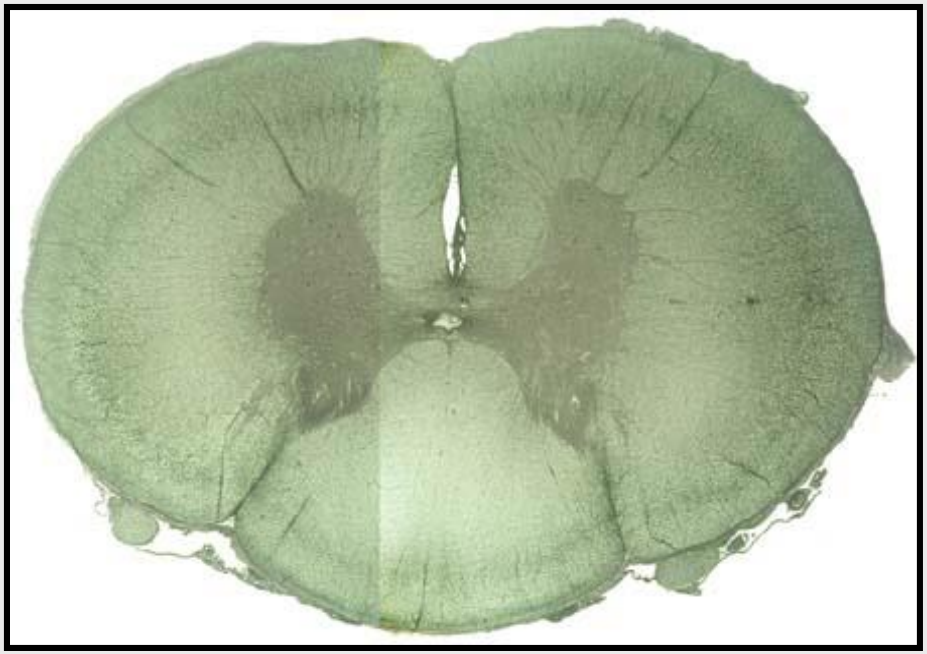
White matter lacks nerve cell bodies (**NO** perikarya), but has many **processes (axons)** of neurons. The white appearance is the result of the **myelin** that envelops many of the neuronal processes. **Neuroglia** are also found in the white matter and the nuclei seen in white matter belong to neuroglia.
Functionally related bundles of axons in the **white matter** are called ***tract***

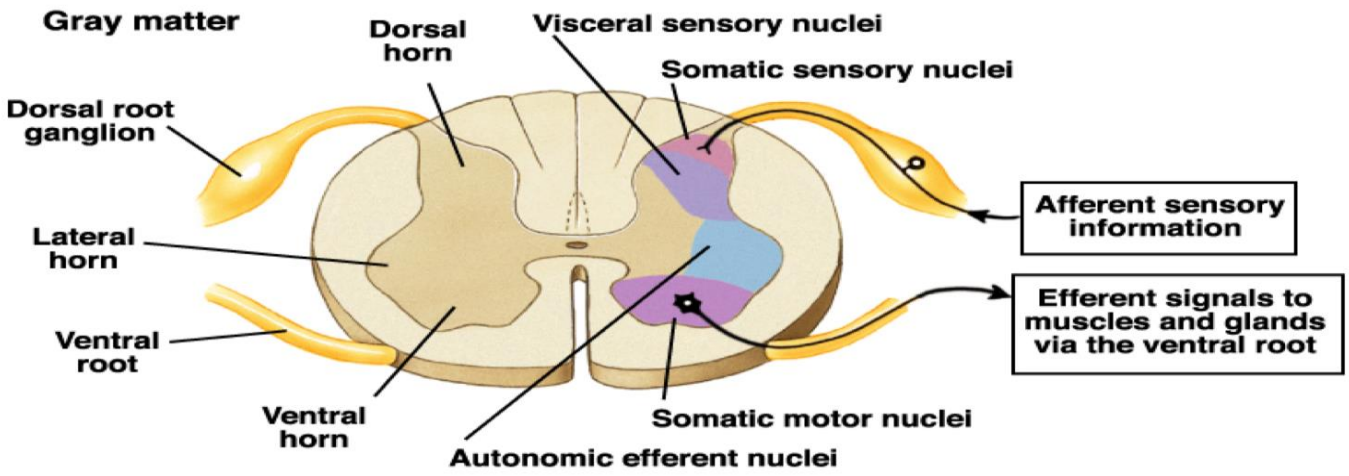
Perikarya in the Peripheral Nervous System (PNS) are found only in **ganglia** (apart from in some **sensory regions** such as the **retina** and **olfactory** mucosa) i.e. **nuclei** of CNS are the morphologic and functional equivalents of the **ganglia** of the PNS


White matter
The white matter surrounds the gray matter in the spinal cord. Made up of the axons of neurons (nervous fibers), it ensures the transmission of nervous impulses between the spinal nerves and the brain.
Epidural space
The epidural space is a cavity filled with adipose tissue and blood vessels. It protects the spinal cord from traumas.
Gray matter
The gray matter, which makes an H in the center of the spinal cord, is mainly made up of the cell bodies of neurons. Responsible for processing information, it acts by emitting a rapid motor response (reflex) when it receives certain sensory messages.
Cervical vertebra
Vertebral canal
The vertebral canal is the space through which the spinal cord passes. It is filled with cerebrospinal fluid, which serves to protect the spinal cord from shocks and infections.
Sensory root
Motor root
Spinal nerve
The spinal nerves are attached to the spinal cord by sensory and motor roots.
Transversal cross section of the spinal column
© QA INTERNATIONAL

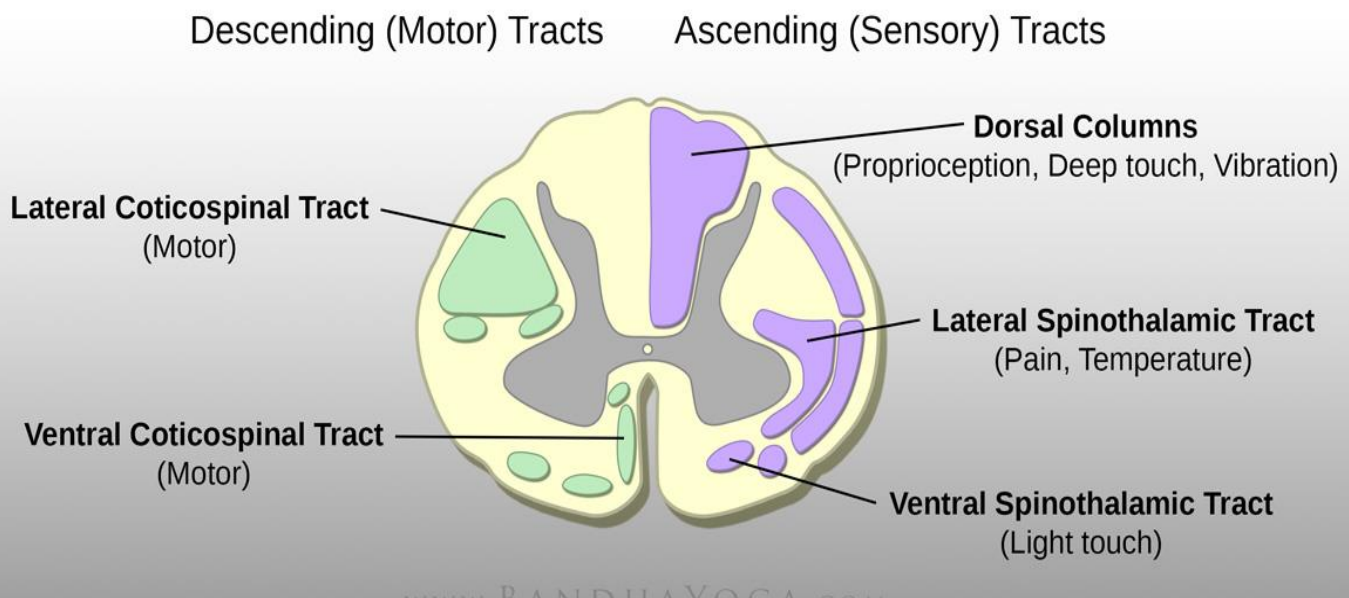

White matter
Gray matter
A.D.A.M.


Glial cells
Fiber tracts
Glial cells
Neuron somata in "grey matter"





nuclei



tracts

NEUROHISTOLOGY

The nervous system develops embryologically from **ectoderm**, which forms the **neural plate**. Successive growth and folding of the plate results in the formation of the primitive **neural tube**.

The **neuroblasts** in the wall of the neural tube differentiates into :

 # Nerve cells (Neurons) the functional unit of the nervous tissue
Receive and conduct impulses

 # Supporting cells non conducting cells with intimate contact with neurons to provide physical support/ electrical insulation/ and metabolic exchange

Neuroglia (glia) / in **CNS**

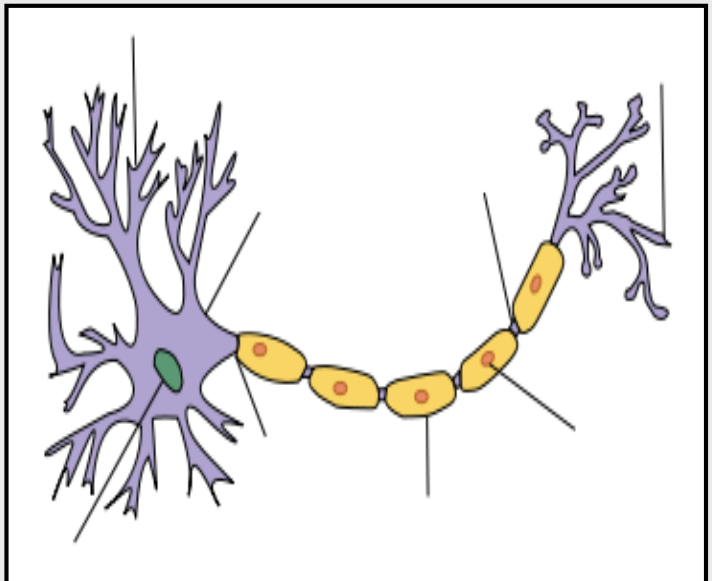
Schwann cells (surrounding cell processes) and **satellite cells** (surrounding cell bodies) / in **PNS**

 # Ependymal cells:

- Lines the lumen of the tube. (**epithelial cells**)
- Specialized **neuro-ectodermal** cells which lines the ventricles of the adult brain

THE NEURON

- The neuron is the **structural** and **functional** unit of the nervous system.
- Neurones are generally **large** cells.
- The vast majority of neurons are generated **before birth**.
- Neurones are "intended" to last a **lifetime**. Mature neurones are not mitotically active, i.e. they **do not divide** so they are called **postmitotic cells**.
- Neurones have two special properties:
  - **Irritability** (the ability to respond to a stimulus)
  - **Propagation of impulses** (the ability to conduct impulses).
- The neuron associates with other neurons by means of **synapses**..
- Axons may be **short** (**Golgi Type II**) e.g. **interneuron**
  long neuron (**Golgi Type I**) e.g. **pyramidal** neuron
- Most neurons have three main parts:
  - **Dendrites**
  - **Perikarya** or **soma** (cell bodies)
  - **Axon**



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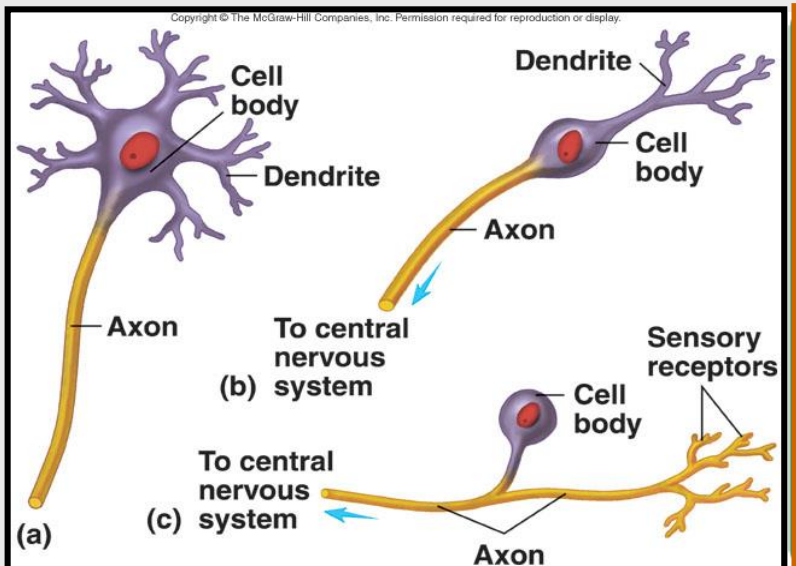
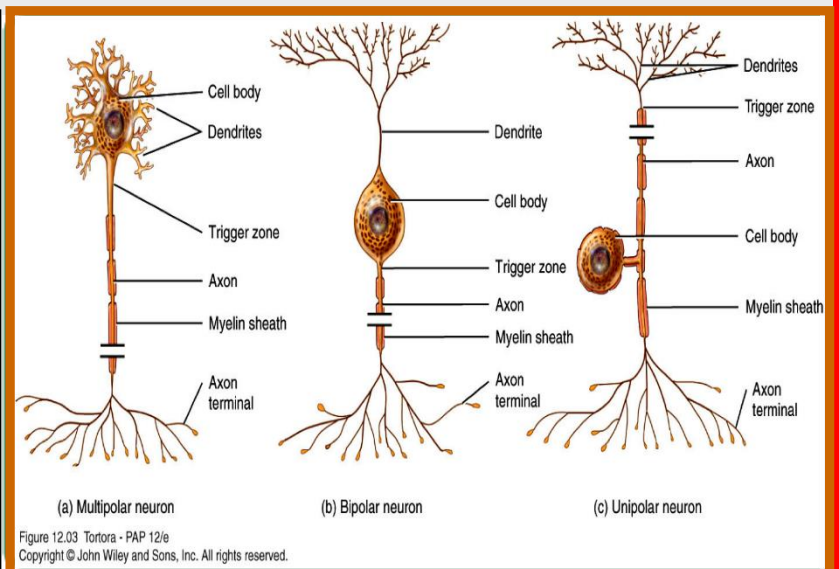
Neurons are classified according to the **size, number** and **shape** of their processes and also to their **function**

SHAPE depends on the number of processes from the cell body:

- **Unipolar neurons** (pseudounipolar) have a single process (axon). These are found in **sensory ganglia of dorsal roots** of spinal nerves.
- **Bipolar neurons** have two processes (one **dendrite** and one **axon**). These are very rare and have a limited distribution in the body. They are present in **special sensory** structures including the **retina**, **olfactory** epithelium, and **vestibular** and **cochlear** nerves).
- **Multipolar neurons** possess several processes (**several** dendrites and a **single** axon). Most neurons belong to this category.





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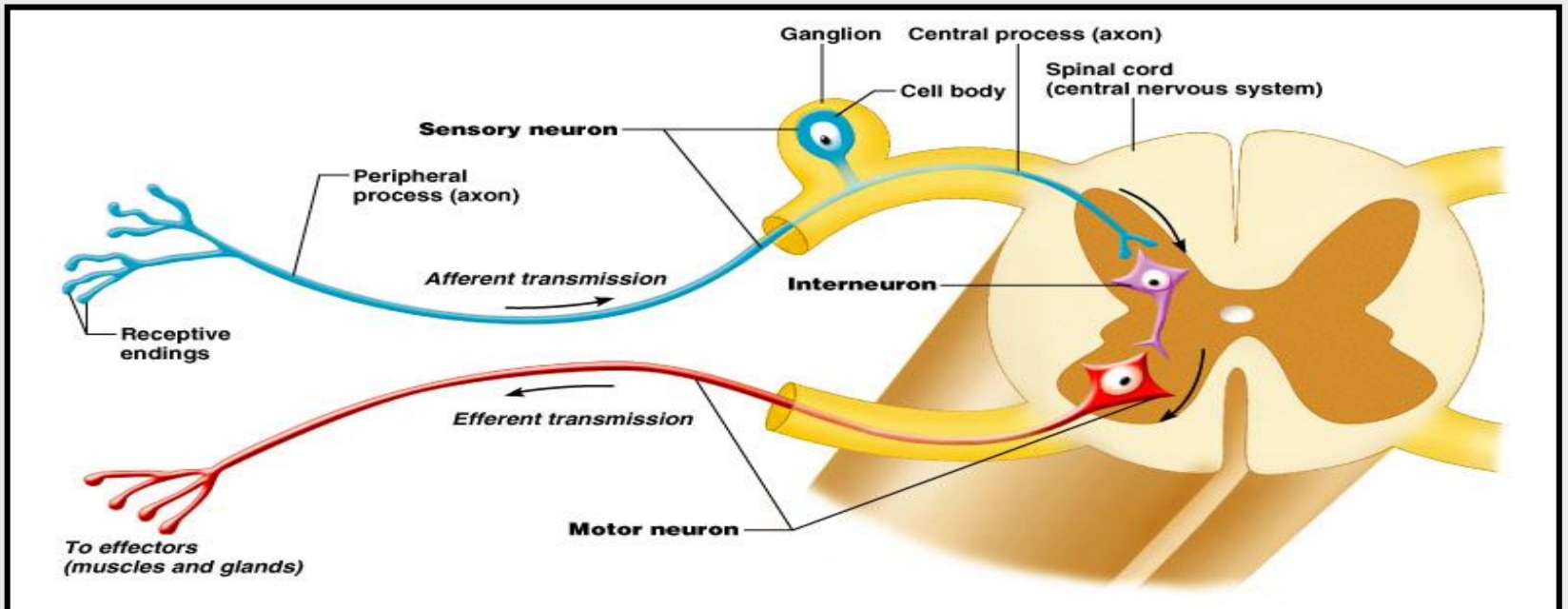
Neurons may also be classified according to their **FUNCTION**

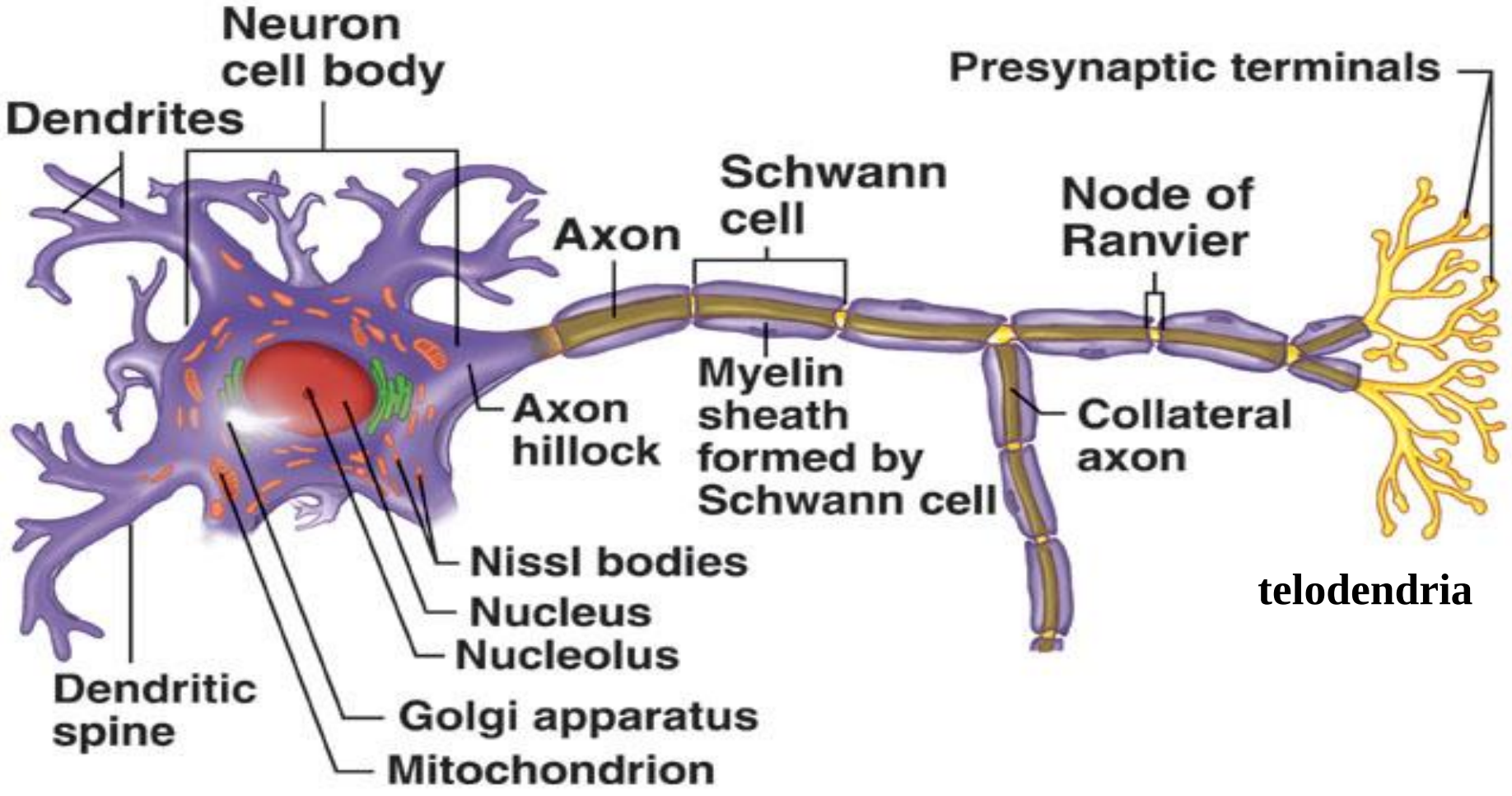
- **Sensory neurons (afferent)**. These receive sensory stimuli from the environment (from receptors) and from within the body (e.g. unipolar neurons).
- **Motor neurons (efferent)**. These control the effecter organs (muscles, exocrine glands, endocrine glands)
- **Interneurons** (**Intermediate neurons**). These are typically found in the CNS and connect between other neurons (often between sensory and motor neurons).
- **Neurosecretory neurons**. These are specialized neurons that synthesize and secrete hormones**.**



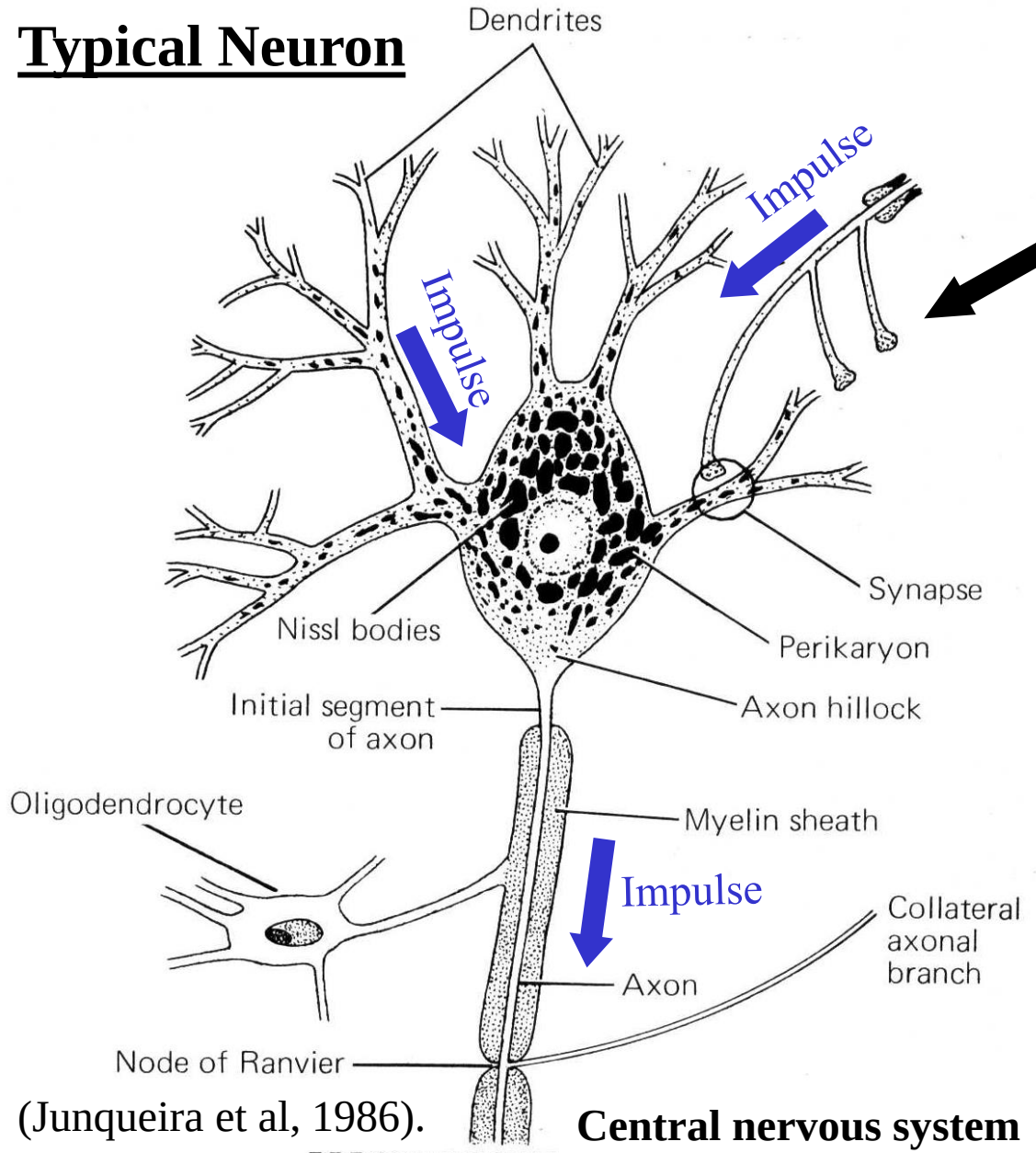
MORPHOLOGY OF NEURONS

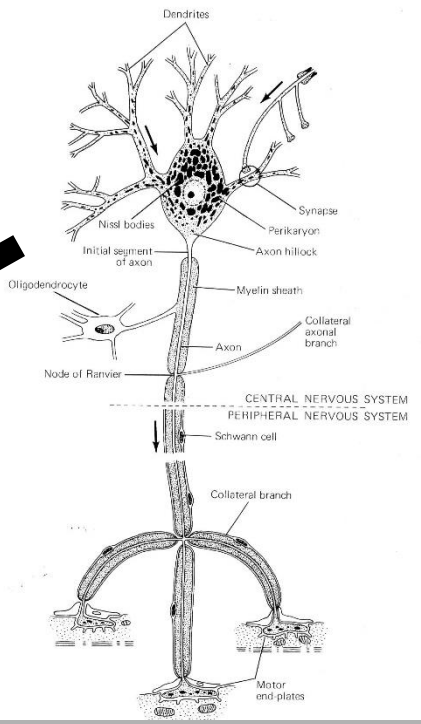
I. Dendrites (Dendrons)

- The **dendrites** are receptive to stimuli dendrites conduct impulses **towards** the cell body (sensory epithelial cells or other neurons), unlike axons (conduct impulses **outwards** the perikaryon) .
- Most nerve cells have **several** dendrites to increase the receptive area of the neuron.
- Dendrites are usually **tapered** i.e. do **not** maintain a constant diameter (unlike axons).
- Typically dendrites have large numbers of **spines**, which are now known to be areas of **synaptic contact** which are swollen or **knobby** at the end.
- Dendrons terminate an axons or cell bodies of other neurons.
- Dendrons are naked, i.e. have **no myelin** sheaths.
- Although they are short extensions of the cell body, they may include **Nissl bodies** and **neurofibrils.**



Typical Neuron





Impulses are conducted in one direction only

Dendrites conduct towards the cell body
Axons conduct away from cell body

(Junqueira et al, 1986).

