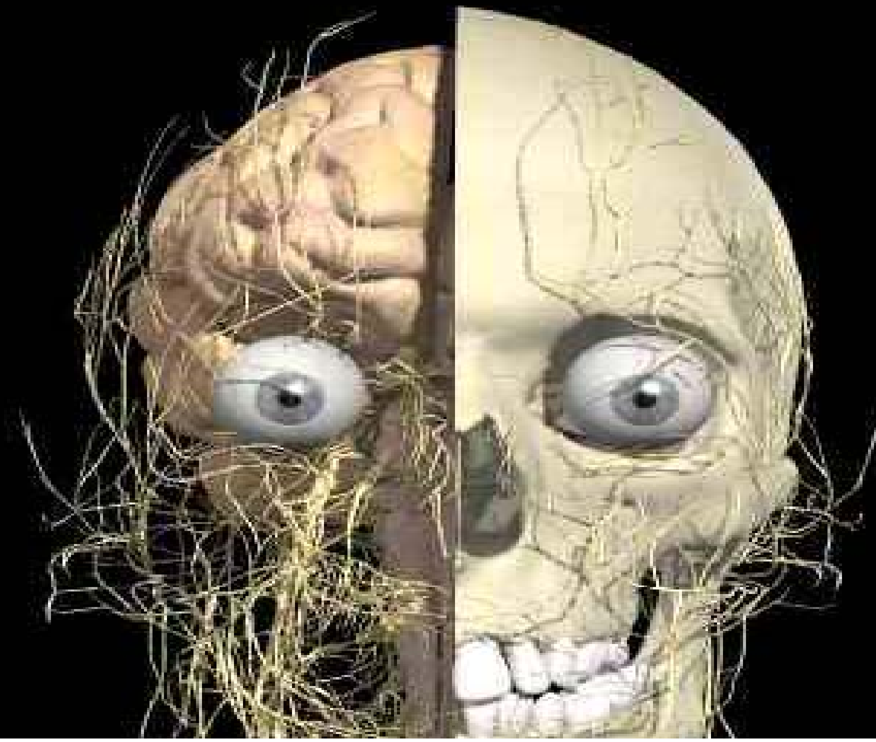
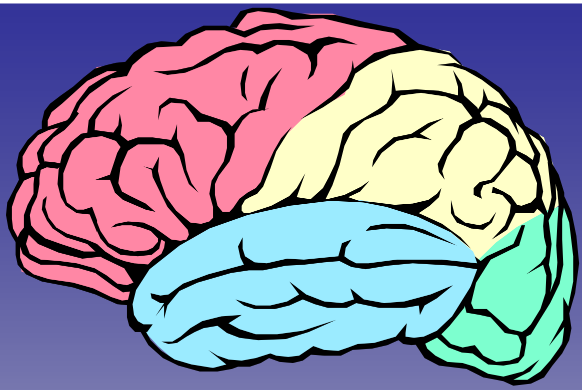


NERVOUS SYSTEM GENERALITY

INTRODUCTION-HISTOLOGY

D.HAMMOUDI.MD