Central nervous system

The functional unit of the nervous system is the neuron. It has dendrites and 1 axon. The cell body lies in a ganglion or in the central nervous system. The cell body (Perikaryon) has a nucleus (karyon). The Nissl bodies lie around the nucleus.

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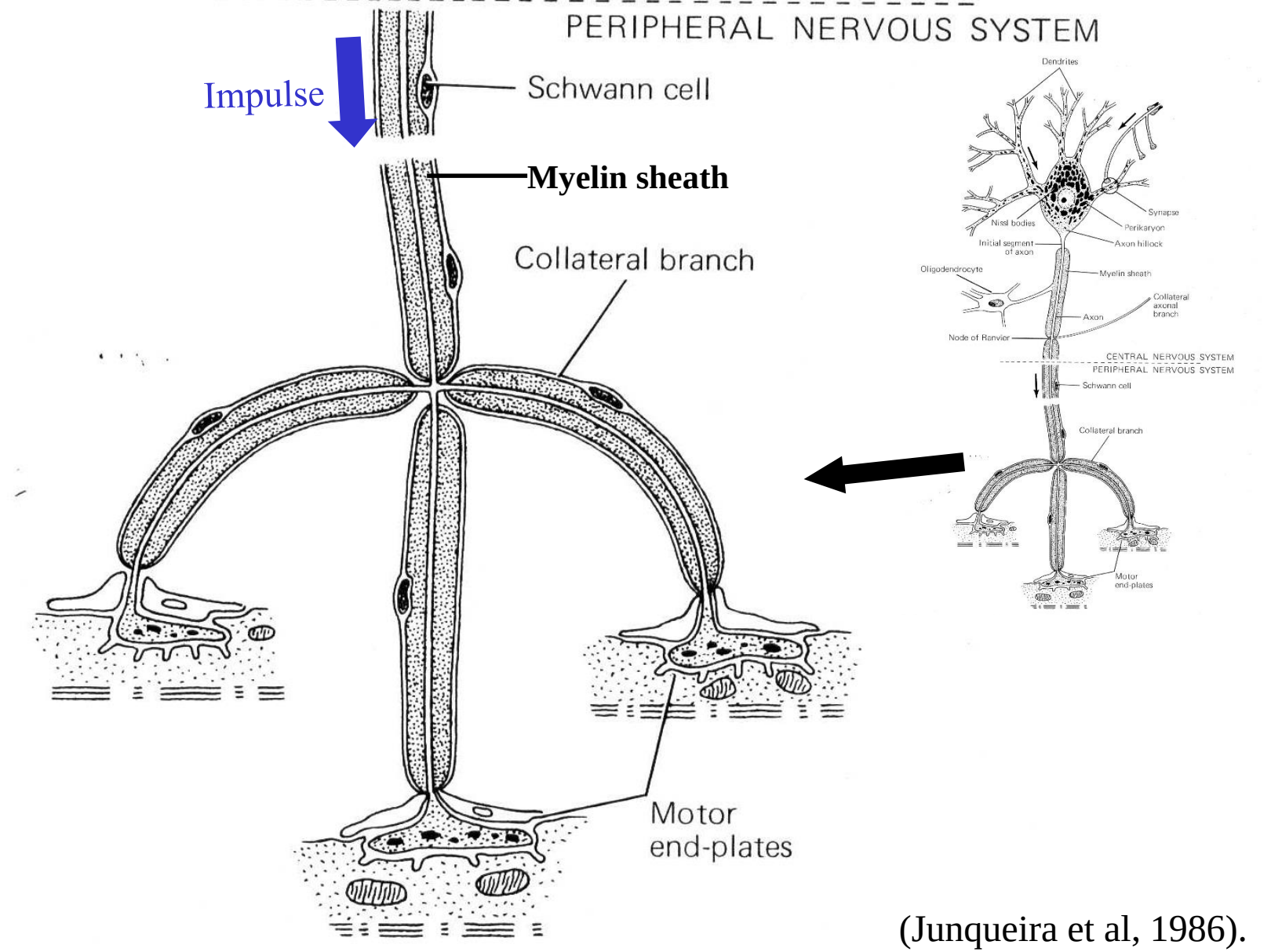
II. Axons

- Each neuron has a **single** axon (only **one** axon per cell). The diameter of the axon is fairly constant (**uniform**). The **length** of axons is fairly **variable**, and some reach up to 100 cm (the axons innervating the toes have their cell bodies in the spinal cord).
- Axon is **longer** and more **slender** than the dendron.
- All axons originate in a short pyramid-like structure called the **axon hillock**, which is devoid of **Nissl substance** and **Golgi cistrenae**.
- Axons conduct impulses **away** from cell body
- Neurofilaments, neurotubules, mitochondria and vesicles pass through the axon hillock into the axon to transport molecules toward far parts via the **axonal transport system**.
- The plasma membrane of the axon is termed the **axolemma**, and the cytoplasm of the axon is termed the **axoplasm**.
- The axon terminates in a set of branches called the **telodendria**.
- The axon may have slender, lateral branches at a **node of Ranvier** called **collaterals**.
- Nerve fibers tend to run in bundles in the central nervous system (**tracts**) and in the peripheral nervous system (**nerves**).
- An accessory sheath may cover the axon (**myelin sheath**). This sheath can be formed by **Schwann cells** (PNS) or by the **oligodendria** (CNS).



(Junqueira et al, 1986).

The axon carries the impulse away from the cell body. The axon can break up into collateral branches. In this case they carry the impulse to muscle fibers where they form motor end plates.

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III. The Cell Body (Perikaryon)

- Size varies from 4 to 135µm.
- The **perikaryon** (cell body or soma) is also **receptive** to stimuli, but also serves as the **trophic** or synthesizing center for the whole nerve.
- The surface of the perikaryon **receives** nerve impulses and is the **site of many synapses**, bringing excitatory or inhibitory stimuli.

Nucleus

- The nuclei of perikarya are **large** (intense synthetic activities), regular, round or oval, typically situated fairly **centrally**.
- The nuclei are **euchromatic** (pale staining with dispersed chromatin) giving the nucleus a reticular appearance under light microscopy.
- Sex chromatin (**Barr's body**) is commonly seen in the nuclei of females.

Rough Endoplasmic Reticulum (rER) - Nissl bodies

- rER is **abundant** in the cytoplasm and is associated with the protein synthetic activities of the neurons.
- The rER is **basophilic** as seen in regular (H&E) staining by light microscopy.
- Under LM irregular clumps of intensely basophilic material called **Nissl bodies** can be found widely distributed throughout the cytoplasm. Under electron microscopy, these Nissl bodies are found to be composed of **rER** with associated **ribosomes** and **polyribosomes**. After injury to the cell, these bodies **disperse** their contents throughout the cytoplasm. This produces a **darkening** of the cell. This effect is referred to as the **Nissl Reaction** or **chromatolysis**
- Nissl-bodies are prominent in **motor neurones** located in the **ventral horn** of the grey matter of the spinal cord.
- Nissl bodies extend into the dendrites but **NOT** into axons which helps to **distinguish** between axon and dendrites in electron microscopic preparation.

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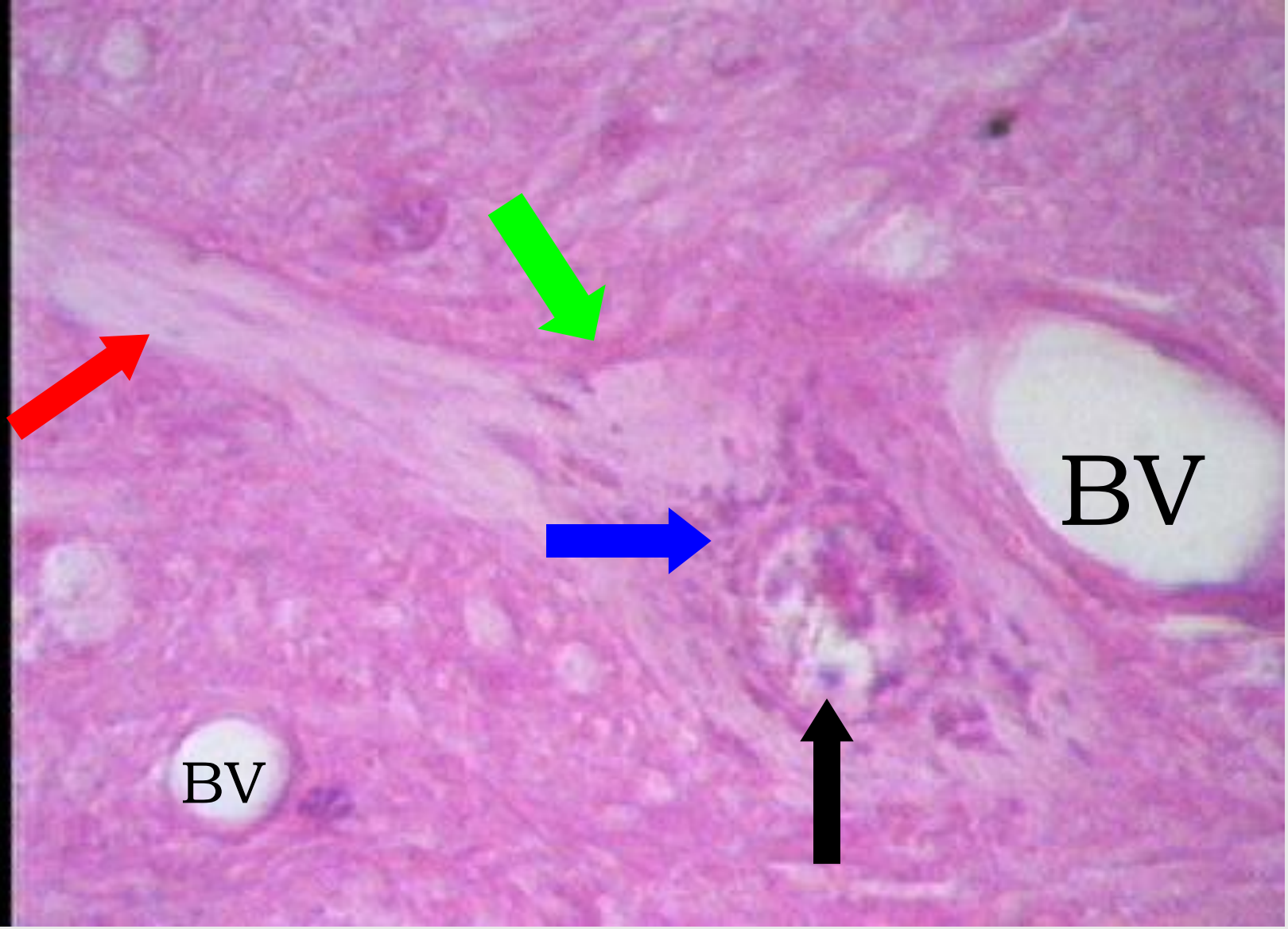

This is the cell body of a neuron. The ⬆ indicates the nucleolus. The ➡ indicates the Nissl substance. The ↘ indicates the axon hillock and the ↗ indicate the axon. The **BV** stands for blood vessel.

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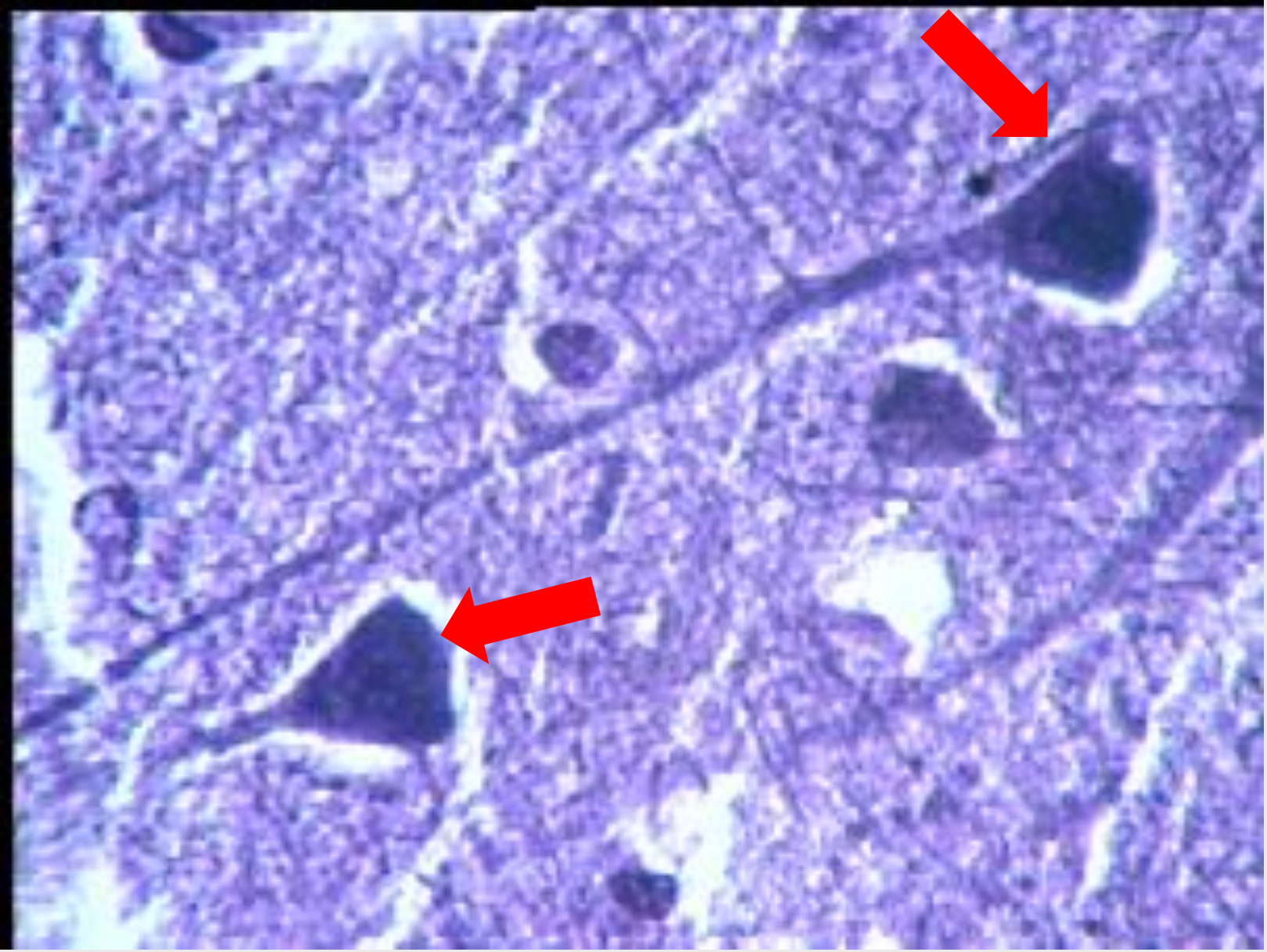

The ↙↘ indicate pyramidal neurons in the central nervous system.

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Golgi bodies and **Mitochondria**

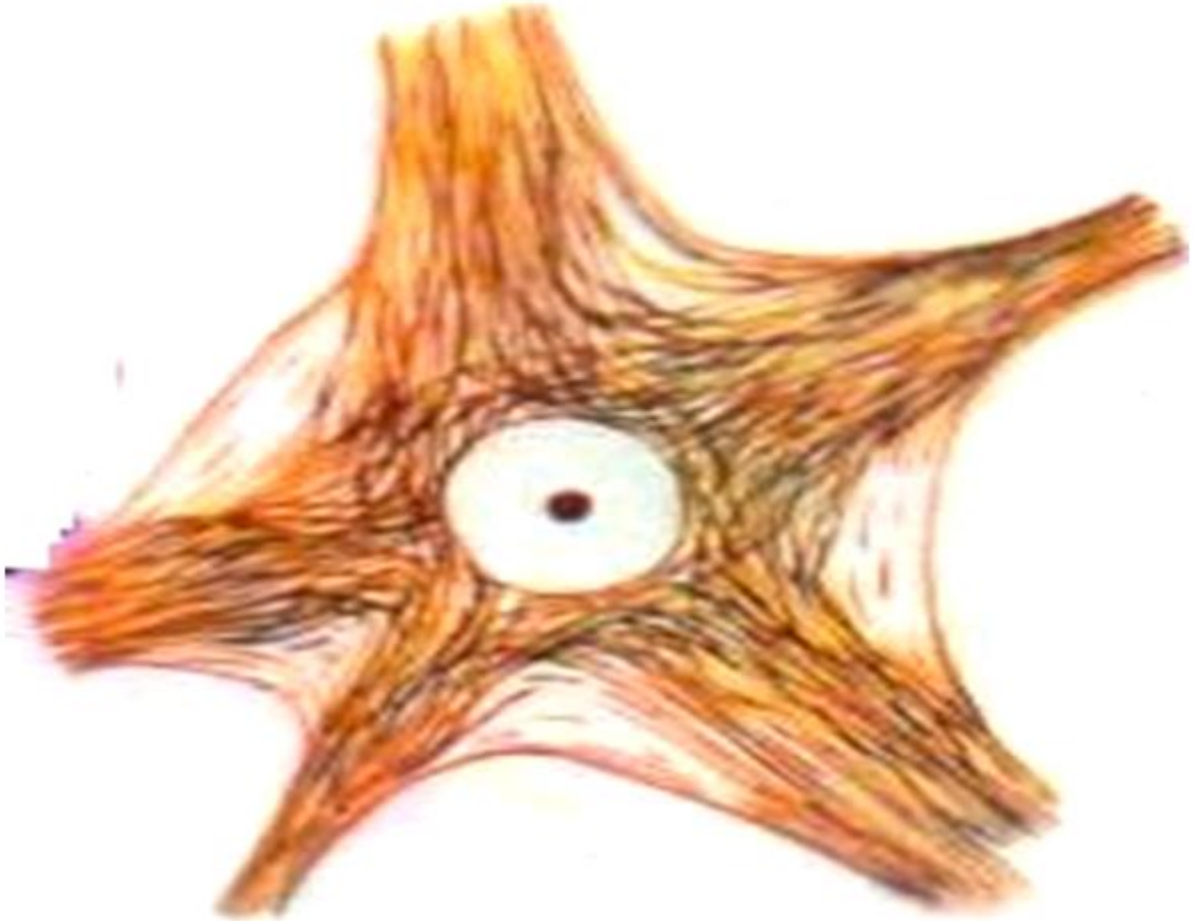
- Golgi complexes and mitochondria are **numerous**.
- **Large** well developed Golgi bodies are present in the perikarya.
- Many **large** mitochondria are found throughout the perikaryon.
- The presence of rER, Golgi and mitochondria indicative of high level of **anabolic activity** needed to maintain these large postmitotic cells.

Neurofibrils

- Neurofibrils are present in both the cell **body** and in cell **processes**. These are composed of microtubules and microfilaments (**neurofilaments** and **neurotubules**) as seen under EM.
- The neurofibrils are thought to be responsible for the **intracellular transport** of materials throughout the cell

Neurofibrils:

A network of neurofibrils is in the perikaryon and in the dendrites and axon. Is unique to neurons. Support, drainage.



Synapses

•Neurons interconnect by way of synapses
•The axon forms small, bulb-shaped swellings called **boutons** at the ends (**terminal** boutons) or along the course of its branches called **boutons en passant**.
•The synapses in the human body are **chemical synapses**. They involve the release of **neurotransmitters**, which combine with receptors on the post-synaptic membrane and result in the transmission of the impulse.
•Synapses are morphologically specialized contacts between a bouton formed by one neurone, the **presynaptic neurone**, and the cell surface of another neurone, the **postsynaptic neurone**. **Synaptic vesicles** contain the neurotransmitters. Synaptic vesicles typically accumulate close to the site of contact between the bouton and the postsynaptic neurone. The release of the neurotransmitter from the synaptic vesicles into the **synaptic cleft** , i.e. the space between the bouton and the postsynaptic neurone, mediates the transfer of information from the pre- to the postsynaptic neurone. The neurotransmitters combine with specific **receptors** on the postsynaptic membrane leading to the transmission of the impulse

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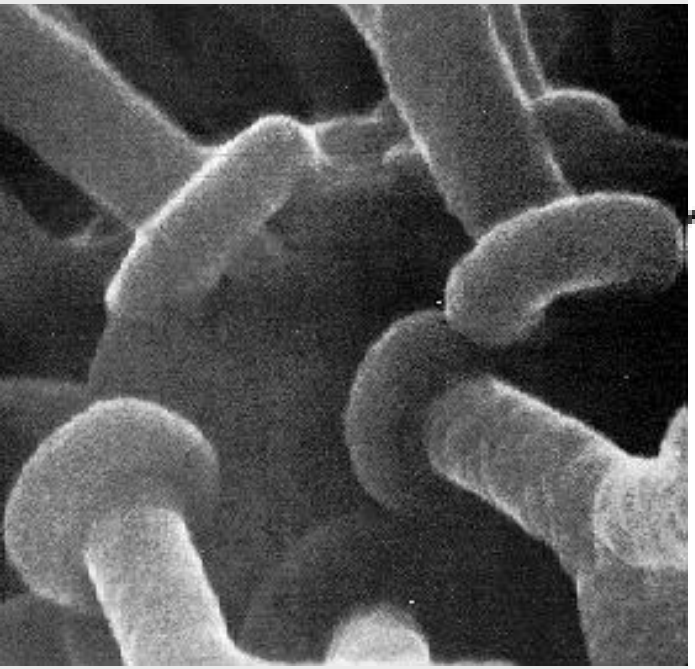
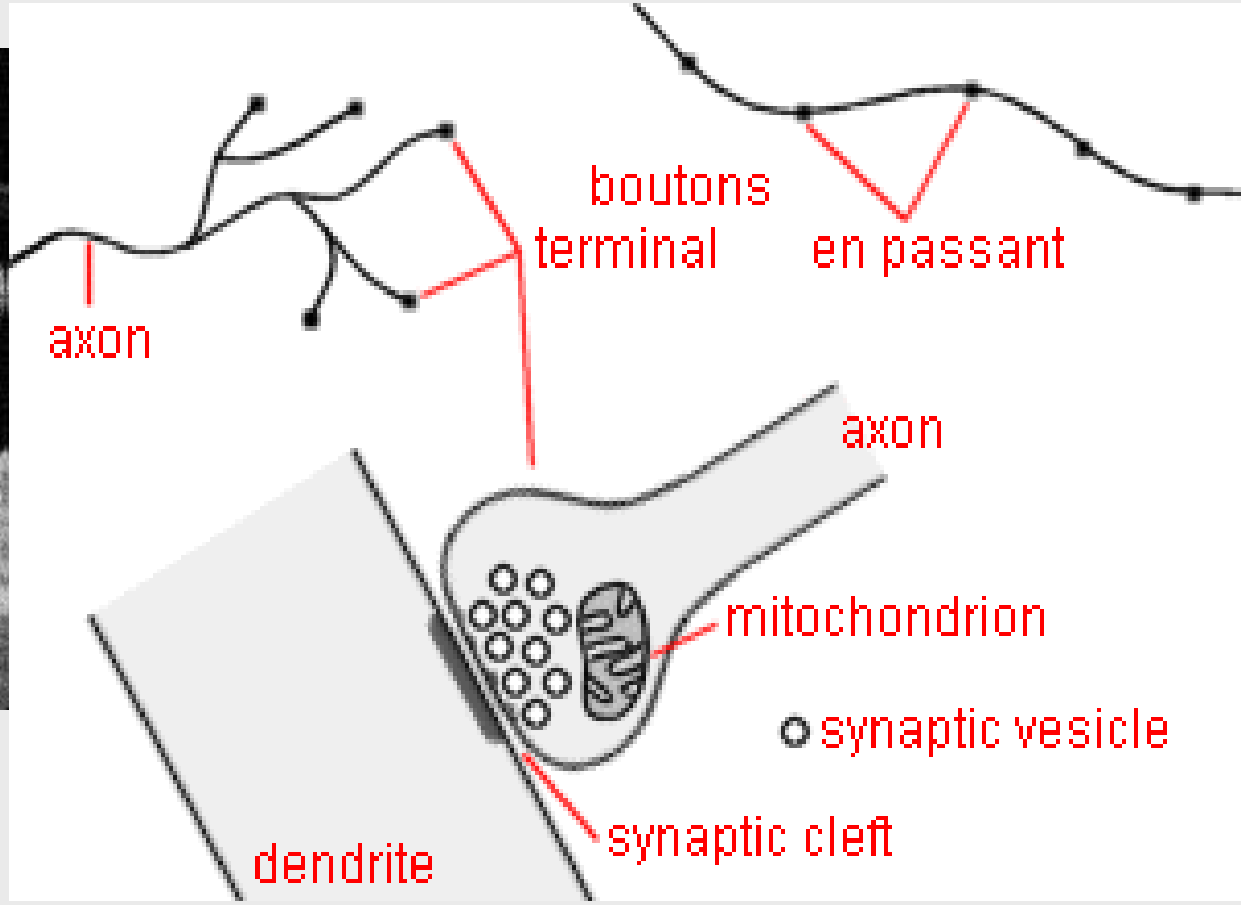
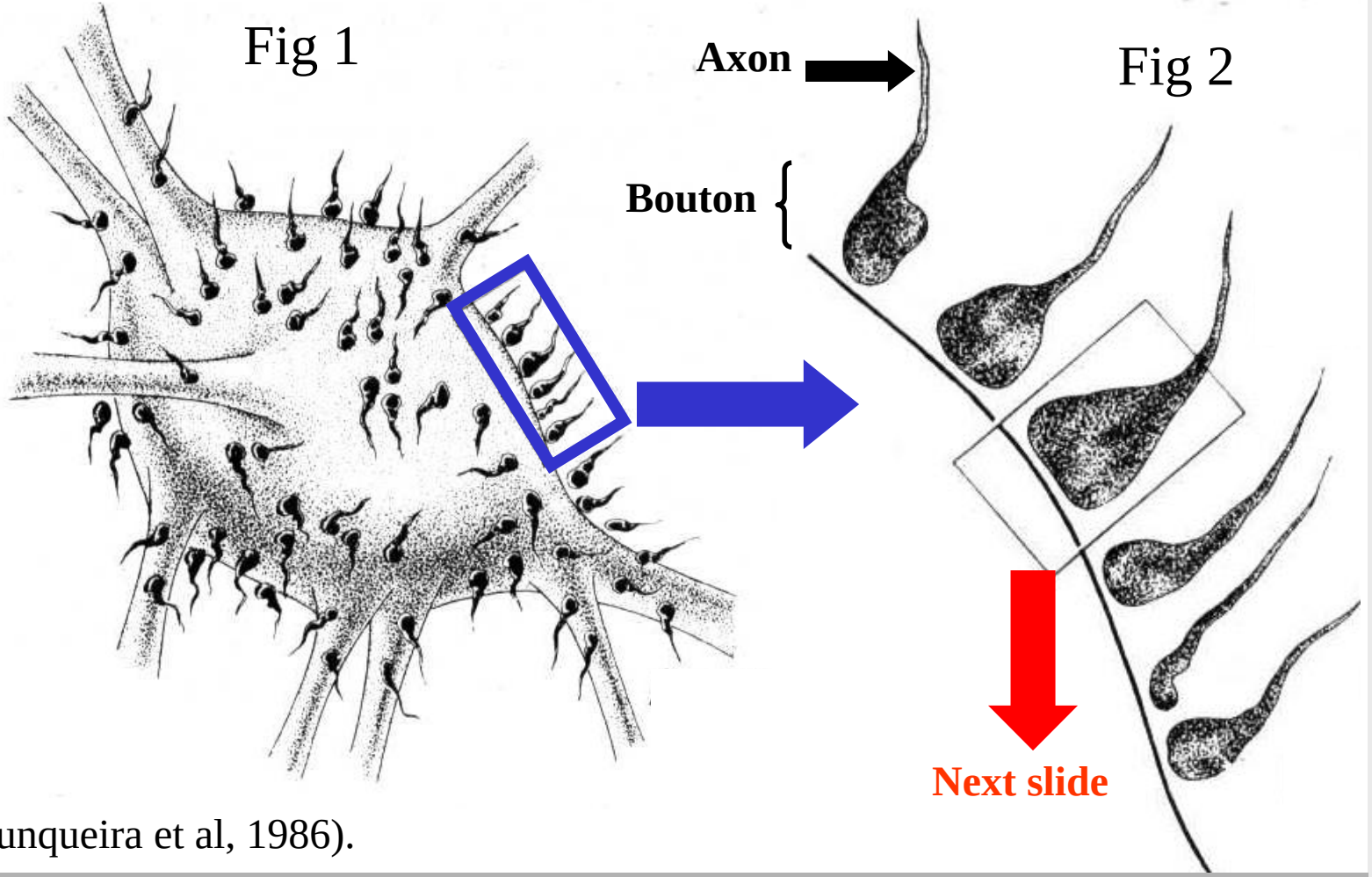
- Some synapses are **excitatory**, whereas others are **inhibitory**. Various categories of synapses are found including:

axo-dendritic **-axo-somatic**

dendro-dendritic **-axo-axonic**







(Junqueira et al, 1986).

Fig 1 shows a cell body with numerous boutons forming synapses. Fig 2 shows a number of boutons synapting with the cell membrane of a neuron cell body.

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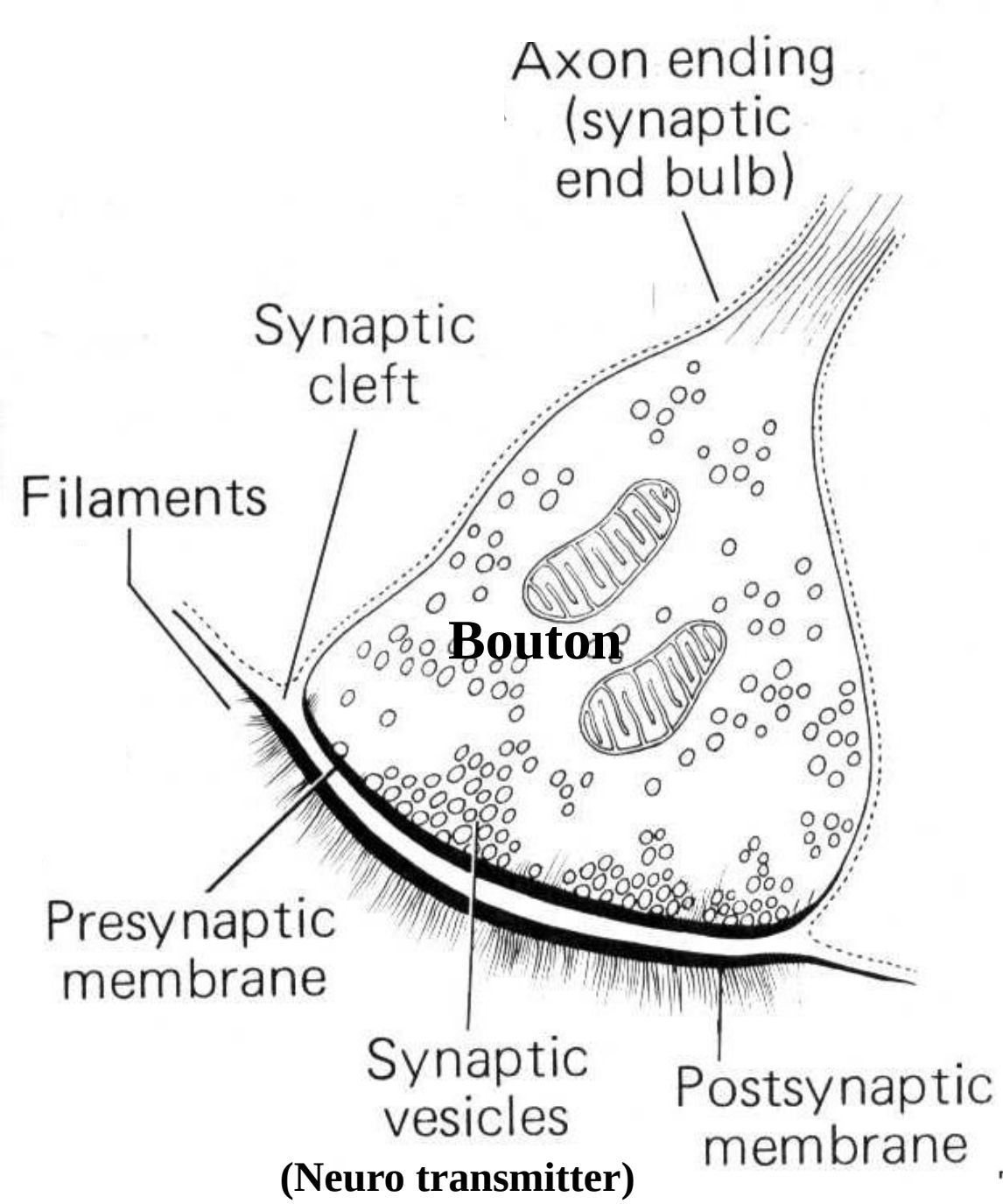


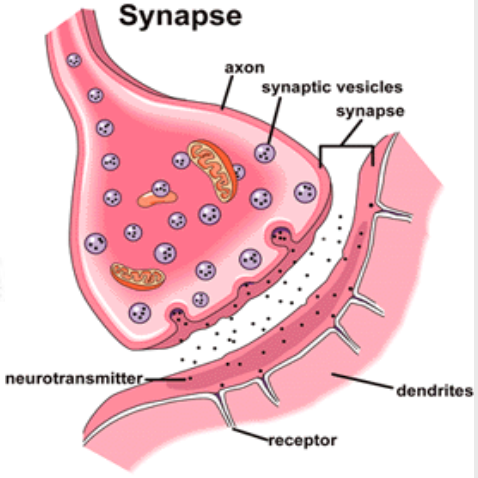
(Neuro transmitter)

Synaps

This drawing shows a bouton, which is the end of an axon, with its presynaptic membrane and post synaptic membrane with the cleft inbetween.

Notice the mito-chondria in the bouton.

The synaptic vesicles contain neurotrans-mitter



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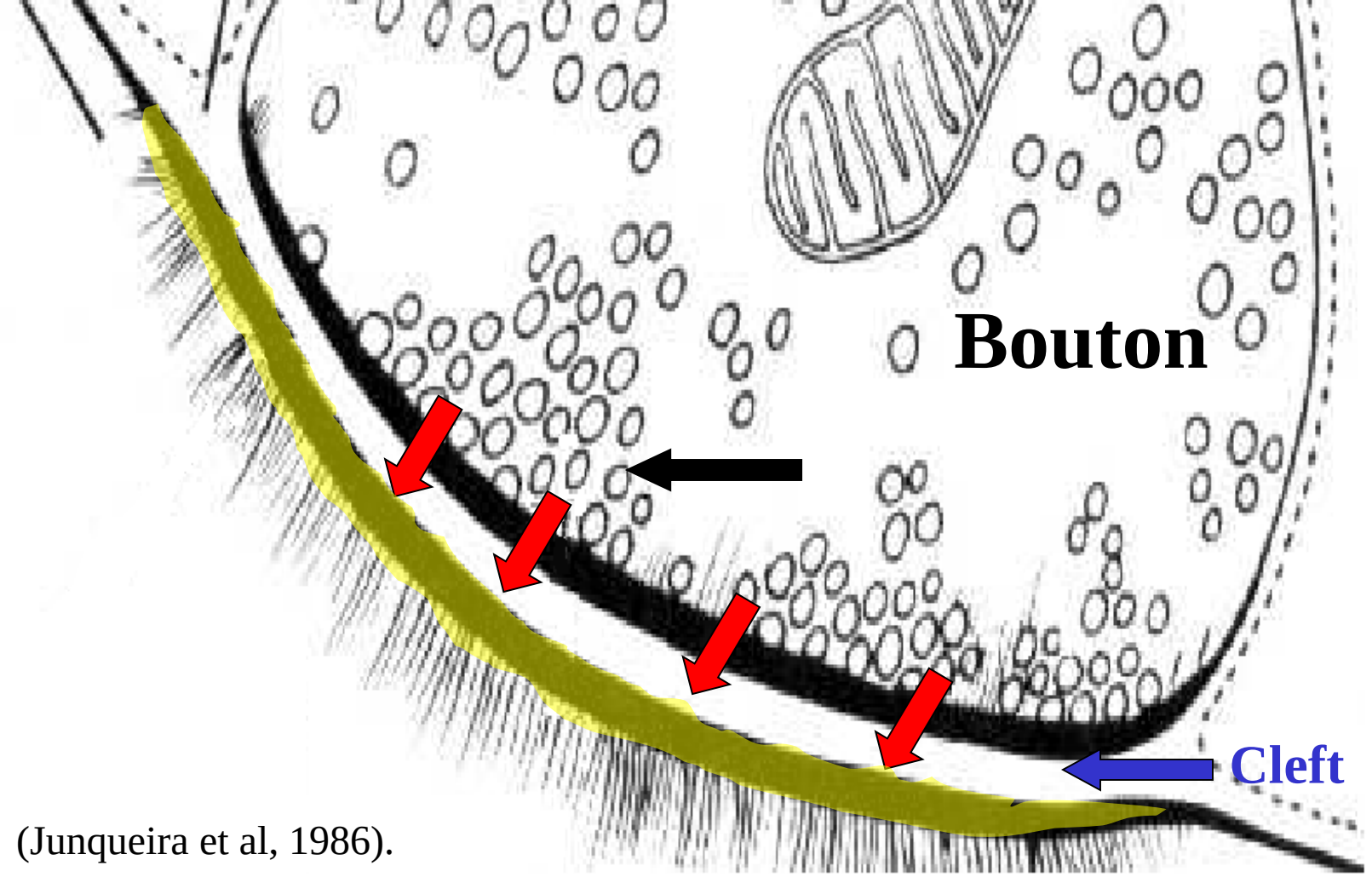

(Junqueira et al, 1986).

This is a high magnification of the contact between the bouton (axon) and the effector (muscle fiber). The little circles ⬅ are vesicles that contain nerotransmitter.

The neurotransmitter will move across ⬇ the **presynaptic membrane,** **cleft** and stimulate receptors lying in the **postsynaptic membrane.**

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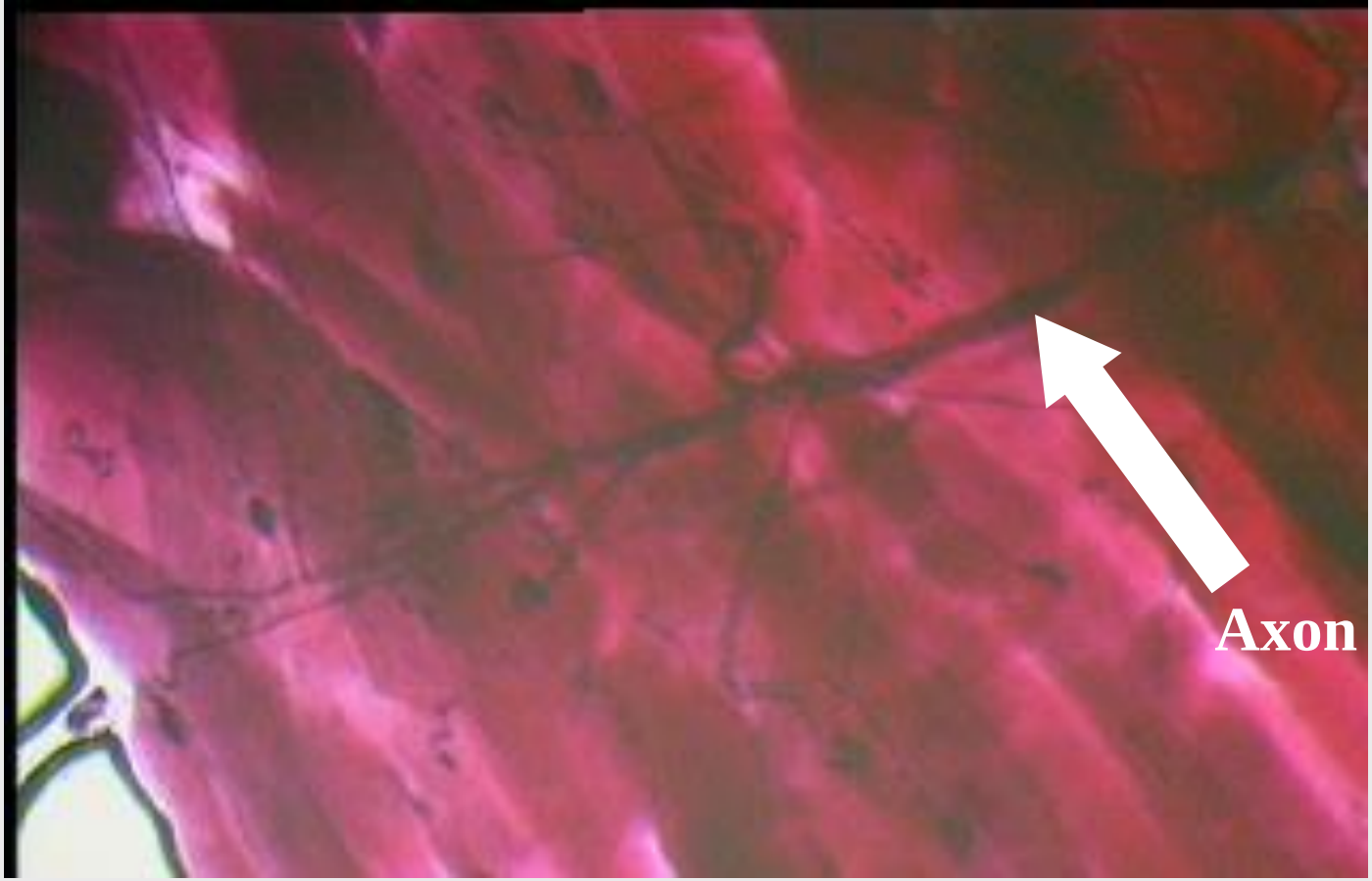

Motor endplate(neuromuscular junctions)

Seen in periphery on striated muscle fibres

- known as boutons
- has no continuous myelin covering from the Schwann cells
- passes through perimysium of muscle fiber to "synapse"
- A single motor nerve may innervate a single fiber or may have several neuromuscular junctions. A single motor nerve and all the muscle fibers it innervates is called a **motor unit**. bouton
- contains numerous synaptic vesicles and mitochondria

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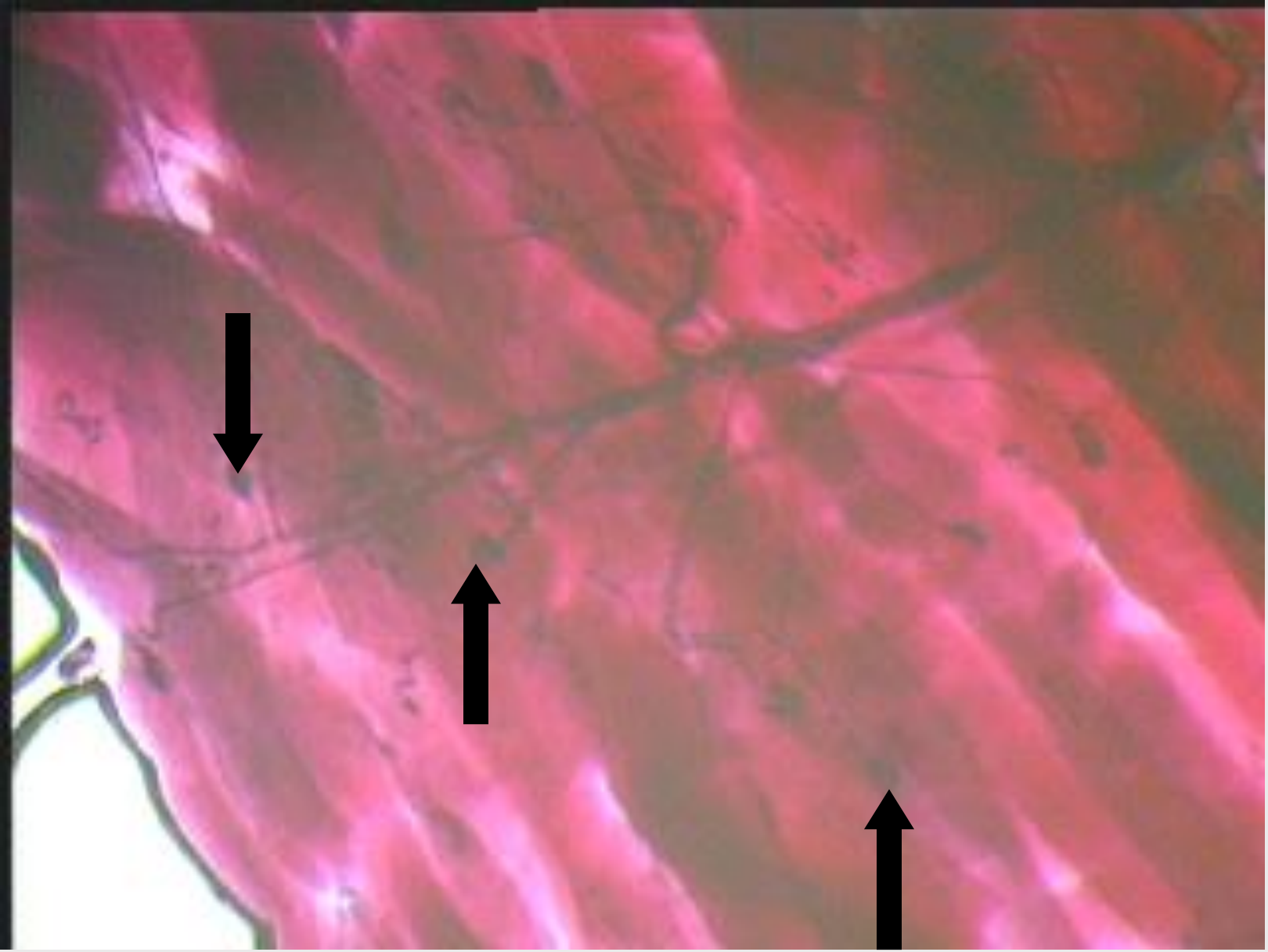

The black arrows ⬆ in this slide indicate motor end plates all coming from the same axon.

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This is a high magnification of a motor end plate .

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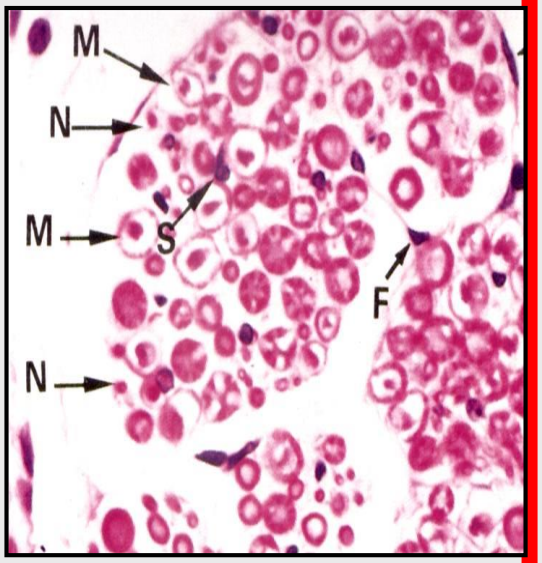
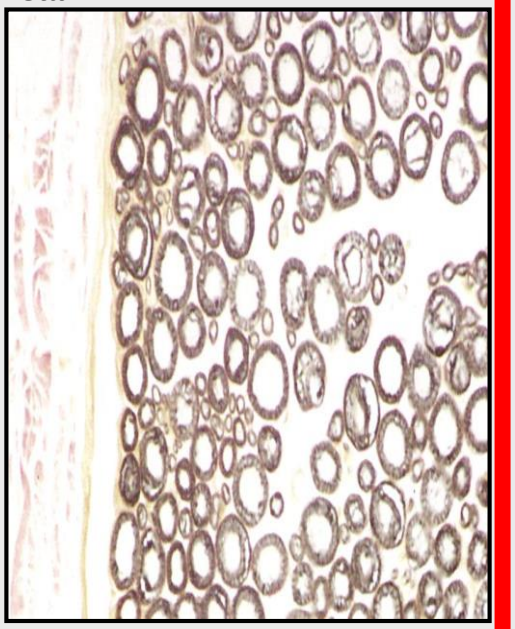
Myelinated fibers

- Axons of the nervous system may insulated by **myelin sheath** (lipid rich sheath) though described as **myelinated** or may be **unmyelinated**
- Myelin fatty material contains **phospholipids**, **cholesterol** and some **proteins**
- Soluble and not seen in H&E-sections as it has been **dissolved** in the process, **leaving empty** spaces around the axons, appeared **white** in the fresh state=== ***Osmium fixation***
- The myelin sheath is composed of **multiple layers** of Schwann cell membrane **wrapped** circular fashion around the axon, seen as concentric rings in cross section. The Schwann cell becomes surrounded by its **basal or external lamina**
Myelin sheath is formed by two types of cells
-Within the CNS by **Oligodendrocytes**
-On the PNS by **Schwann cells**
- The myelin sheath surrounding the axon is seen as a series of myelinated **internodes segments** (0.08-0.1 mm) separated by **nodes of Ranvier** (no myelin). Tangential non-stained areas (similar to arrow heads) are seen in the myelin of the internodes (**Schmidt-Lantermann clefts**). These are areas of cytoplasm of the Schwann cells, where the membranes are **not closely apposed.**

H&E stain



Osmium fixation, van Gieson stain



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• Myelinated nerves conduct impulses **rapid** than the unmyelinated fibres

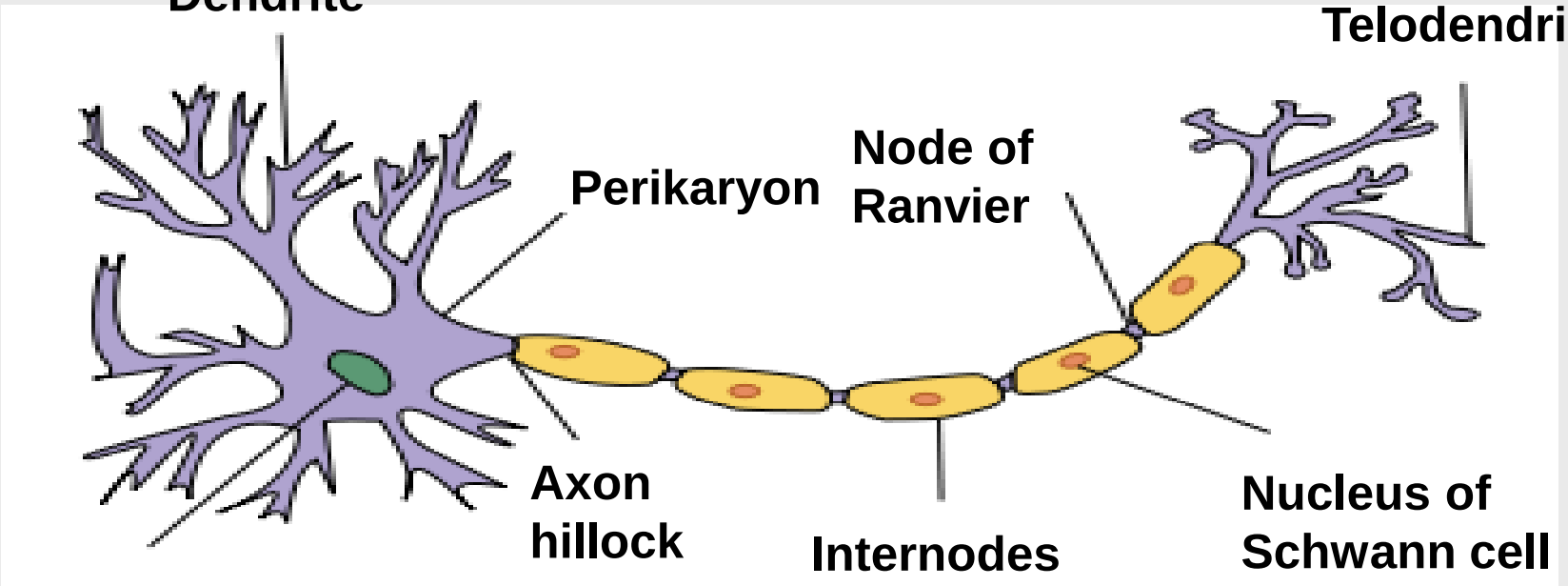
•**Large-diameter** myelinated fibres conduct impulses more **rapidly** than **small-diameter** ones because they have longer internodal lengths of myelin than do the small axons

•**The nodes of Ranvier have several important features:**

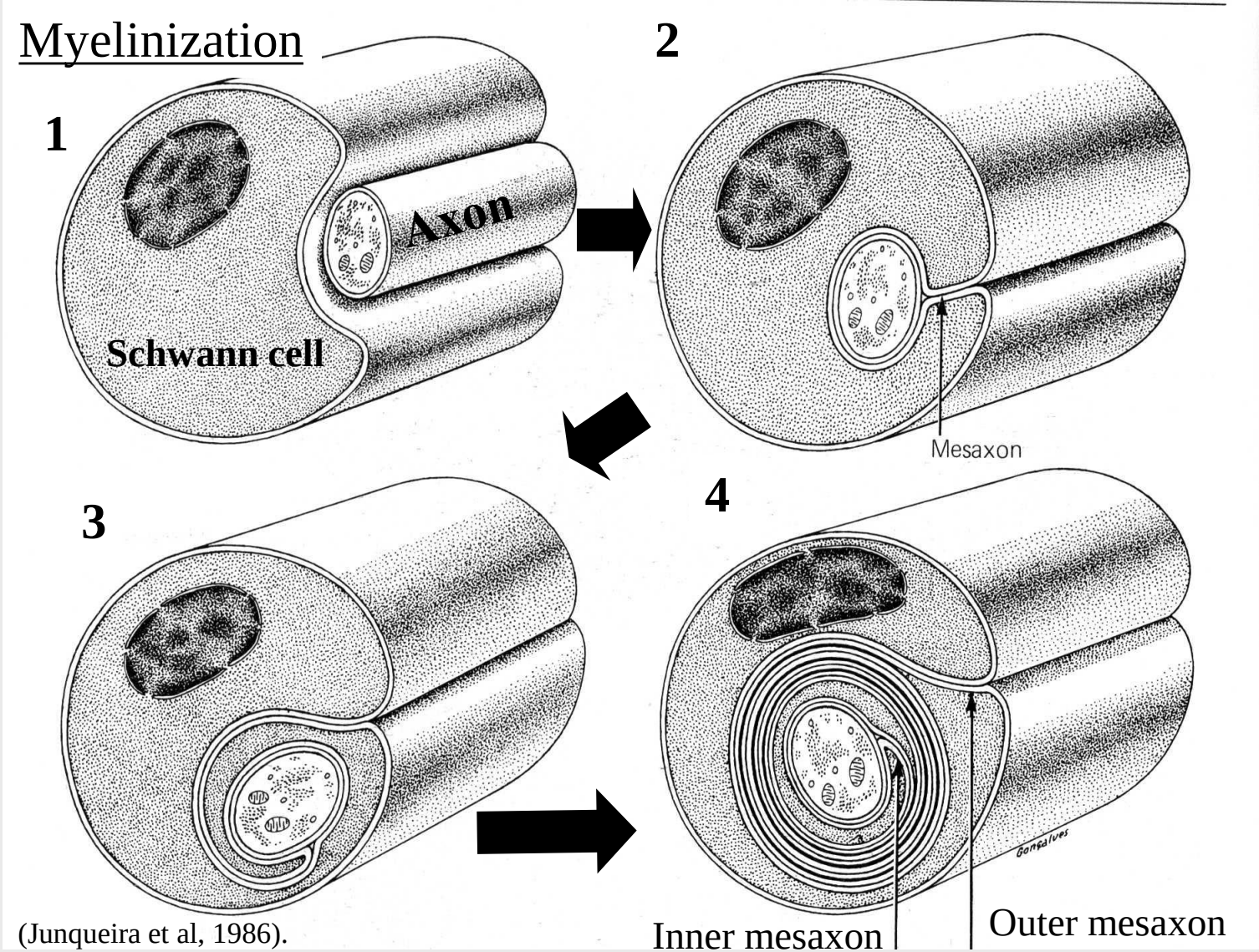
* sites of axon collaterals

* large concentrations of mitochondria in the axon at these sites (high local metabolic activity)

* site of saltatory conduction (discontinuous conduction)



Myelinization



(Junqueira et al, 1986).

1 – The axon starts to invaginate the Shwann cell
2 – Once the axon has invaginated the Shwann cell a mesaxon is formed.
3 – Next the mesaxon winds to wrap around the axon.
4 – This winded mesaxon forms the myelin. The nucleus and cytoplasm of the Shwann cell is pushed to the ouside.

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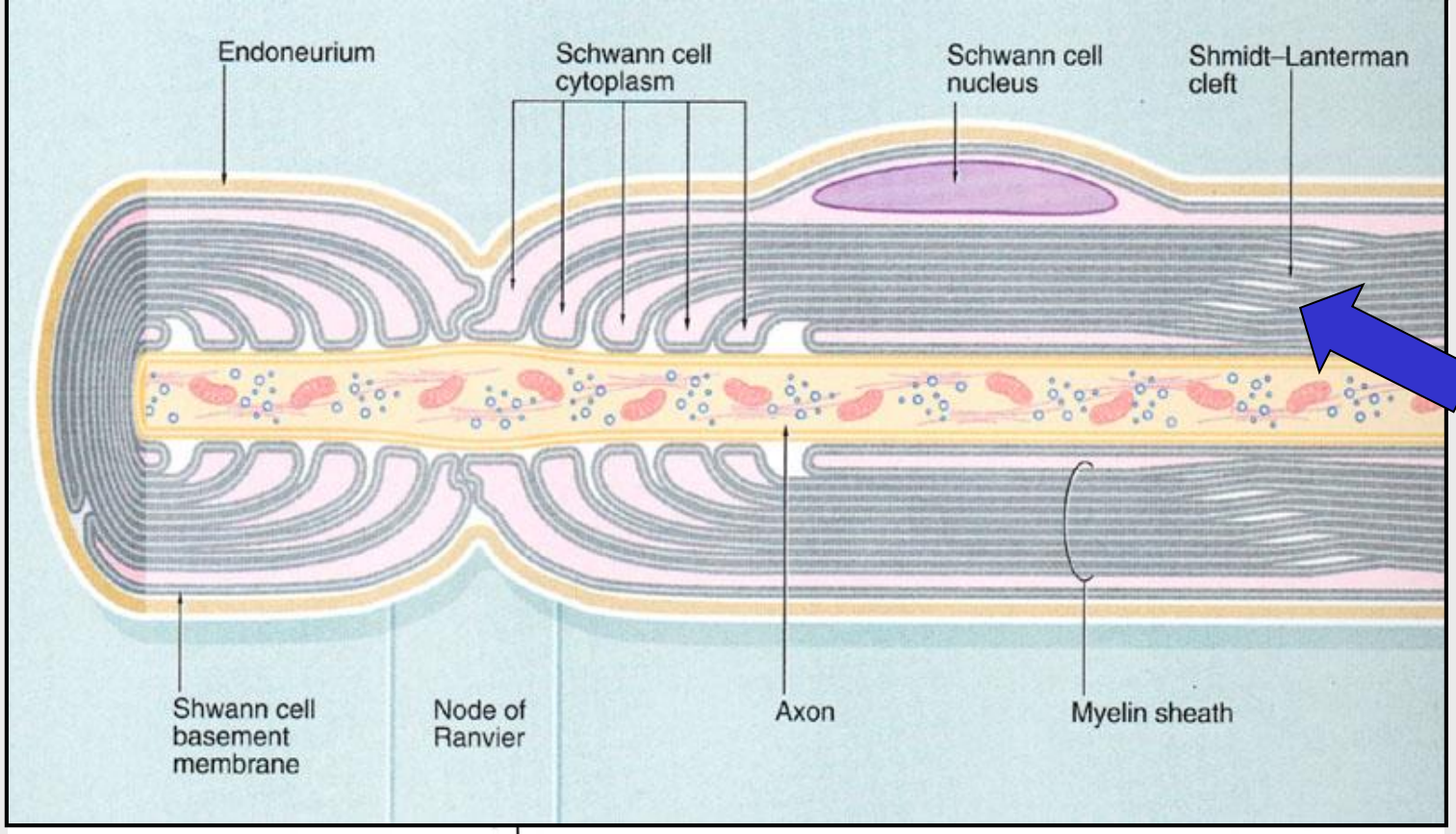

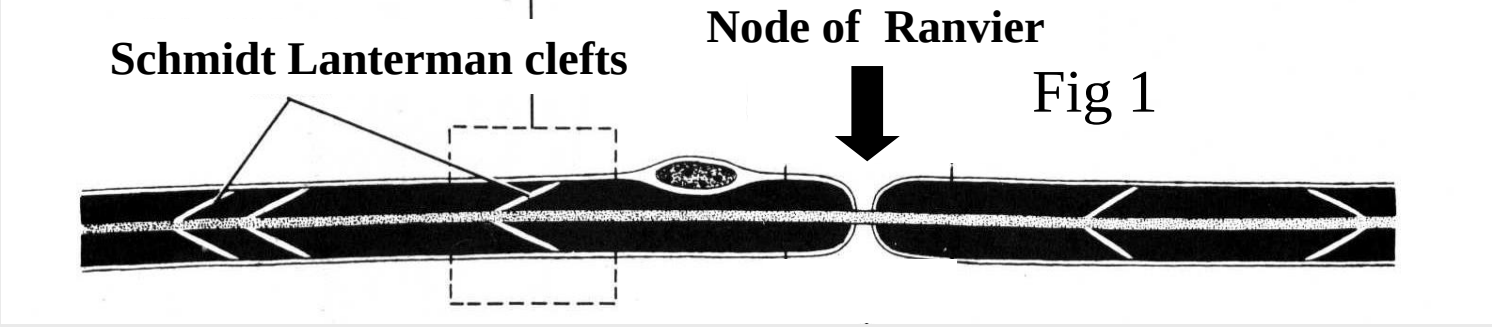

Fig 1

Fig 1 shows a myelinated nerve fiber. The node of Ranvier is indicated as well as Schmidt Lanterman clefts which is some cytoplasm of the Schwann cell that is trapped during myelinization. **Fig 2** shows the Schmidt Lanterman clefts.

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Fig 1

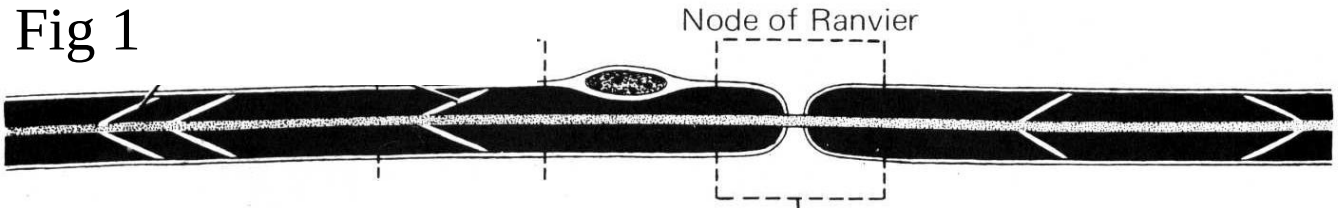
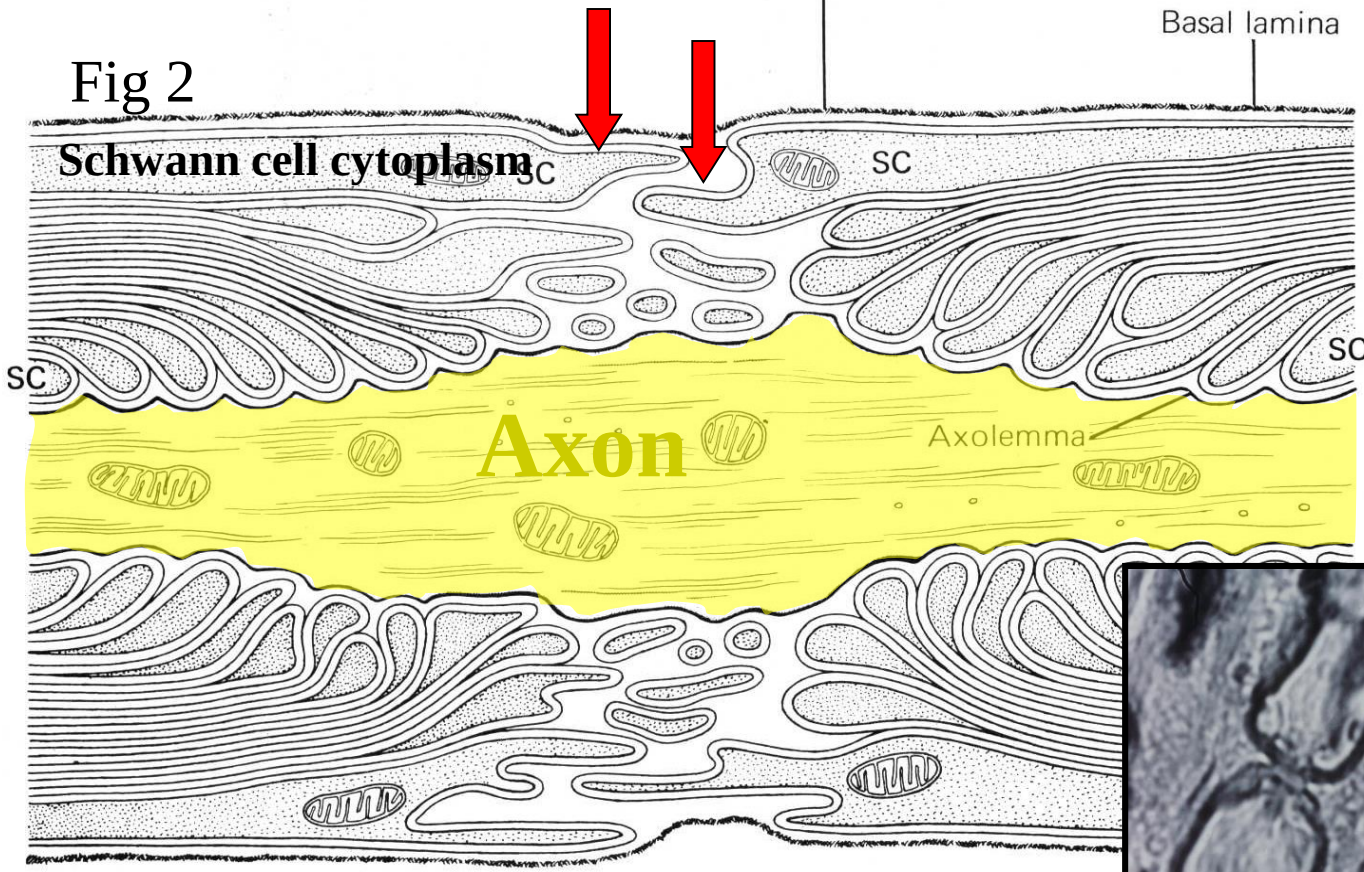


Fig 2



(Junqueira et al, 1986).

Fig 1 shows the myelinated nerve fiber with a node of Ranvier. **Fig 2** shows the ultrastructure of the node. Notice the **interdigitating processes** ⬇ ⬇ of the Schwann cell. The lower right hand corner shows a an electromicrograph of a node of Ranvier.

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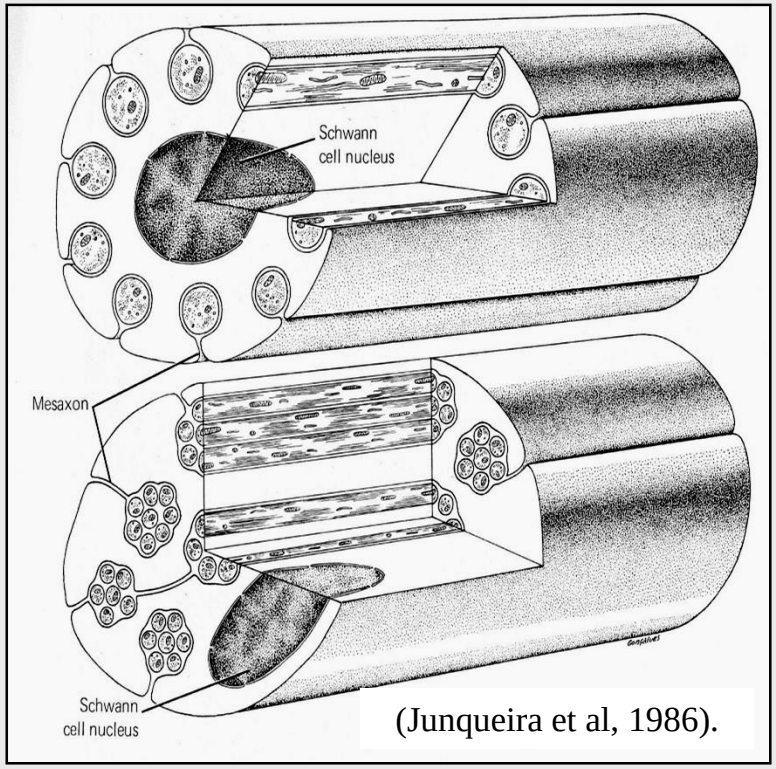
NON-MYELINATED NERVE FIBERS

- Non-myelinated nerves are found in **both** the CNS and PNS e.g. **Postganglionic fibers** of the **autonomic** nervous system are non-myelinated.
- The axons are enclosed in simple **clefts** of oligodendrocytes or Schwann cells. Each Schwann cell may **enclose several** non-myelinated axons.
- A **single** or a **group** of axons may be enclosed in a **single** invagination of Schwann cell
- Unmyelinated axons generally have a **smaller** diameter than myelinated axons



(Junqueira et al, 1986).

Non Myelinated fibers outside the central nervous system invaginate the Schwann cell, forming a mesaxon but the mesaxon does **not roll** around the fiber and therefore does not form myelin.

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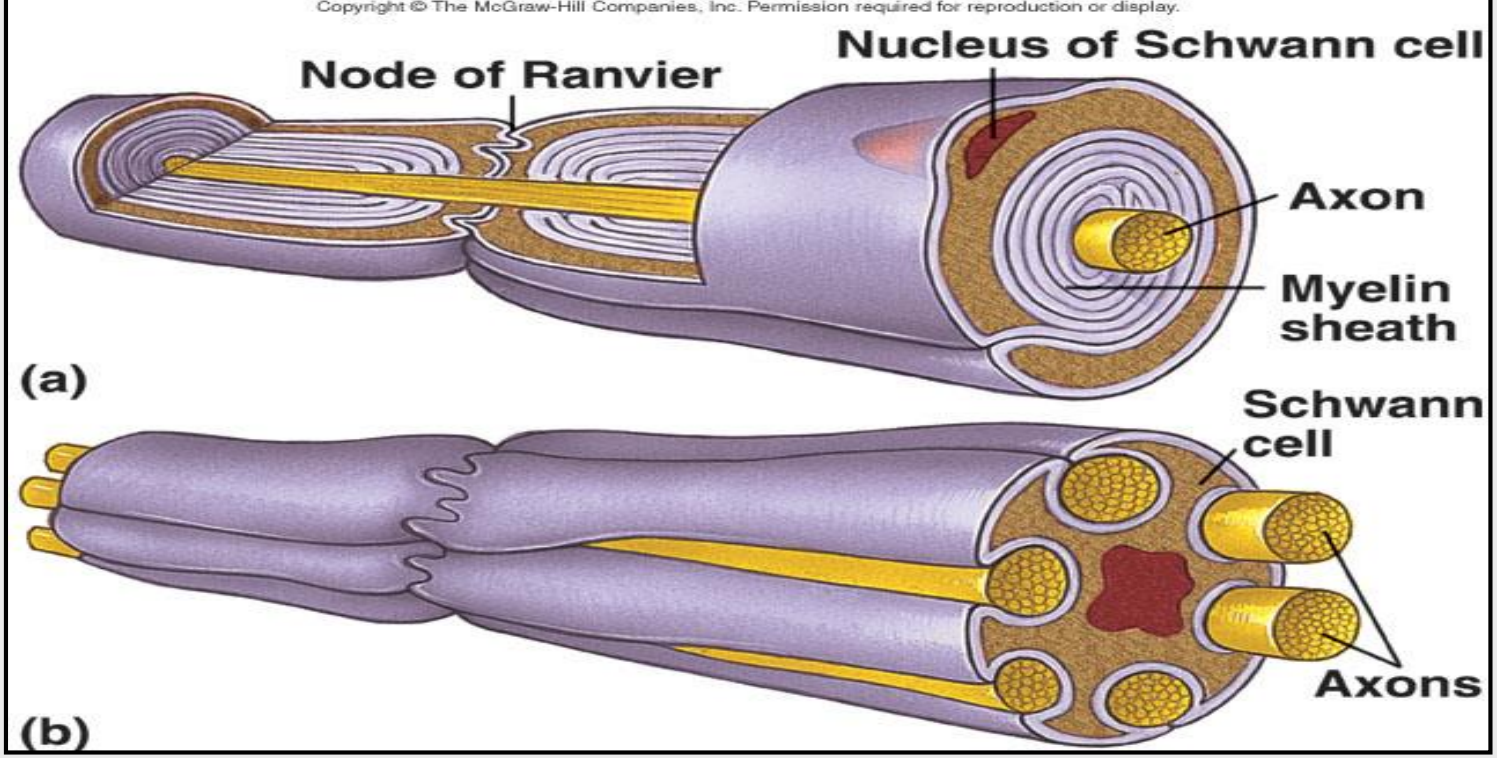
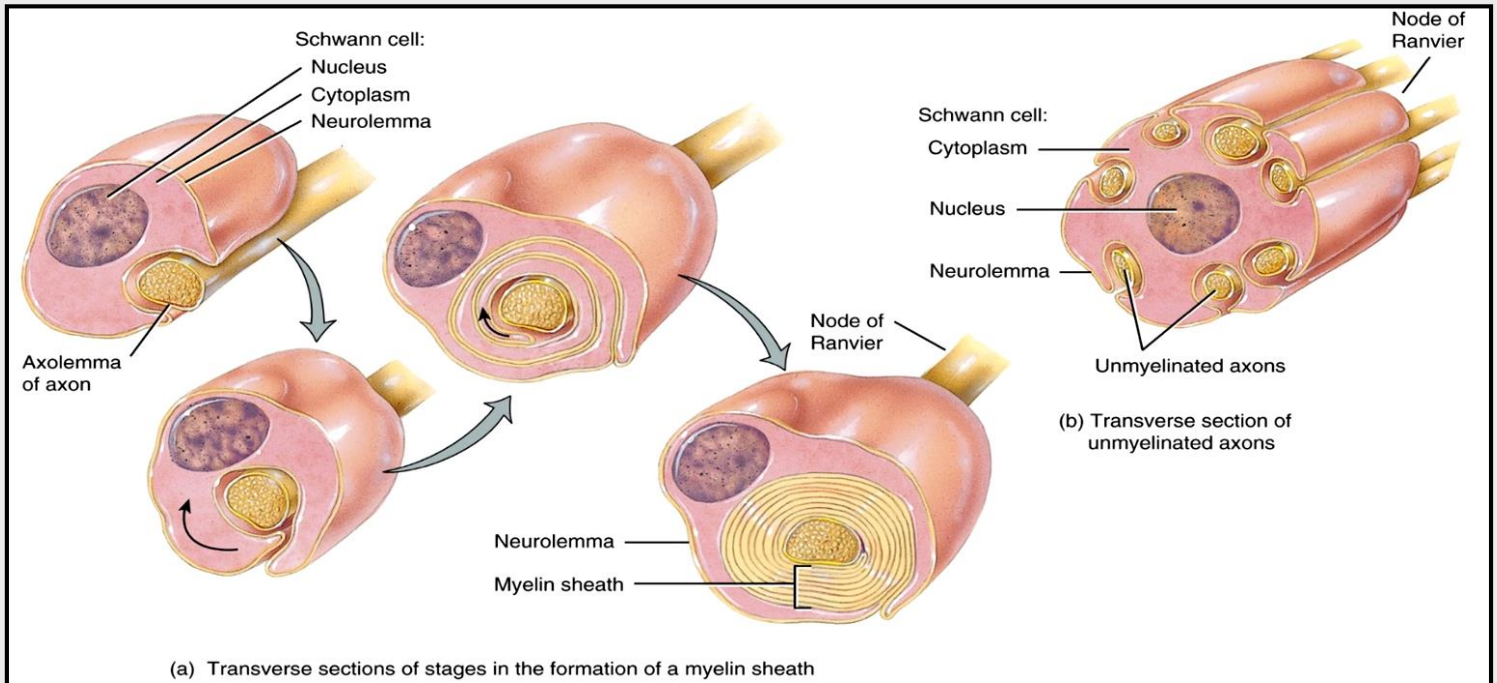
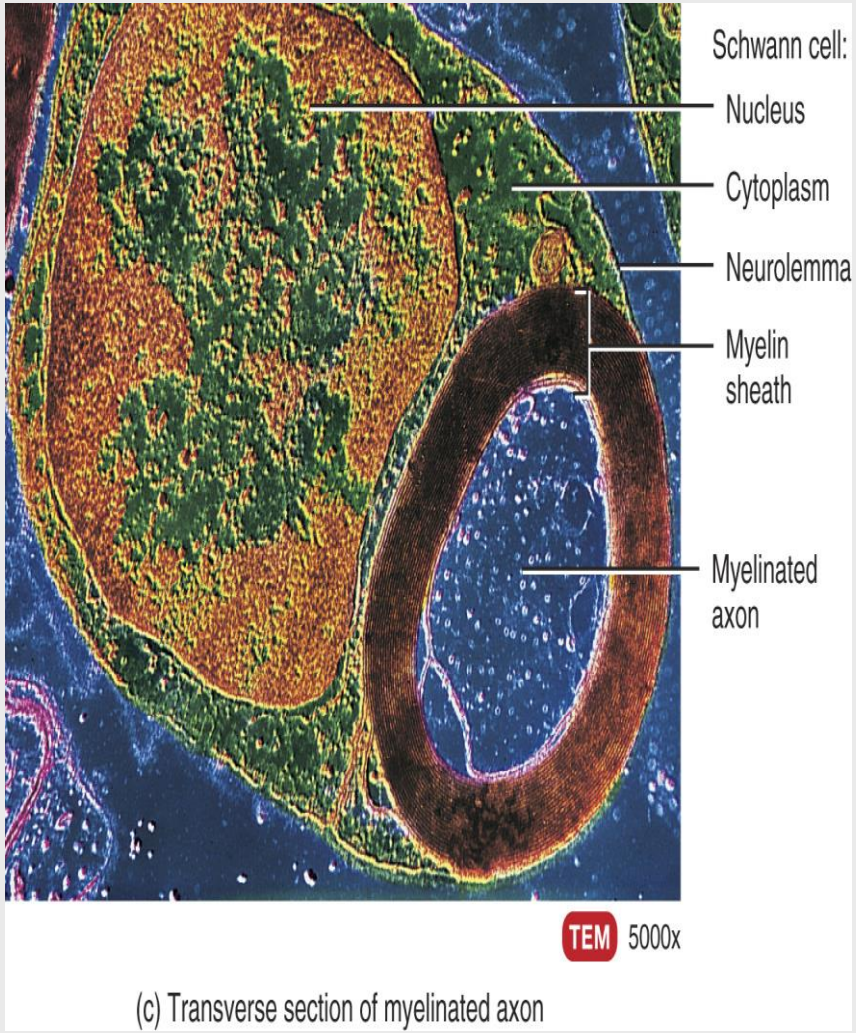
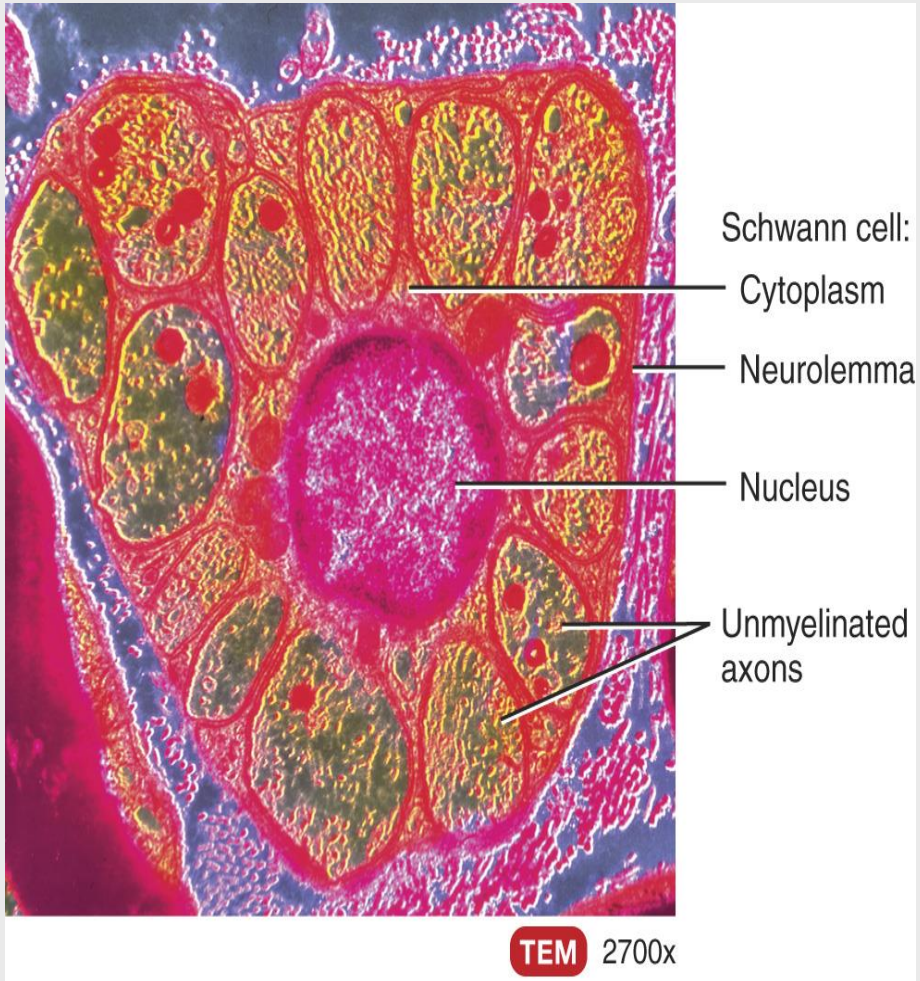




(a) Transverse sections of stages in the formation of a myelin sheath



(c) Transverse section of myelinated axon



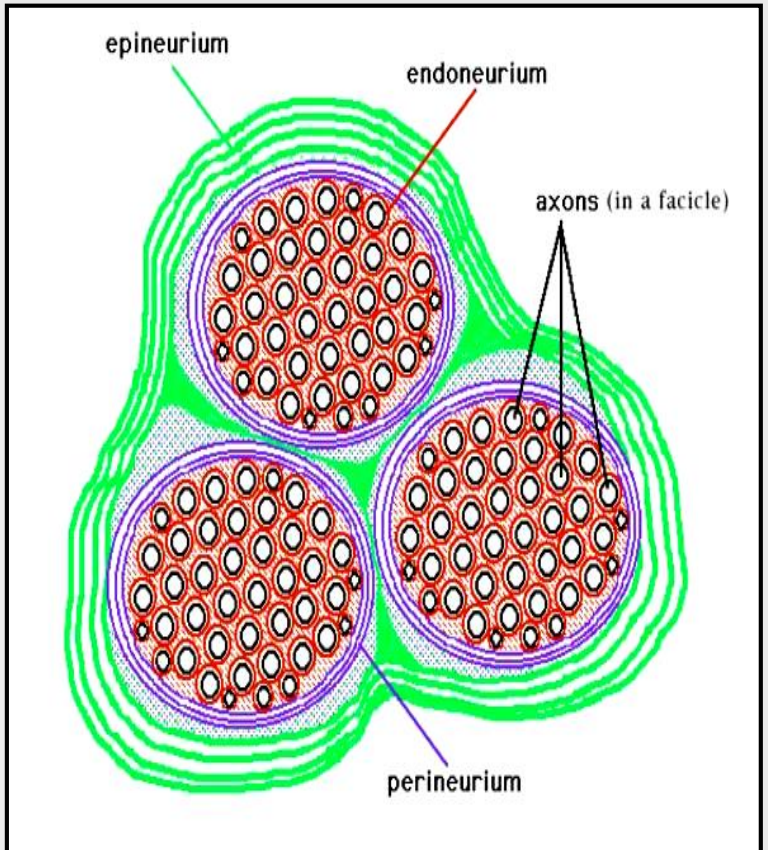
(d) Transverse section of unmyelinated axons

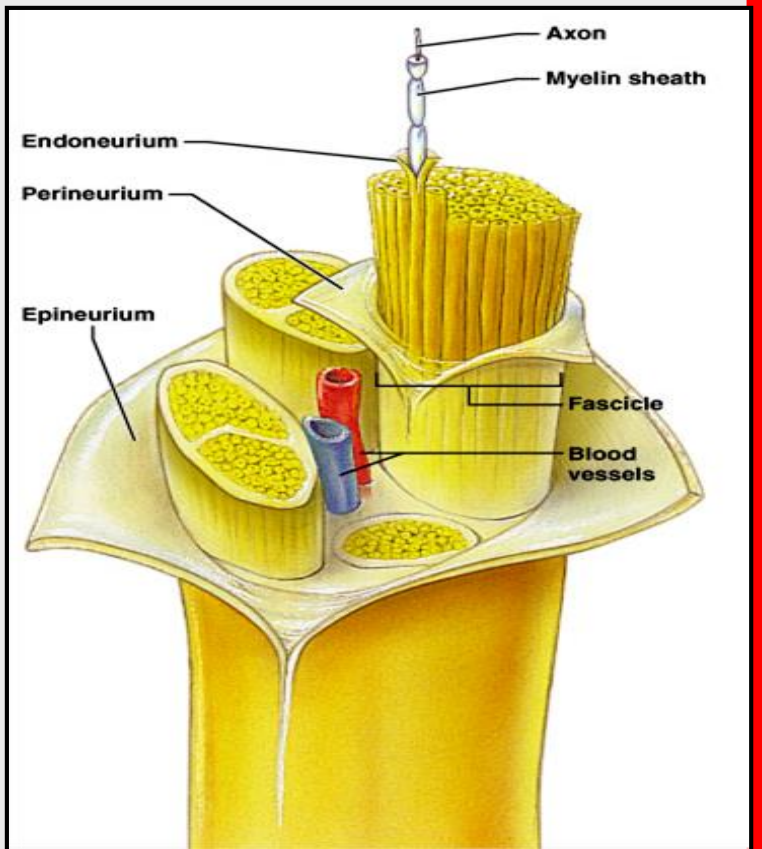
Connective Tissue of Peripheral Nerves

Examination of a peripheral nerve shows a thin connective tissue layer surrounding each individual fiber. This is the **endoneurium** (also known as the **Key and Retzius sheath**).

Fibers are grouped in bundles (**fascicle)**, which are also surrounded by a connective tissue layer, known as the **perineurium**.

The **epineurium** is a more extensive dense connective tissue that surrounds and binds together nerve **fascicles** into a common **bundle**





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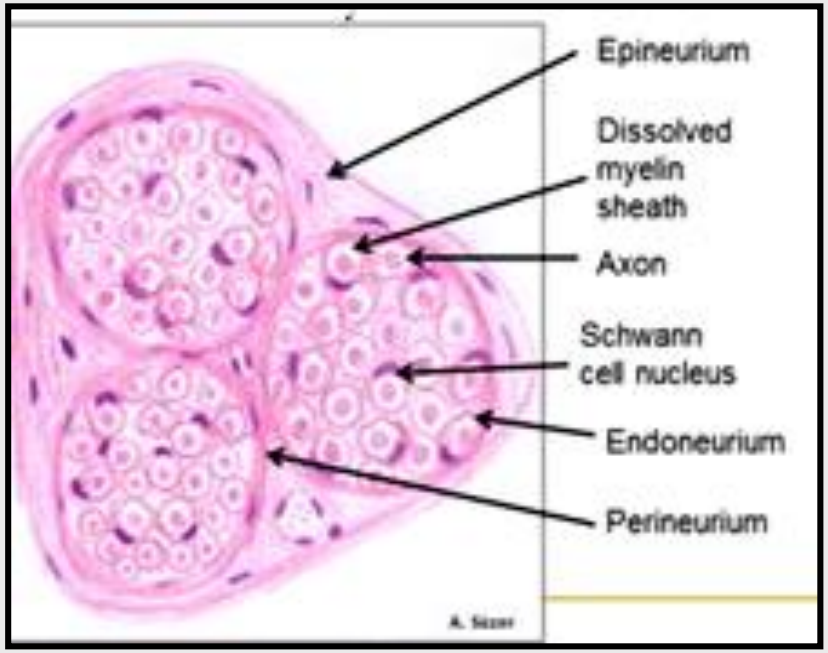
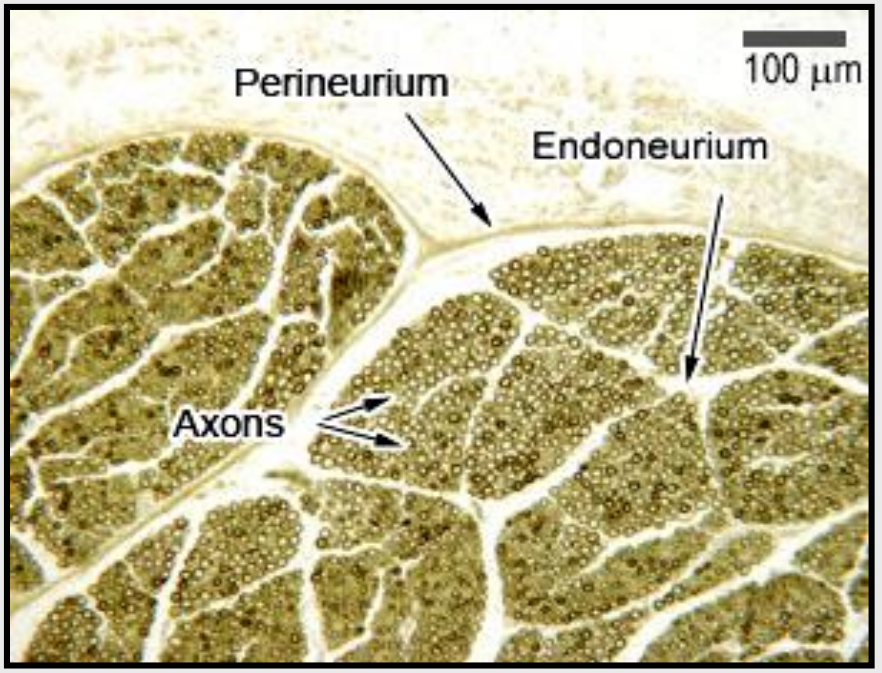
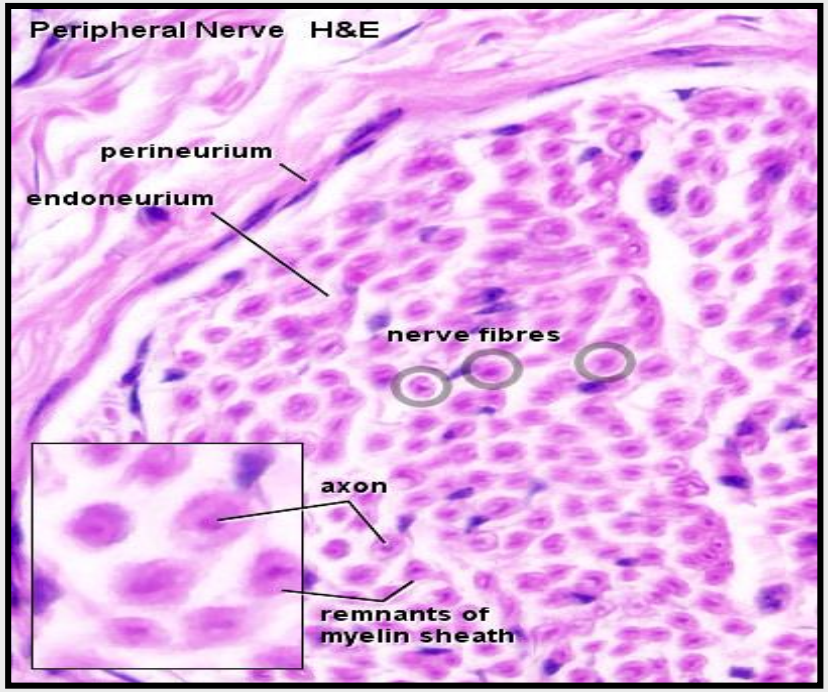
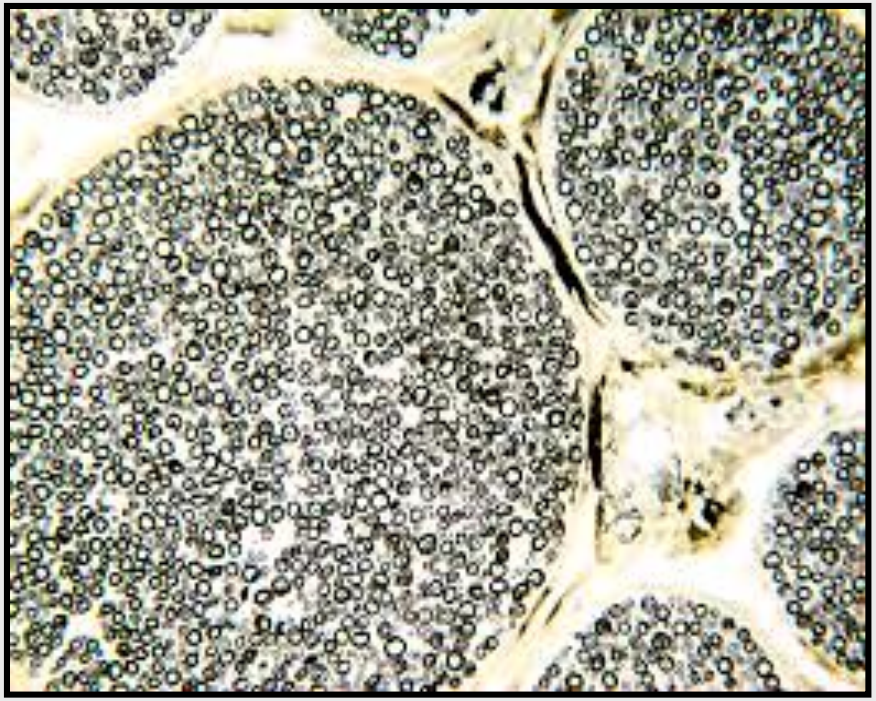
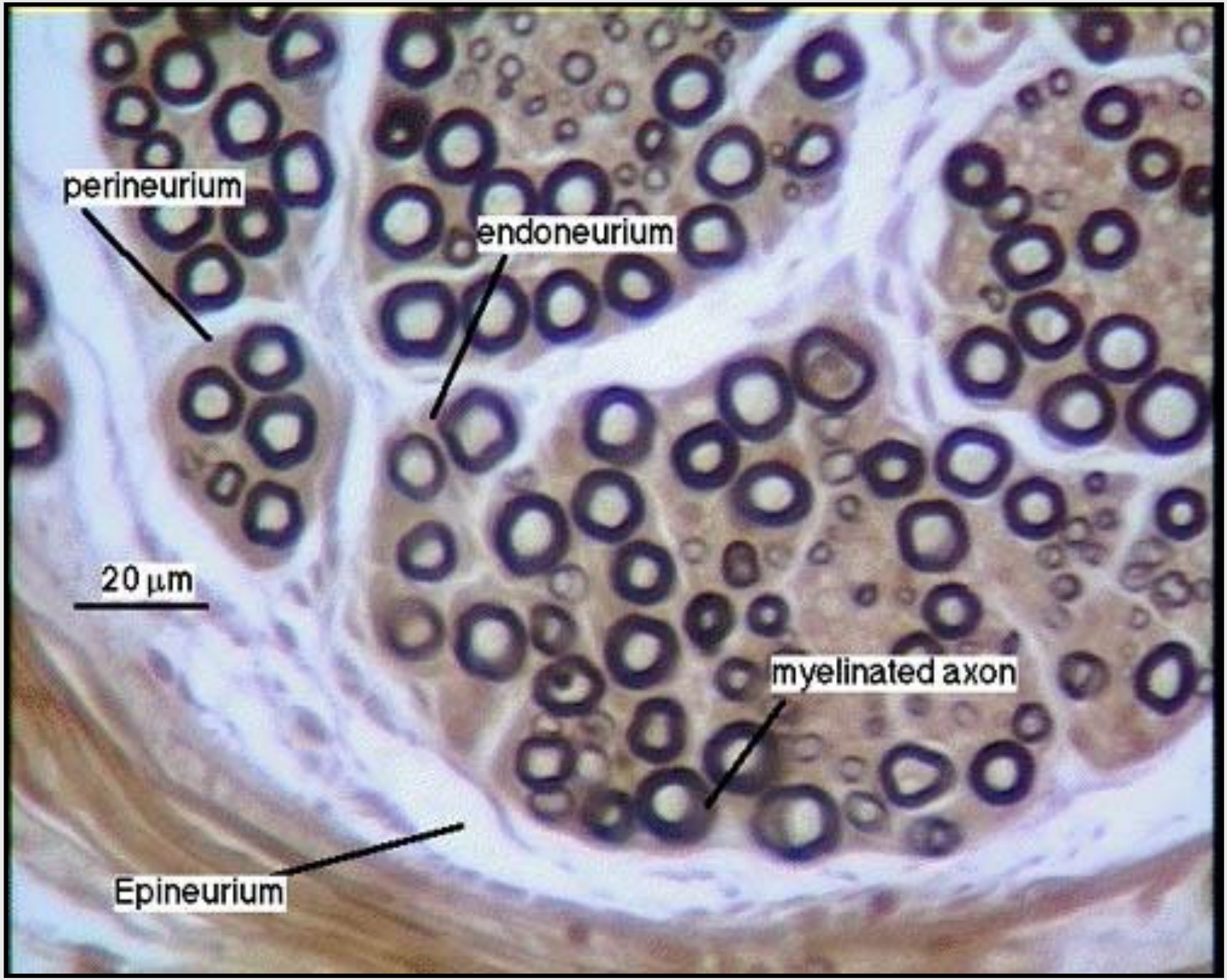

Epineurium
Dissolved myelin sheath
Axon
Schwann cell nucleus
Endoneurium
Perineurium


Perineurium
100 µm
Endoneurium
Axons


Peripheral Nerve H&E
perineurium
endoneurium
nerve fibres
axon
remnants of myelin sheath




perineurium
endoneurium
20 μm
myelinated axon
Epineurium

Axonal transport system

- Substances are synthesized in the cell body and require transport to axon and dendrites via the **axonal transport system** which serves as a mode of intracellular communication
- The axonal transport involves **neurotubules** and **neurofilaments**.
- It is bidirectional

Anterograde transport, from the cell body to the periphery

Retrograde transport, from axons and dendrites to the perikaryon. Retrograde transport is the pathway followed by **toxins** and **viruses** that enter the CNS e.g. **polio** in the ventral columns and **syphilis** in the dorsal columns.

- It is fast or slow
  - **Slow axonal transport** system, from the cell body to the terminals in a **single direction** (**anterograde**) at a rate of about **0.2-4mm/ day**. This system conveys components needed for growth and regeneration of the axon.
  - **Fast axonal transport** system, which occurs in **both directions (**anterograde and retrograde), at a rate of about **20-400 mm/ day**. This system involves transport of enzymes needed for synthesis of neurotransmitters within the terminal synapse.

Supporting cells of the nervous tissue

- Supporting cells are **nonconducting** cells that are in intimate physical contact with neurons
- Supporting cells provide
  - **Physical support** (protection) for delicate neuronal process
  - **Electrical insulation** for cell bodies and processes
  - **Metabolic exchange** pathways between the vascular system and the nervous system
  - Participation in the blood-brain-barrier (e.g. astrocytes**)**
  - **Repair** processes following damage or injury to nerves

Supporting cells differ from neurons:

- Supporting cells have **no action potentials** and cannot transmit nerve impulses
- Supporting cells **are able to divide** (and are the source of tumors of the nervous system)
- Supporting cells **do not form synapses**
- Supporting cells **form the myelin sheathes** of axons.

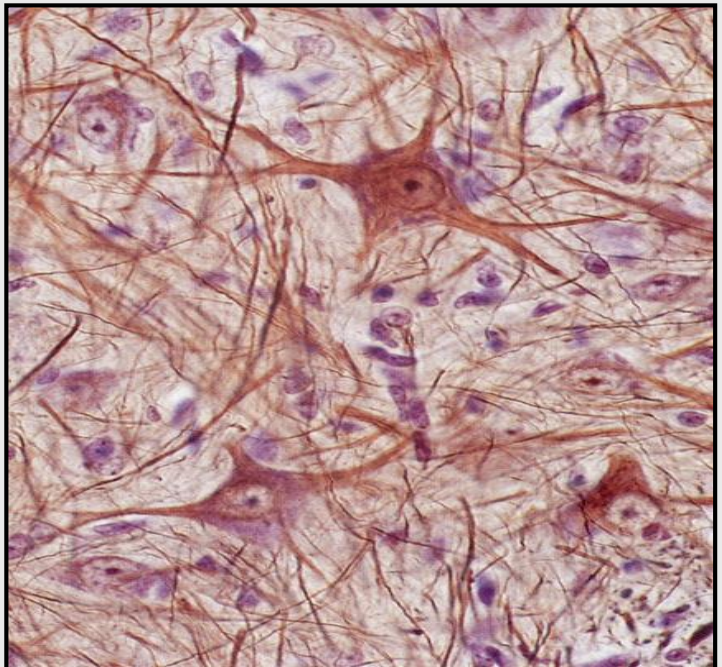
Supporting cells of the PNS

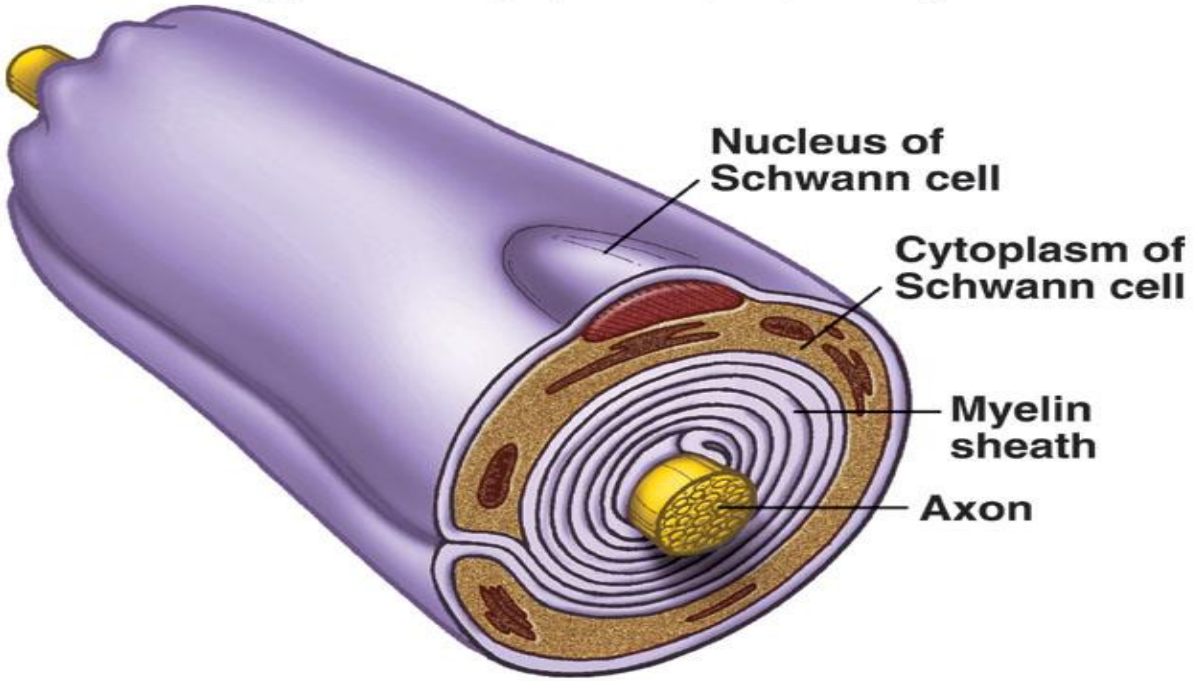
Schwann cells (neurilemmal cells)

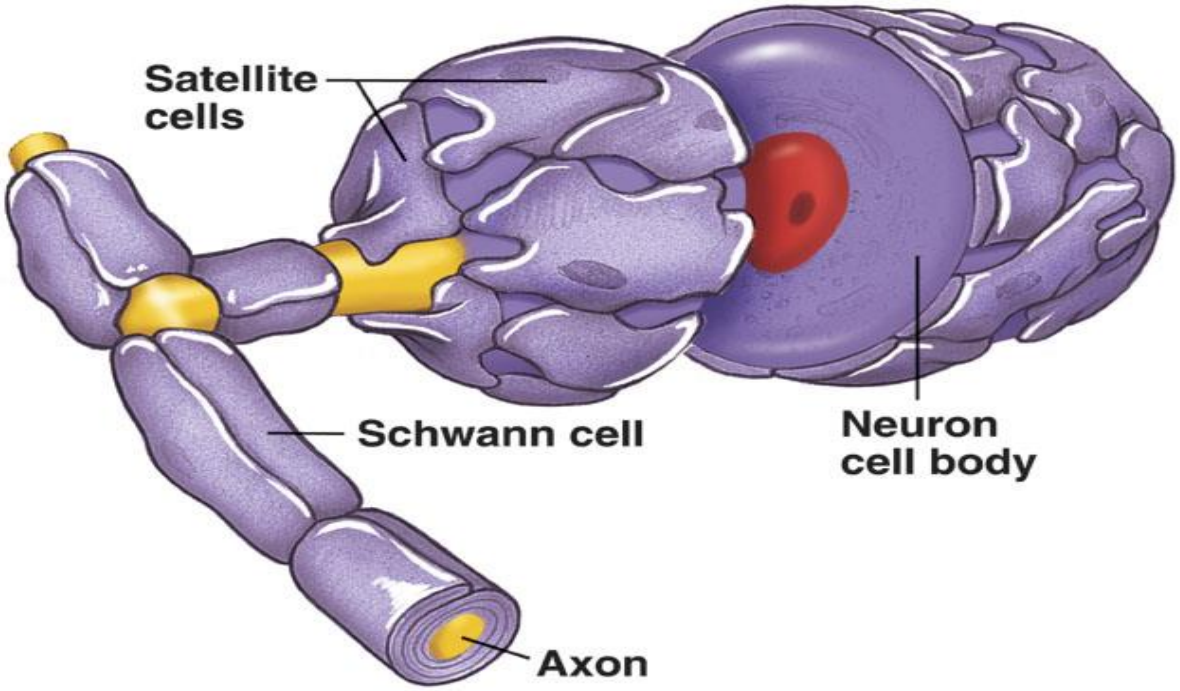
- Responsible for the **formation of myelin** which provides insulation for the axon
- The myelin sheath is composed of multiple layers of Schwann cell membrane wrapped concentrically around the axon forming longitudinal segments (**internodal segments**)
- The junction where two adjacent Schwann cells meet is called **node of Ranvier** (no myelin)
- Myelin is **absent** from dendrites, axon hillock, node of Ranvier and the terminal ends or synapses

Satellite cells

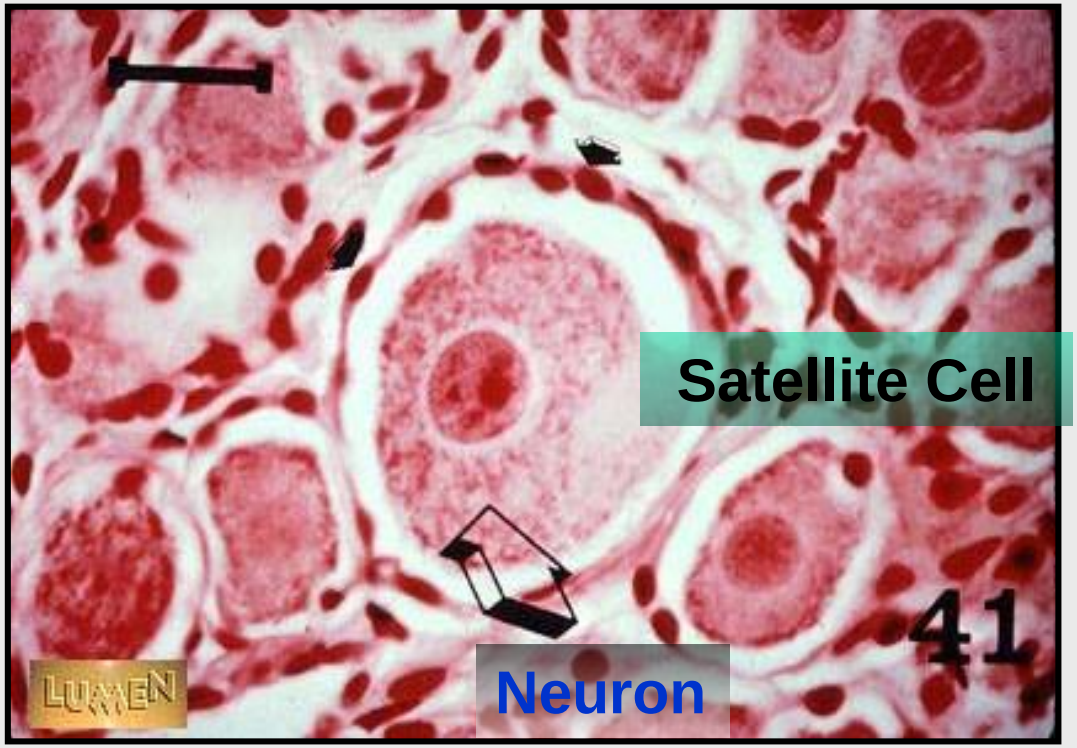
- Surround the neuronal **cell body**, small cuboidal cells
- Provide **electrical insulation** and pathway for **metabolic** exchanges
- They do not form **myelin**

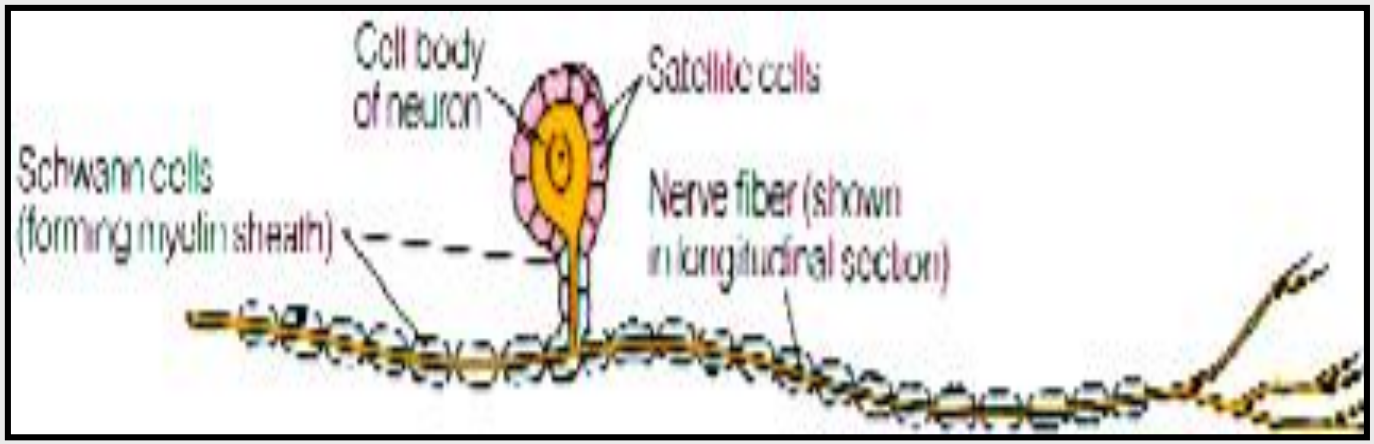






Satellite Cells





Supporting cells of the CNS (Neuroglia or glial cells)

- There is very little connective tissue in the CNS, and the structural support for neurons comes from neuroglia and their processes.
- There are **4 basic types of neuroglia**, based on morphological and functional features.
  - **Astrocytes (Astroglia)** the cells that provide physical and metabolic support
  - **Oligodendrocytes (Oligodendroglia)** the myelin forming cells
  - **Ependymal cells** the lining cells
  - **Microglia** the phagocytic cells

} **large cells** and are collectively known as **Macroglia.**

- It is estimated that for every neuron there are at least **10 neuroglia**
- Neuroglia are much smaller than the neurons they only occupy about **40-50%** of the total volume of nerve tissue.

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Astrocytes (Astroglia)

- These are present only in the CNS and are the **largest** of the neuroglia.
- They have **many long processes**, **star-shaped** cells. Their processes are often in contact with a blood vessel (***perivascular foot processes***) and contribute to the **blood-brain-barrier**.
- Astrocytes provide physical and metabolic **support** to the neurones of the CNS.
- They participate in the **maintenance** of the composition of the **extracellular fluid**.
- They may be involved in the **removal** of transmitters from synapses and the metabolism of transmitters.
- Astrocytes are also the **scar-forming** cells of the CNS.
- Because of their number and their long processes, the astrocytes appear to be the **most important** supporting elements in the CNS.
- There are two kinds of astrocytes:

. **Protoplasmic astrocytes (mossy cells)**. These are present in the **grey matter** of the brain and spinal cord. Their processes are relatively **thick**.
. **Fibrous Astrocytes** found in **white** matter with **thin** processes

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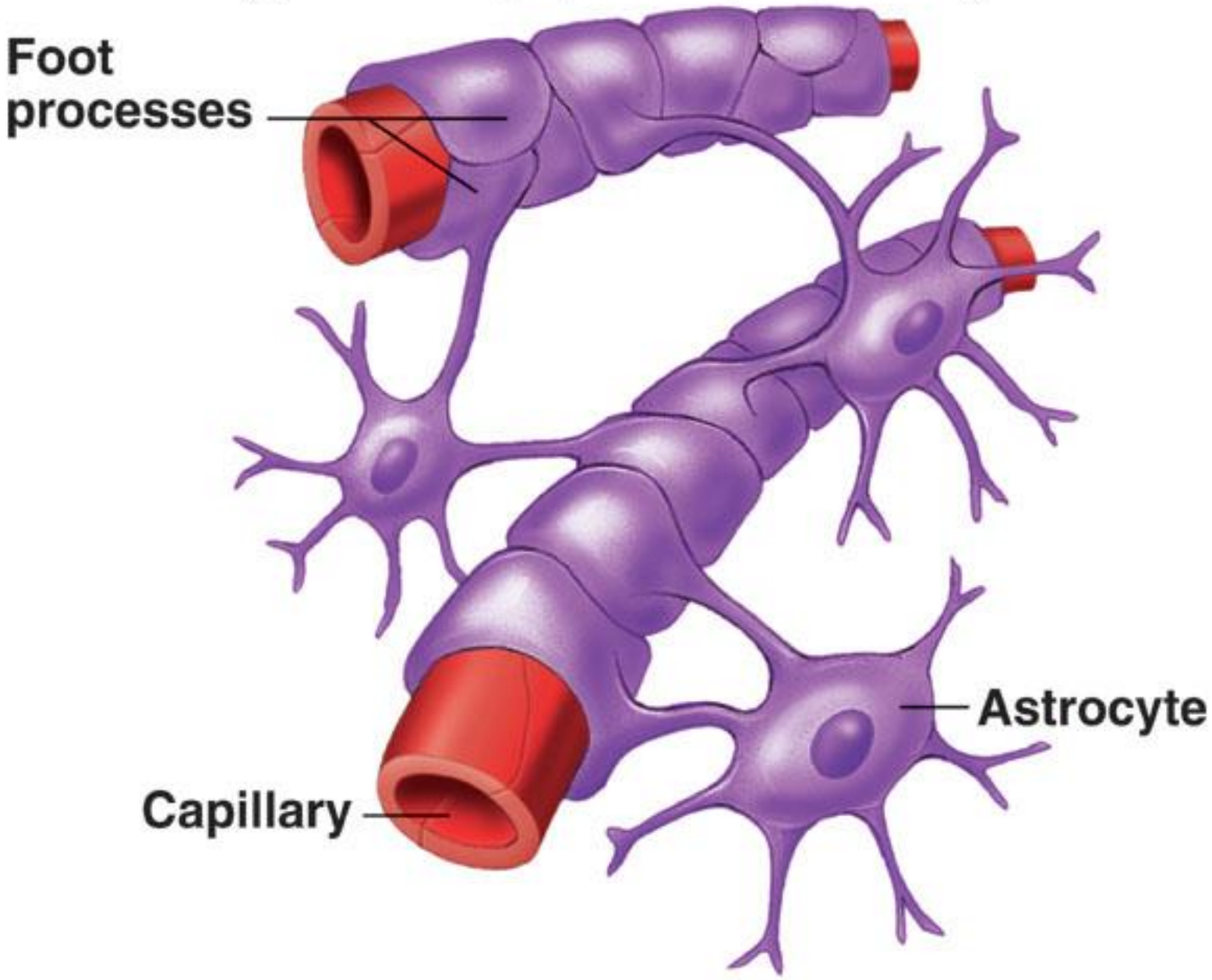

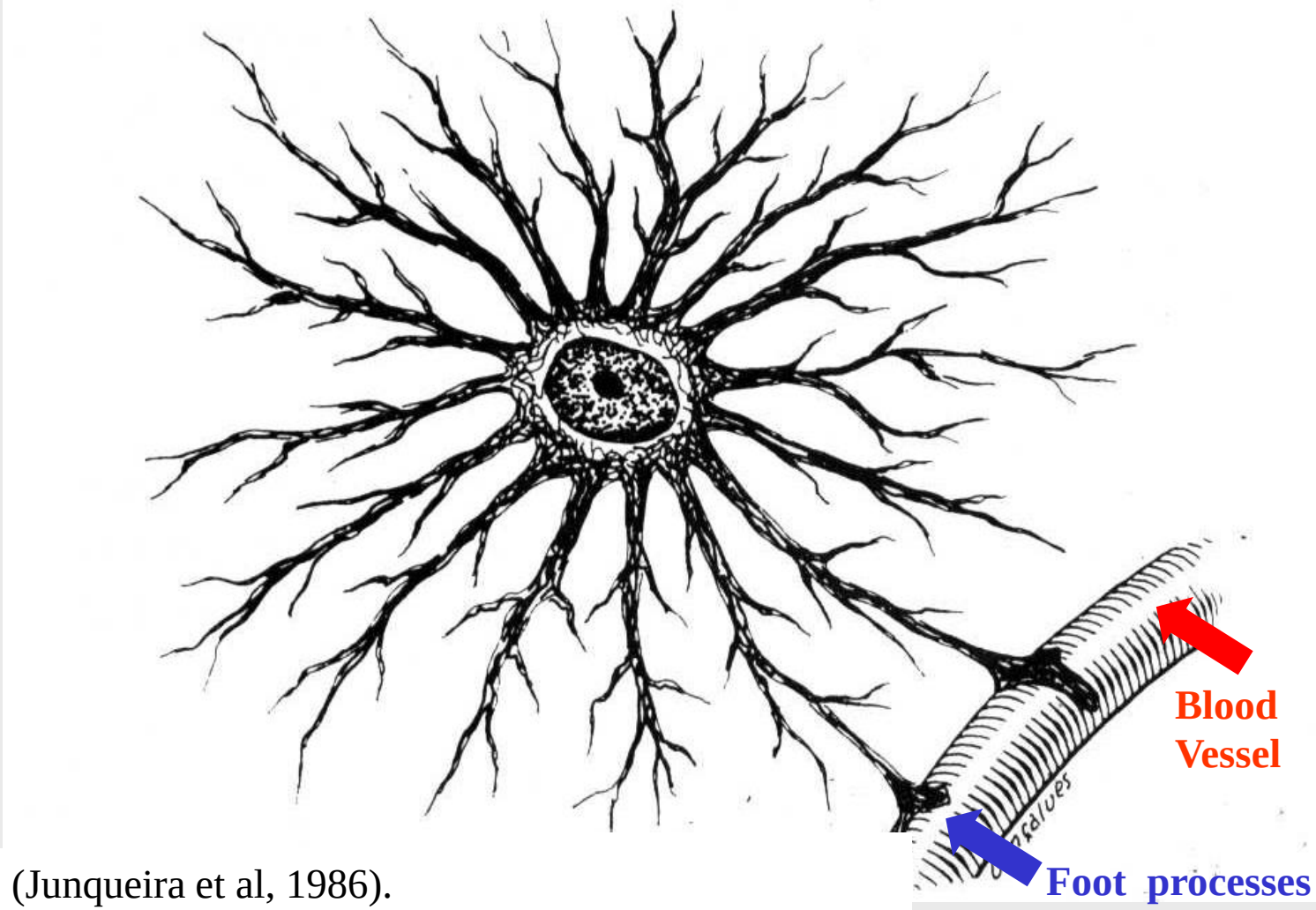

(Junqueira et al, 1986).

Protoplasmic astrocytes:

- found in **grey** matter – has **a round** cell body -
- large **oval** nucleus with prominent nucleolus and large **thick** processes
- processes are short but profusely branched
- perivascular and perineurial **foot processes** sometimes referred to as **mossy fibres**

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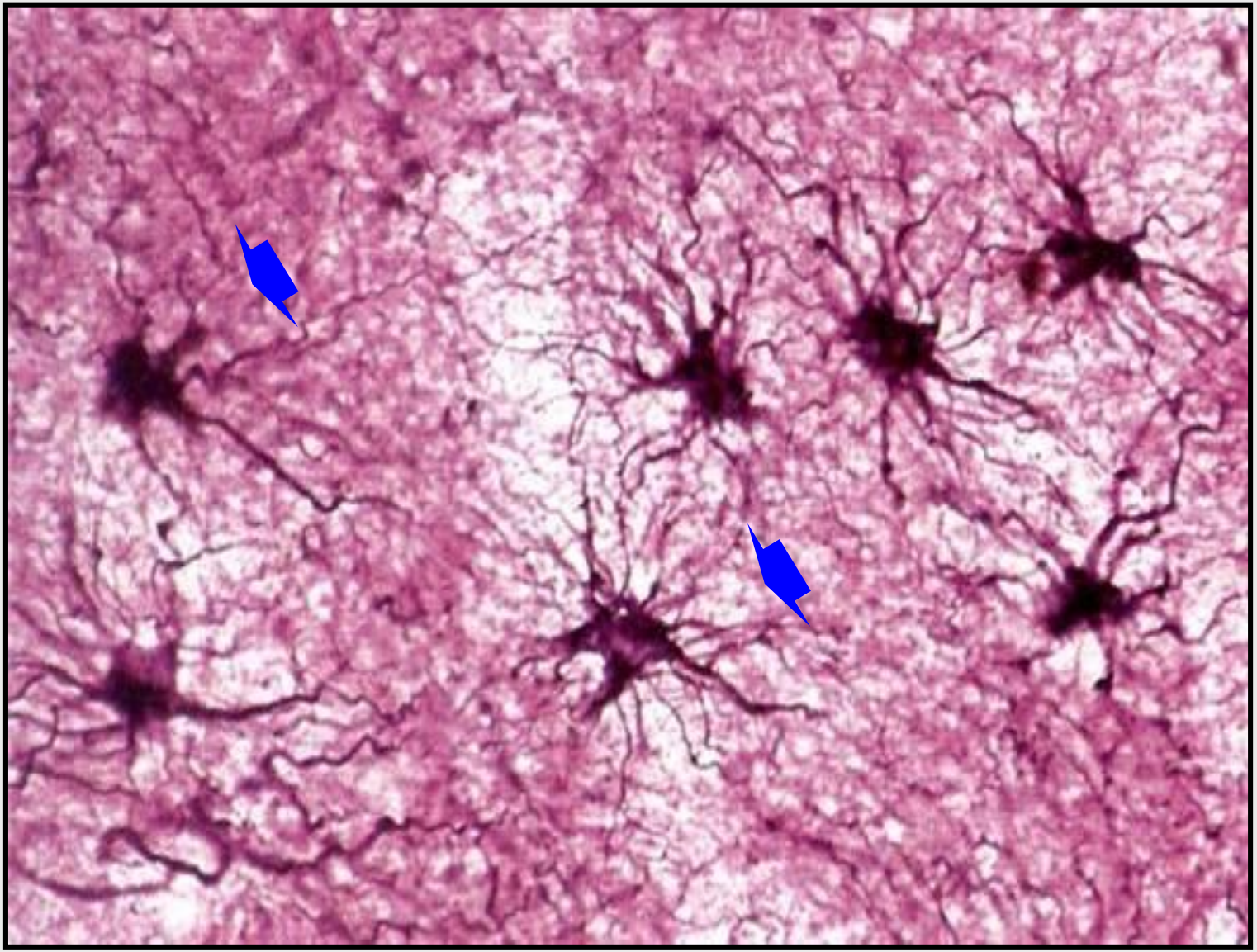

This is a slide of the grey matter of the spinal cord. The ⬇⬇ indicate the **protoplasmic astrocytes.** In the center lies the cell body of a neuron. Notice the big oval nucleus with it's prominent nucleolus.

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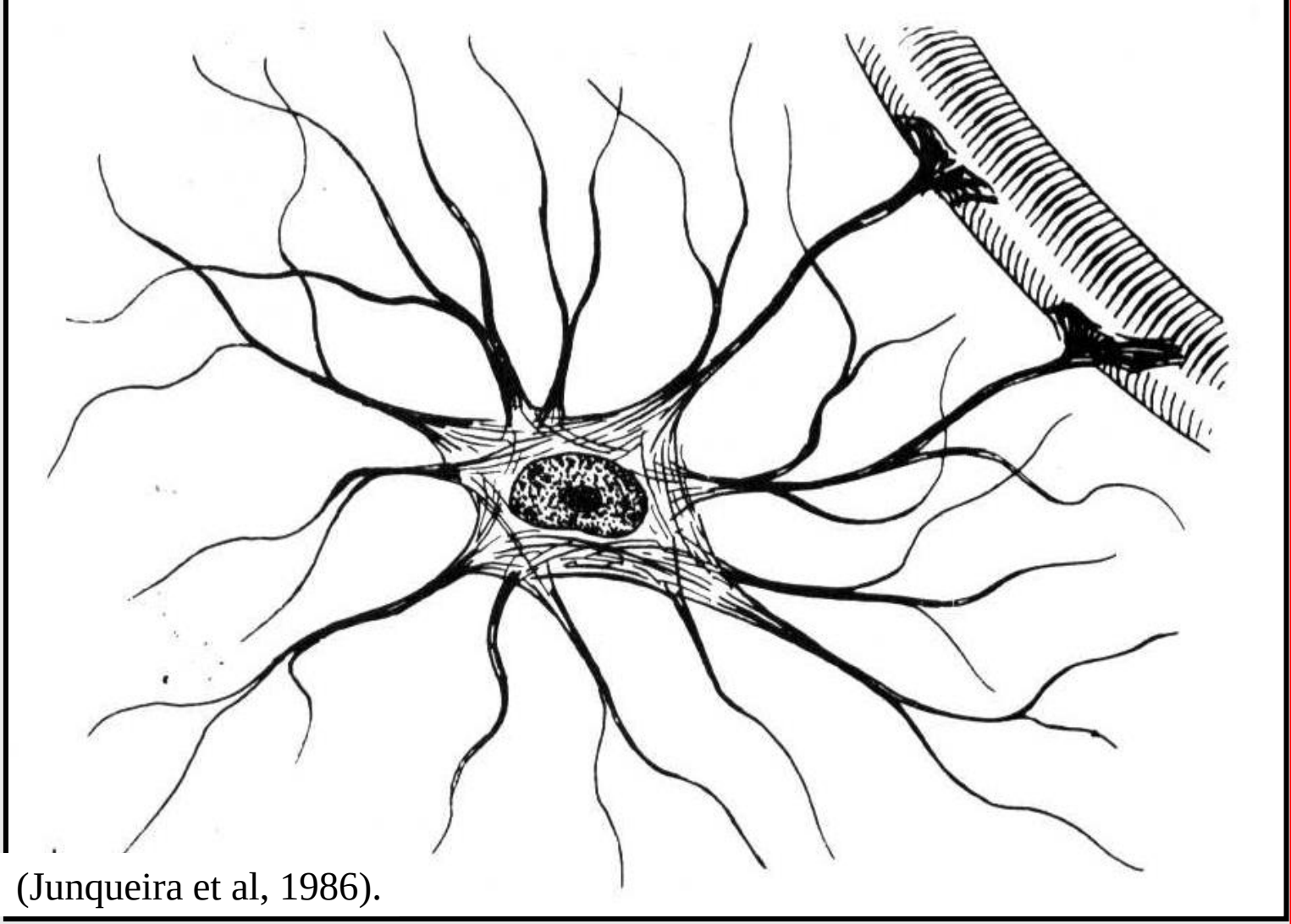

(Junqueira et al, 1986).

Fibrous Astrocytes*:*

- found in **white matter**
- **polymorphic** cells body
- **large oval** nucleus
- **long thin** processes with end feet on blood vessels

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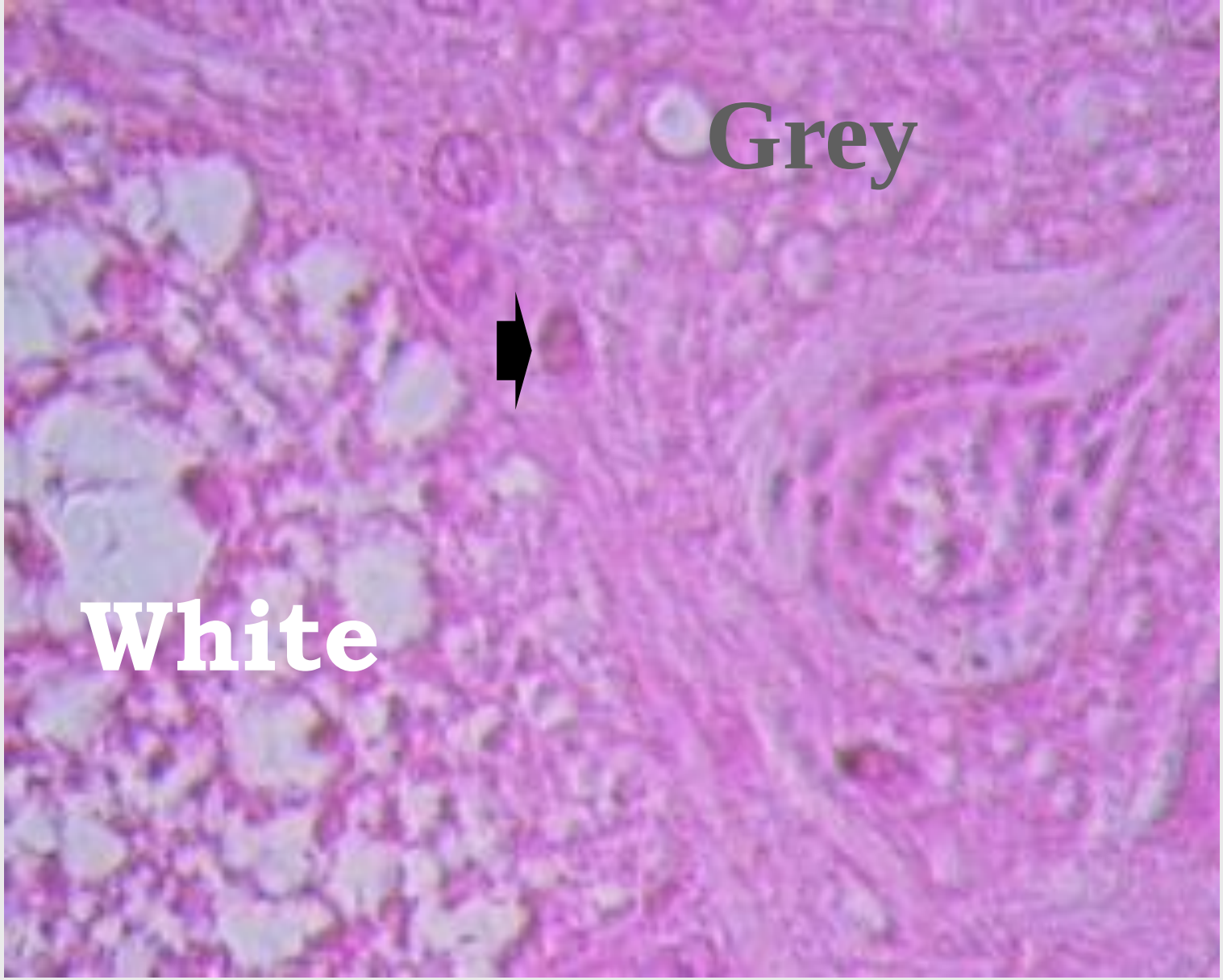

This is a slide of the area where the Grey and white matter of the spinal cord meet.

The ➡ shows a nucleus of an astrocyte that lies on this border and is called the **fibrous astrocyte.**

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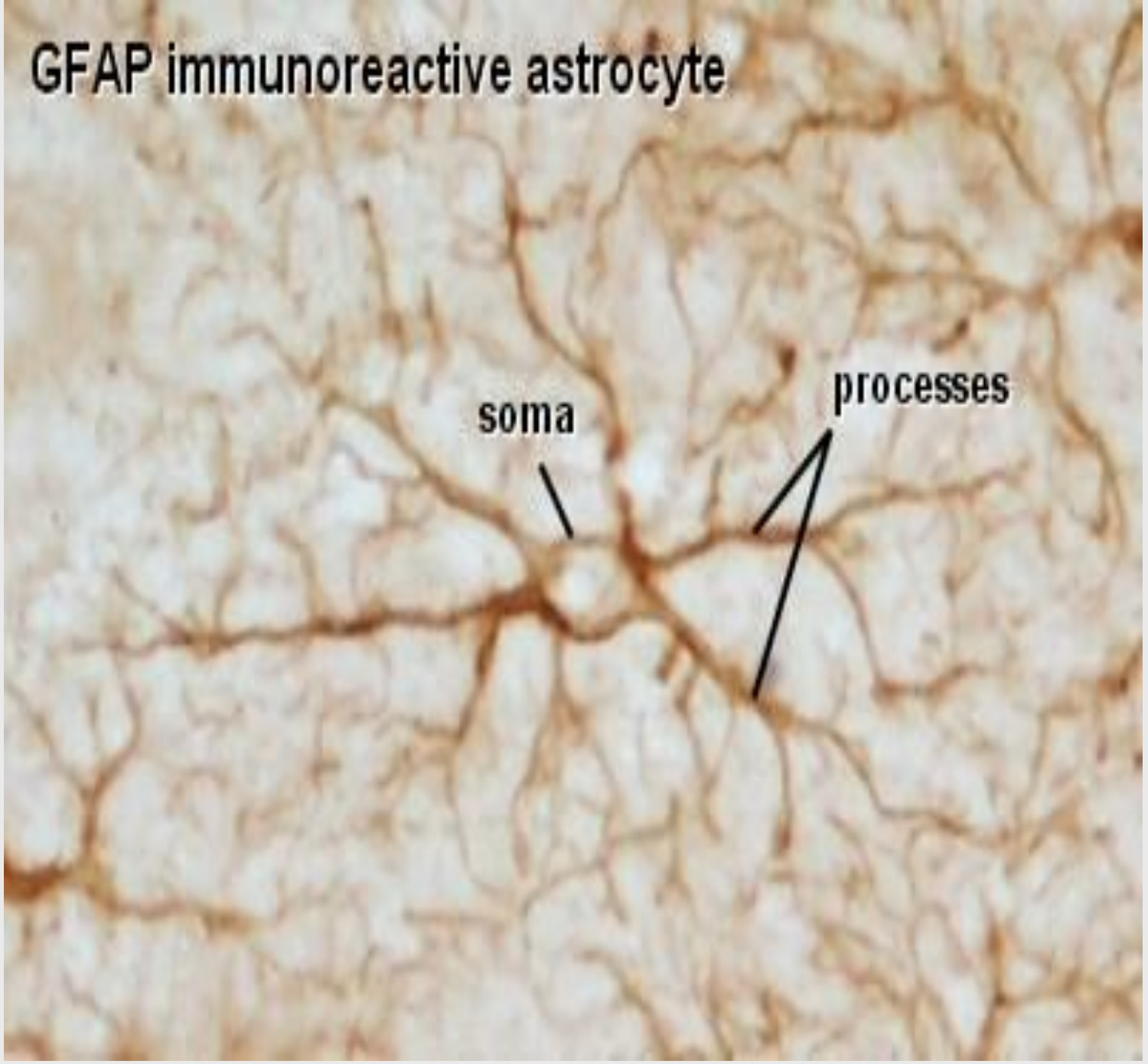

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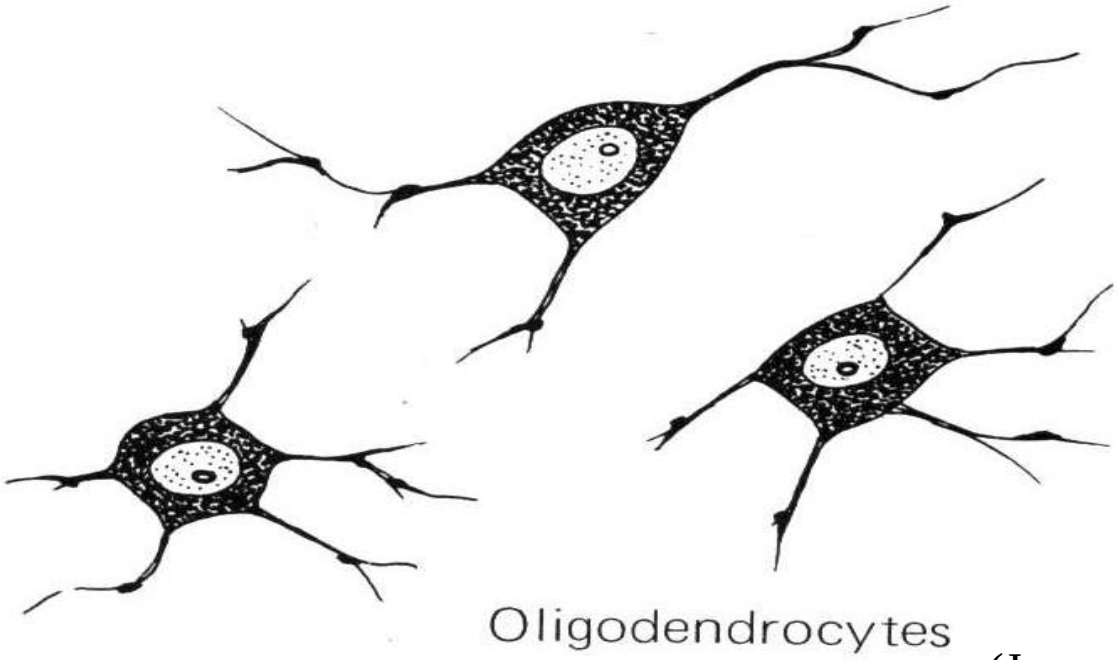
Oligodendrocytes (or oligoglia)

- Have **fewer** and **shorter** processes.
- Oligodendrocytes form **myelin** sheath around axons in the **CNS**
- The functional **homologue** of peripheral Schwann cells.
- Oligodendrocytes may, in contrast to Schwann cells in the periphery, form parts of the myelin sheath around **several** axons via there extended processes.



(Junqueira et al, 1986).

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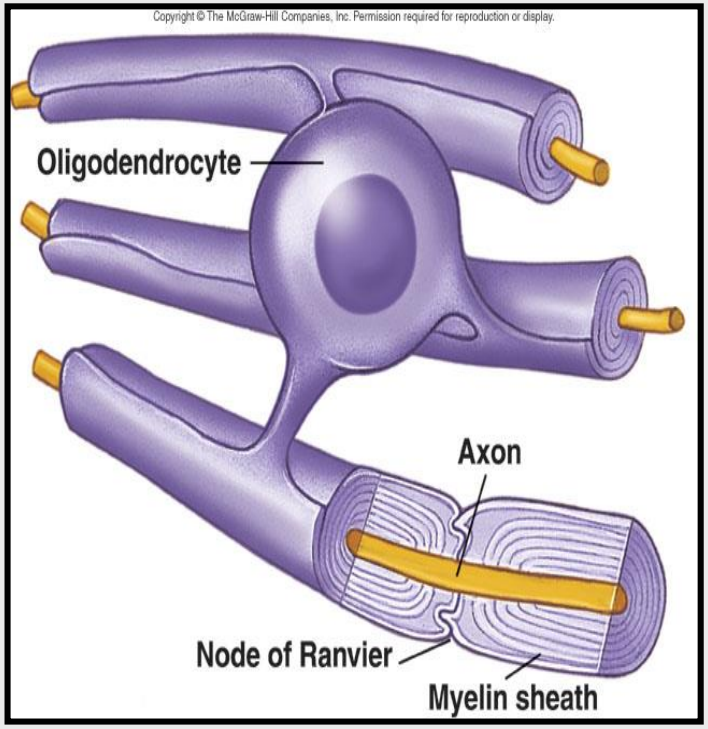
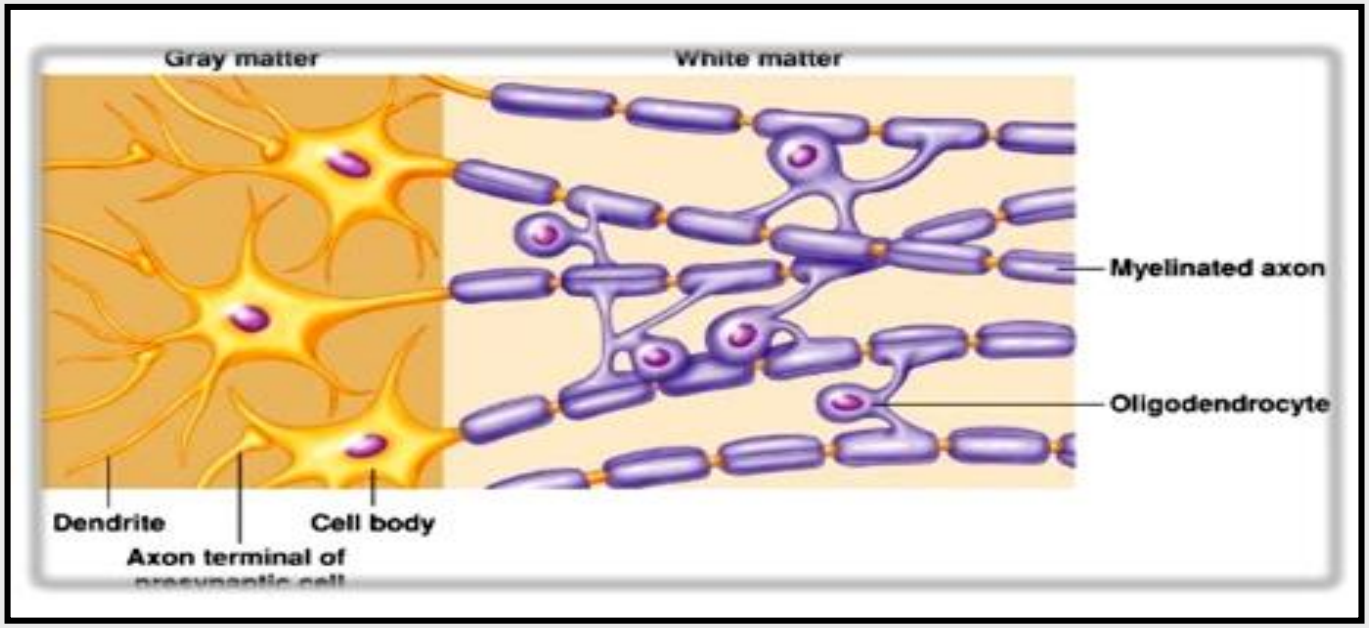


Oligodendrocyte

The oligodendrocyte forms the myelin sheath in the central nervous system (CNS). Notice how one cell sends out processes to form myelin sheaths for a number of fibers.



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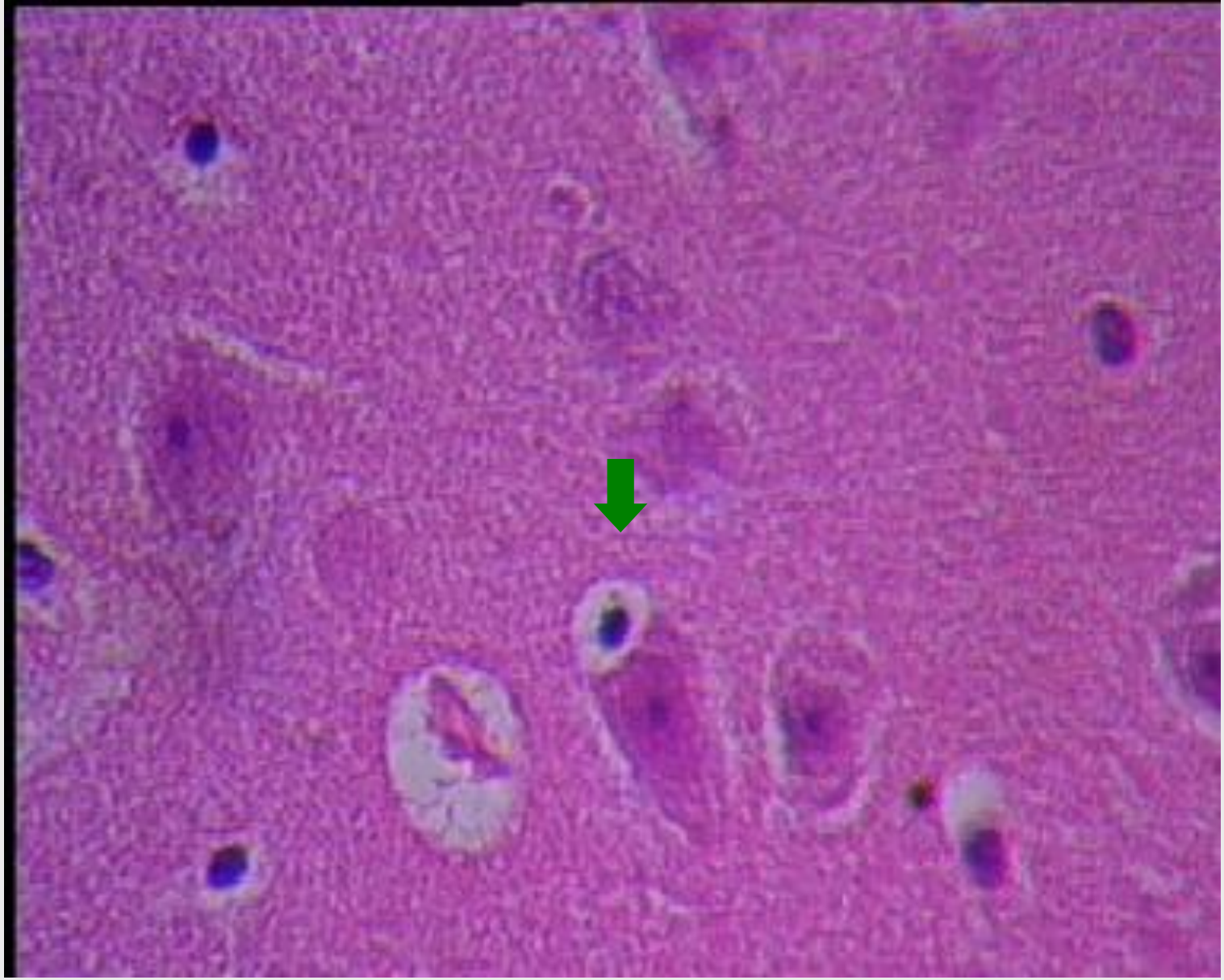

This is a slide from the cerebral hemisphere. The ⬇ shows an **oligodendrocyte** with it's small dark nucleus.

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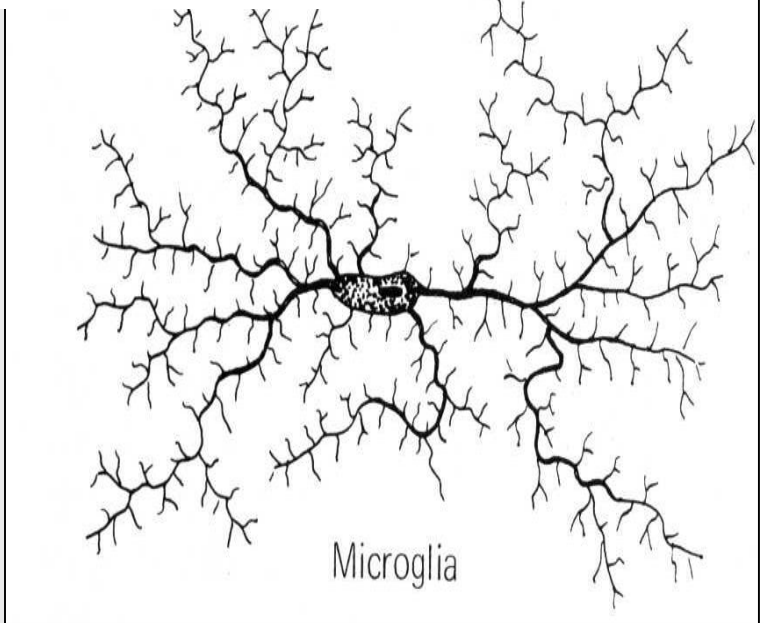
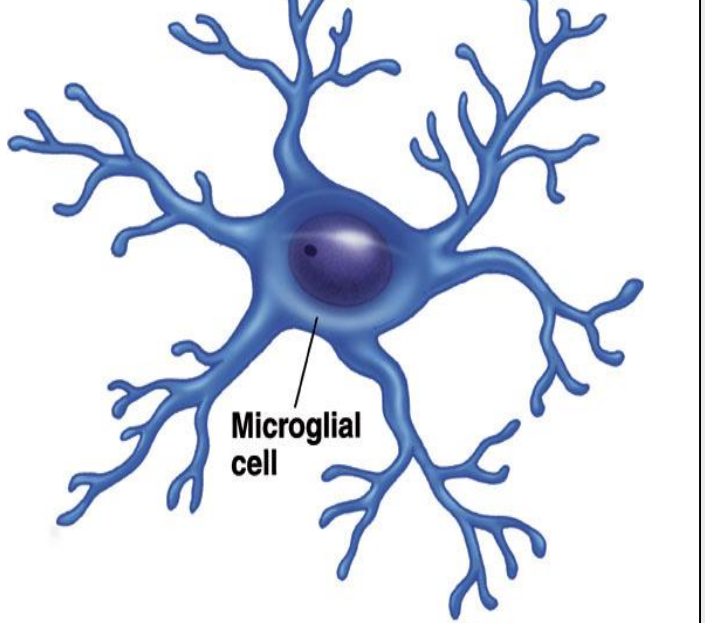
Microglia

• These are **small cells** (the smallest of the glial cells) with **complex** shapes,
• They are found in both the **grey** and **white** matter of the CNS
• They are **phagocytic** cells, thought to function as macrophages (**Neural macrophages**)
• There is some evidence that they are in fact of **mesenchymal** origin and derived from blood-borne **monocytes (not** from the neuronal tube).

(Junqueira et al, 1986).





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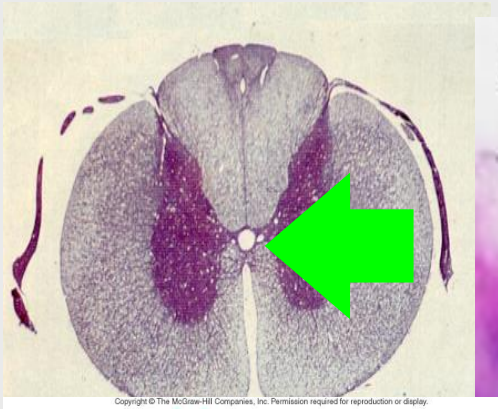
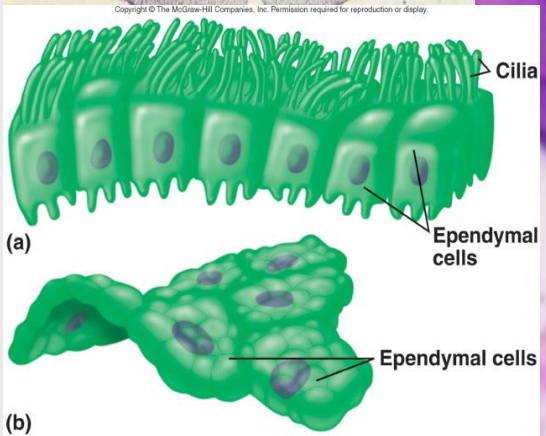
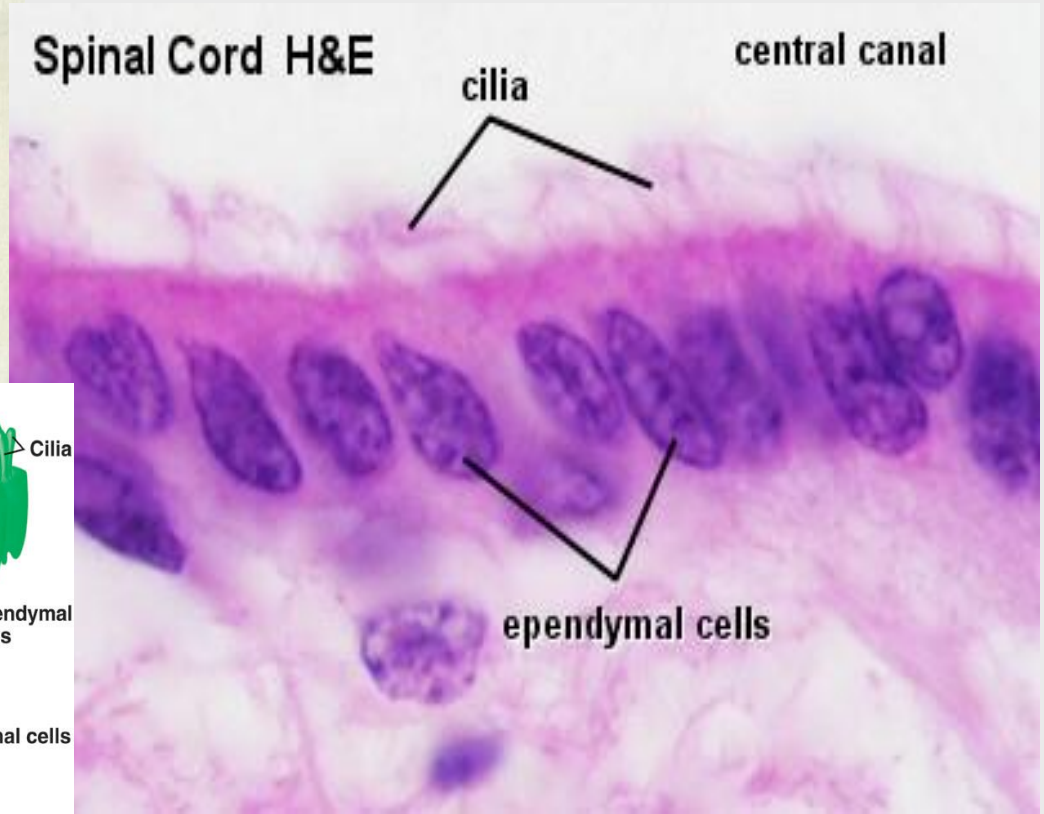
Ependymal cells

- The ependymal cells form the **epithelial lining** (**Ependyma**) of the internal cavities (**ventricles**) of the brain and spinal cord (**central canal**).
- The cells are often **ciliated** and they are simple **cuboidal or columnar** epithelium.
- The ependymal cells are bathed in **cerebrospinal fluid** (CSF).
- **Modified** ependymal cells and **associated capillaries** produce **CSF** and are called **choroid plexus** of the brain ventricles.







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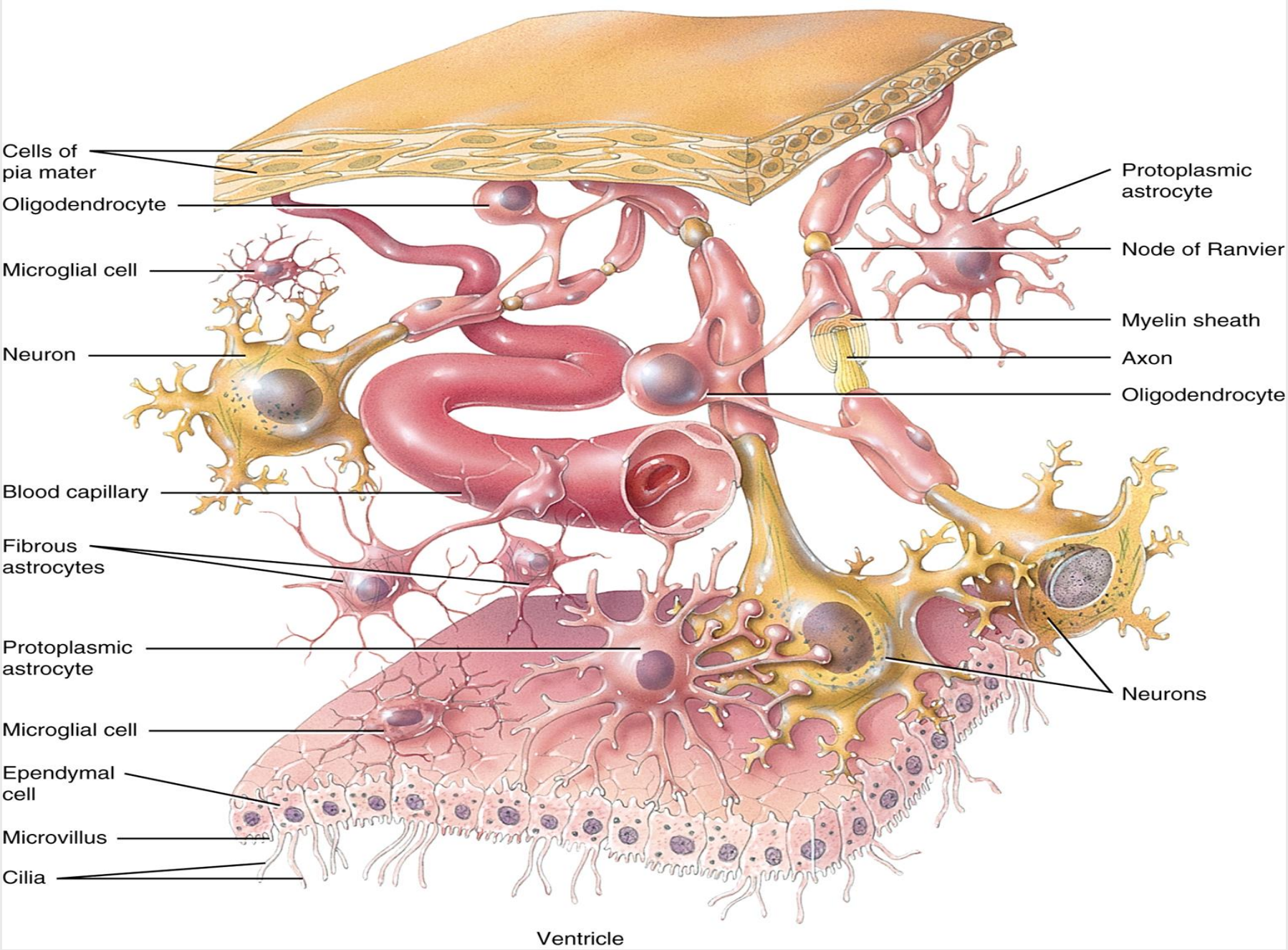


Neuroglia of the central nervous system (CNS).

Organization of the spinal cord

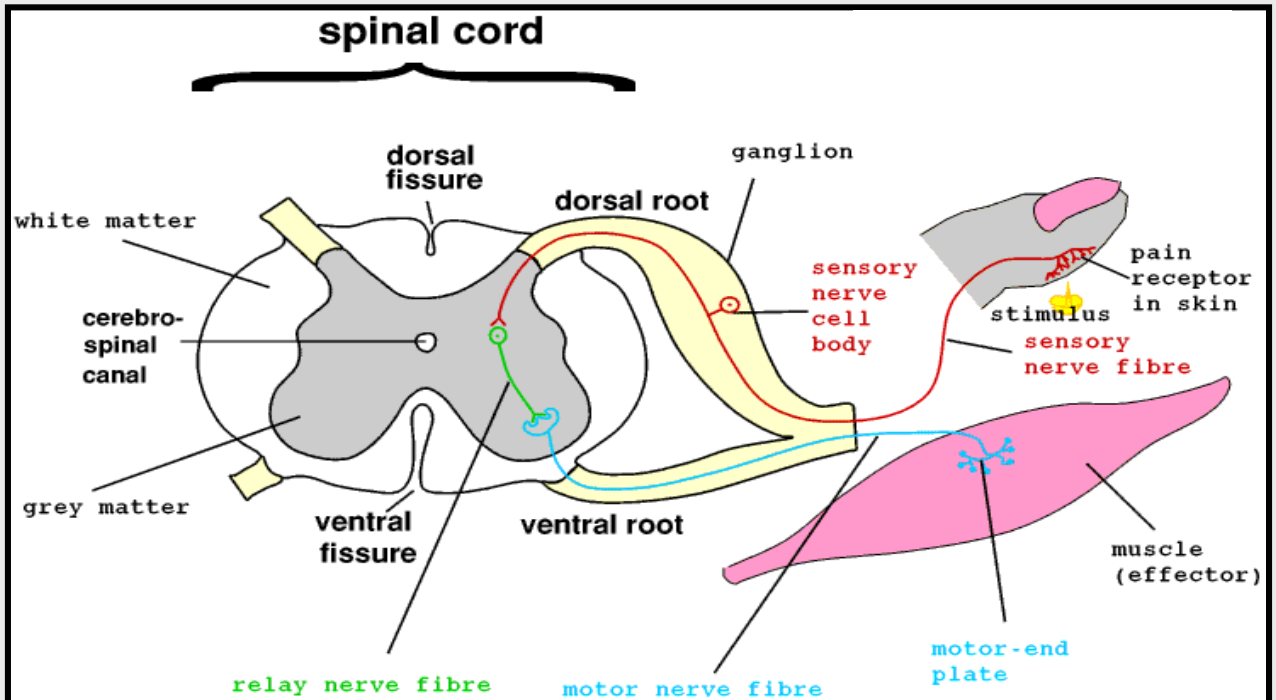
It is divided into **31** segments i.e. **8 cervical, 12 thoracic, 5 lumbar, 5 sacral and 1 coccygeal**

In cross section it exhibit a **butterfly-shaped** inner **grey matter** (contains **cell bodies** and their **dendrites**) surrounding the **central canal**

The gray matter is surrounded by a whitish peripheral substance the **white matter** (contains myelinated and unmyelinated axons)

Functionally related bundles of axons in the white matter are called **tracts**

Functionally related group of cell bodies in the gray matter are called **nuclei**



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Organization of the peripheral nervous tissue

The PNS comprises all nervous tissue outside the brain and spinal cord. It consists of groups of neurones (ganglion cells), called ganglia, plexuses, and bundles of parallel nerve fibres that form the nerves and nerve roots.

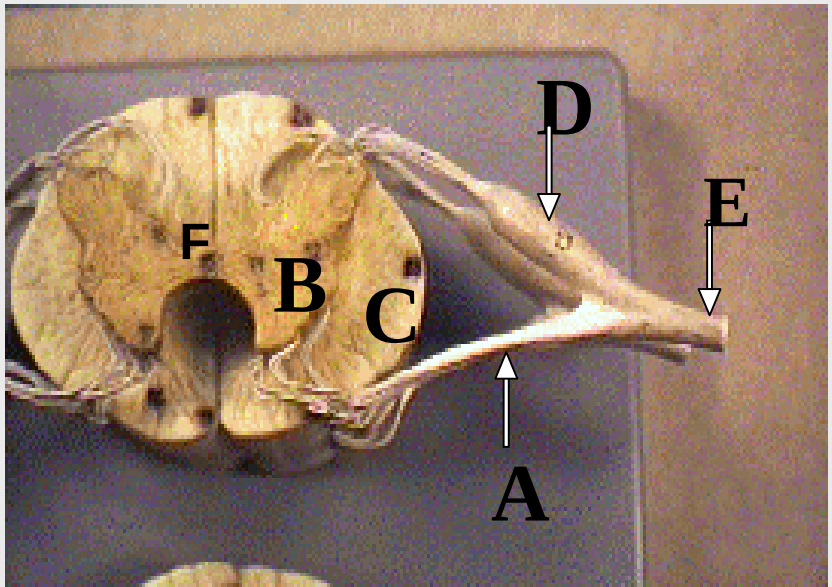
Nerve fibres, which originate from neurones within the CNS and pass out of the CNS in **cranial** and **spinal** nerves, are called **efferent or motor fibers**. Nerve fibres which originate from nerve cells outside the CNS but enter the CNS by way of the cranial or spinal nerves are called **afferent or sensory nerve fibres**

The principal neurotransmitters in the PNS are **acetylcholine** and **noradrenalin**.

Afferent, sensory fibres enter the spinal cord via the **dorsal roots**, while **efferent, motor fibres** leave the spinal cord via the **ventral roots**. Dorsal and ventral roots merge to form the spinal nerves, which consequently **contain both sensory and motor** fibres. As the spinal nerves travel into the periphery they split into branches to innervate a target tissue (both motor and sensory nerves)

A - ventral root of spinal nerve
B - grey matter
C - white matter
D - dorsal root of spinal nerve
E - spinal nerve

F- central commissure



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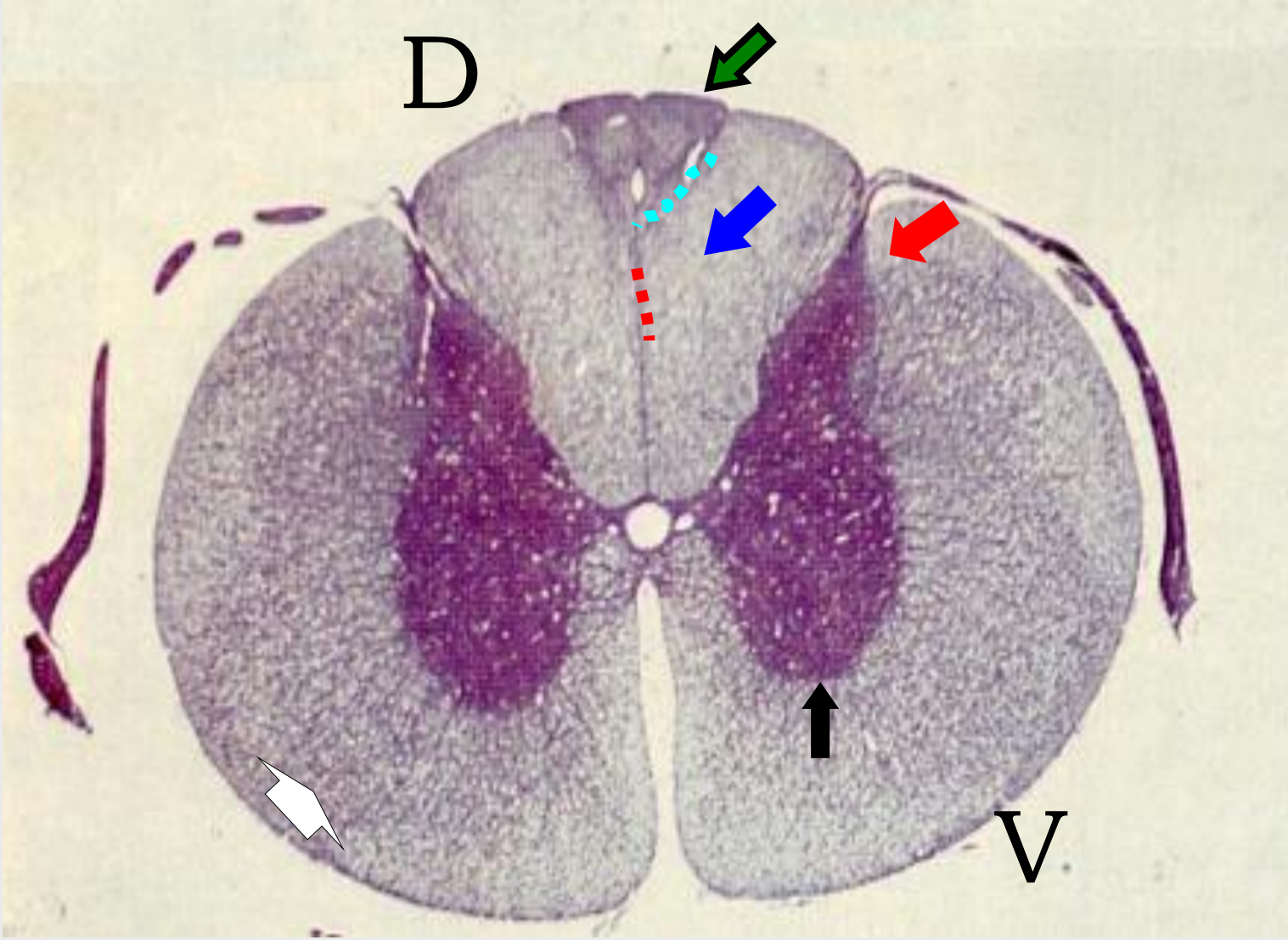

This is a photograph of a X section through the spinal cord. The **D** stands for dorsal and the **V** for ventral. The ↙ indicates the fasciculus gracilis, ↓ the the fasciculus cuneatus, the ↙ the dorsal horn of the grey matter and the ↑ the ventral horn of the grey matter. The ↗ shows the lateral white columns.

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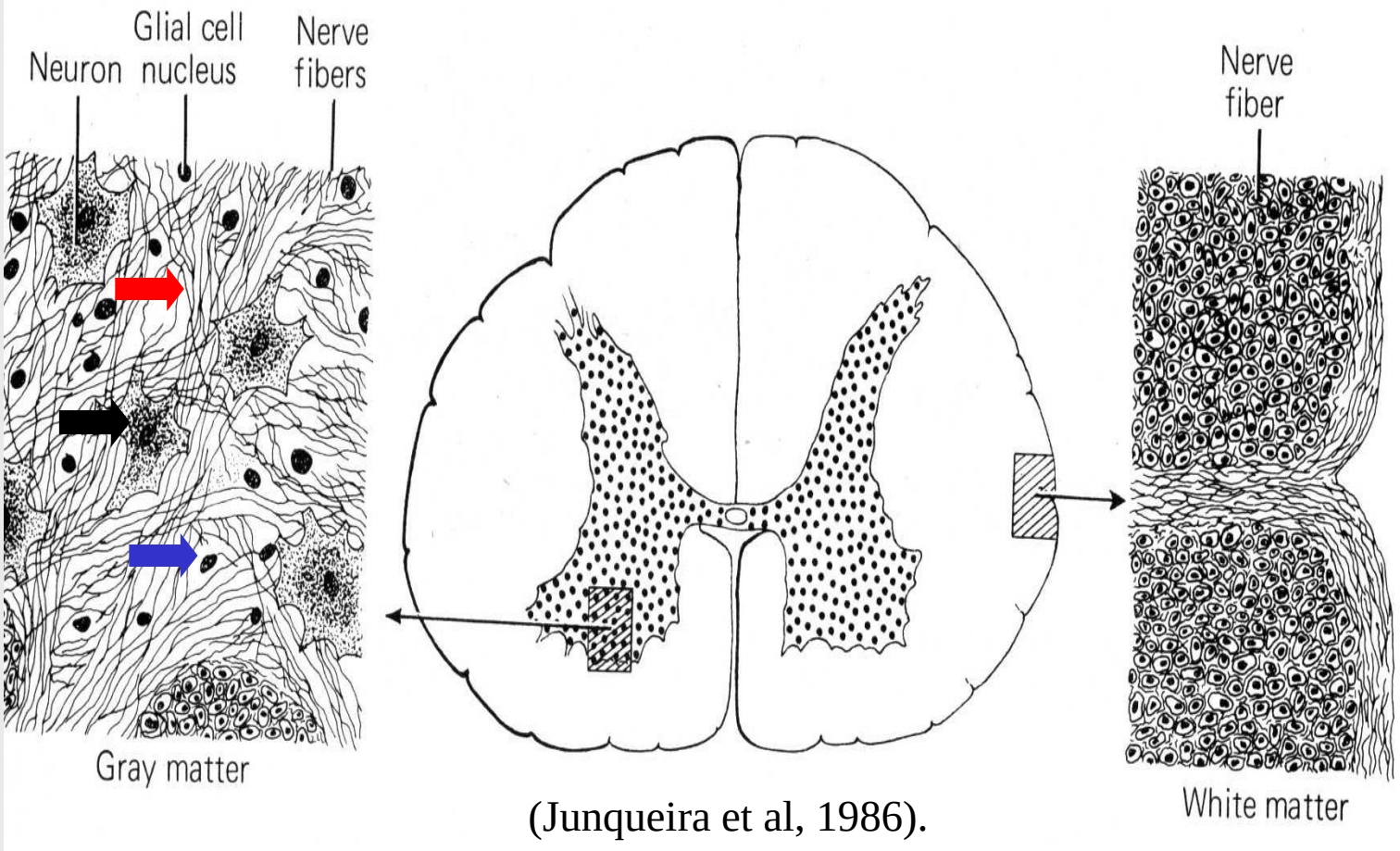

(Junqueira et al, 1986).

On the left is a section from the grey matter of the spinal cord. In the section there are neuron cell bodies ➡ , neuroglial nuclei ➡ and nerve fibers➡. On the right is a section from the white matter of the spinal cord. In the section the nerve fibers (mostly myelinated) can be seen.

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- **Motor neurons** that innervate striated muscle have their cell bodies in **the ventral (anterior) horn or root** of the grey matter as motor neuron conduct impulses away from CNS called **efferent neuron**
- Motor neuron passes through the ventral horn becomes component of the spinal nerve then to the muscle

- **Sensory neurons** have their cell bodies in **ganglia** that lie in the **dorsal (posterior) horn or root** of the spinal nerve. These pseudounipolar neurons have a single process that divides into a **peripheral segment** that bring information from **the periphery to the cell body** and a central segment

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Fibre types in peripheral nerves:

1. **Type A fibres** (myelinated) are 4 - 20 µm in diameter and conduct impulses at high velocities (15 - 120 m per second). Examples: motor fibers, which innervate **skeletal muscles**, and **sensory** fibres.

2. **Type B fibres** (myelinated) are 1 - 4 µm in diameter and conduct impulses with a velocity of 3 - 14 m per second. Example: **preganglionic autonomic fibres**.

3. **Type C fibres** (unmyelinated) are 0.2 - 1 µm thick and conduct impulses at velocities ranging from 0.2 to 2 m per second. Examples: **autonomic and sensory fibres**.

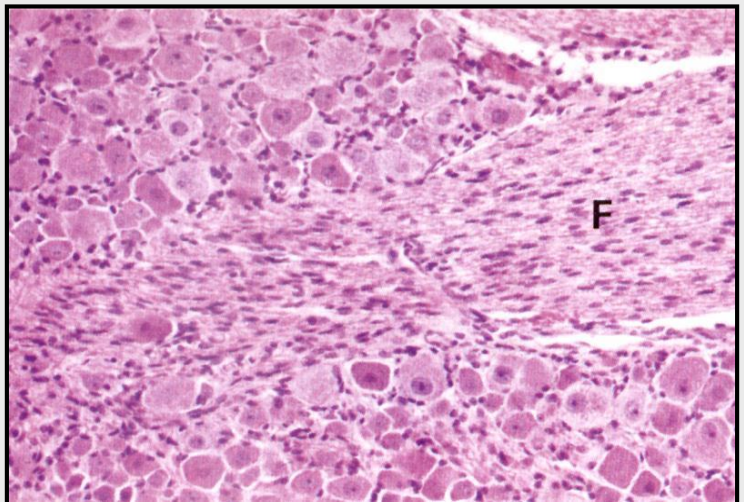
NERVE GANGLIA

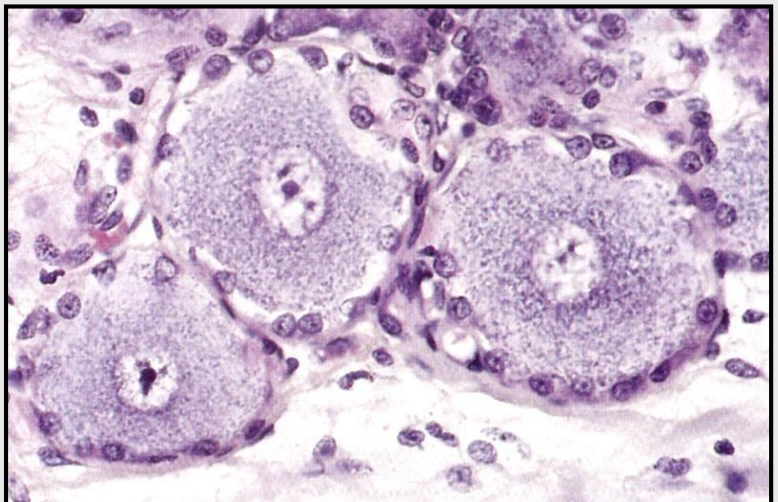
Ganglia are groups of nerve cell bodies **(perikarya)** called ganglion cells **outside** the CNS. Two types of nerve ganglia can be distinguished based on their morphology and function:

- **Spinal (sensory) ganglia** (Dorsal root ganglia)
- **Autonomic ganglia** (sympathetic and parasympathetic)

Spinal ganglia

- Found in the **dorsal** roots of spinal nerves and carry **afferent sensory** impulses.
- Surrounded by a fairly **thick** connective tissue **capsule**
- Neurons are **unipolar** (**pseudounipolar**) with **myelinated** nerve fibres.
- The cell bodies have a purely **trophic** function and are not involved with the nerve transmission i.e. do not receive **synapses**.
- Each perikaryon is surrounded by a layer of **satellite cells**.
- The perikarya are **not** distributed in the ganglia, but are found in **groups**, mainly fairly close to the **periphery**.





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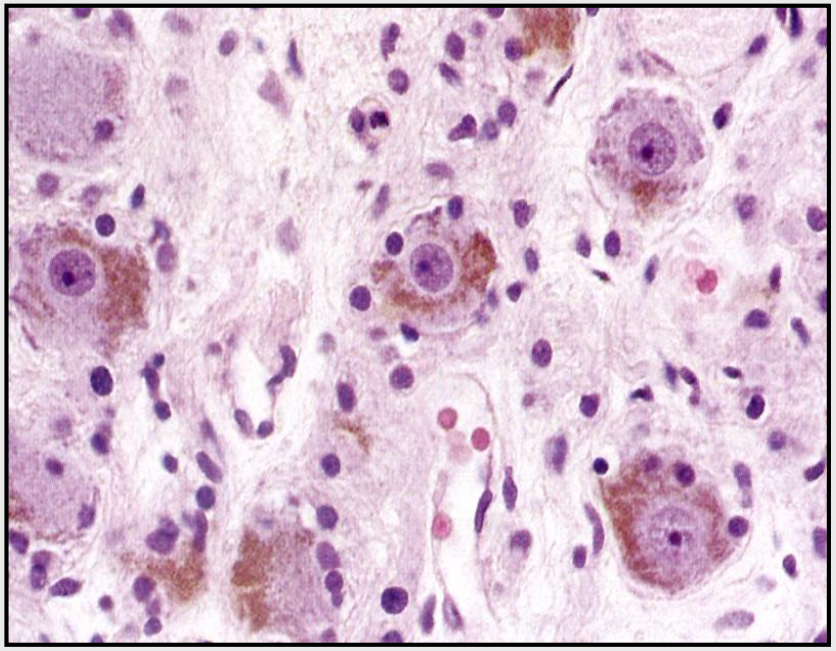
Autonomic ganglia

- Associated with nerves of the **autonomic nervous system**
- They are found as dilatations of autonomic nerves and **may** be encapsulated with **thin** C.T capsule. Present in the sympathetic chain and they are seen in the **walls** of organs (**intramura**l e.g. GIT and bladder) and **lack** a capsule.

They differ from spinal ganglia in that the

- Autonomic ganglia **have synaptic connections**
- Neurons are **multipolar** and **large** in number.
- The perikarya are **smaller**, have **fewer satellite cells**
- **Scattered** all through the ganglion.
- Usually **unmylinated** nerve fibres



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Organization of the brain (cerebrum and cerebellum)

- In the brain the gray matters forms an outer covering or **cortex**; the white matter forms an inner core or **medulla**

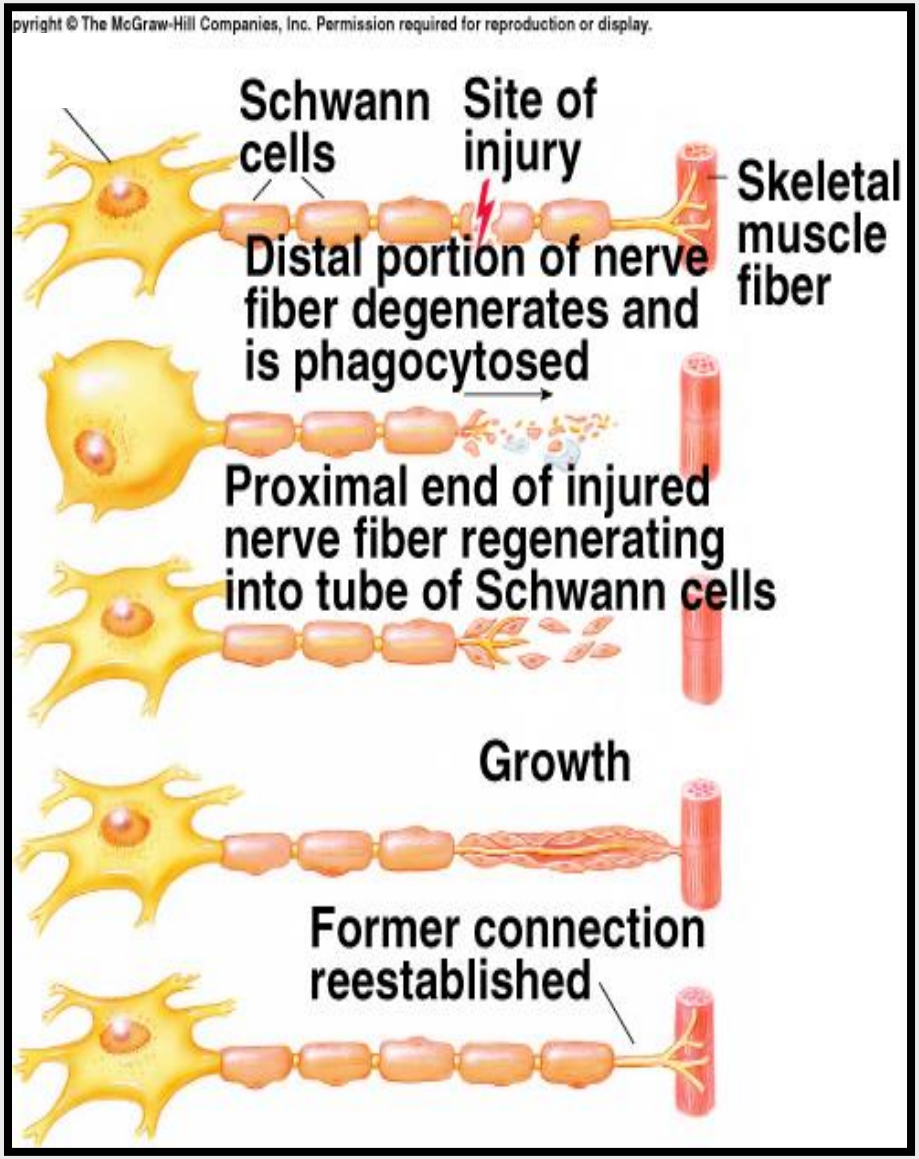
- The cortex of gray matter in the brain contains nerve cells, axons, dendrites and glial cells with synapses plus lands of gray matter nuclei

- The white matter contains only axons of nerve cells and plus the associated glial cells in addition to the tracts

Response of neuron to injury

A. Damage to the cell body

- occurs as a result of injury or disease
- **degeneration** and permanent loss of neuron leading to **atrophy** of the innervated muscle
- **if** the injured neuron makes only one synapses with other neuron **transneuronal degeneration** occurs i.e. destruction of the other neuron



B. Damage to the axon

---Degeneration

- degeneration occurs in the distal portion (**anterograde degeneration**) and the proximal portion (**retrograde degeneration**)
- **Anterograde (Wallerian) degeneration** it takes few days, **2-3 days**, **complete** degeneration of the axon and myelin sheath, fragments phagocytoced by Schwann in PNS, microglia in CNS, and blood **monocytes**
- **Retrograde degeneration,** incomplete degeneration, few internodes (~2 internodes)

-The **perikaryon enlarges**, **eccentric** nucleus and **chromotolysis** (loss of Nissl substance), 1-2 days after injury

-Proximal degeneration and cell body changes takes ~**2weeks**

---Regeneration

- begins in the **third week** after injury

- perikaryon becomes **active** and Nissle body **reappear**

- Schwann cells start to **divide** and **bridge** the injured site forming large number of new nerve processes **sprouts**, **neurites,** from proximal portion

- neurites are guided and mylenated by Schwann cells across the injured site, they grow **3mm/day**

- many of the new sprouts will degenerate, as their large number increase the probability of reestablishing the connection with its end-organ

-This whole process takes approximately 3 months

- if the gap is too wide or the sprouts do not reestablish contact, the sprouts grow in disorganized manner forming **neuroma** causing atrophy to end-organ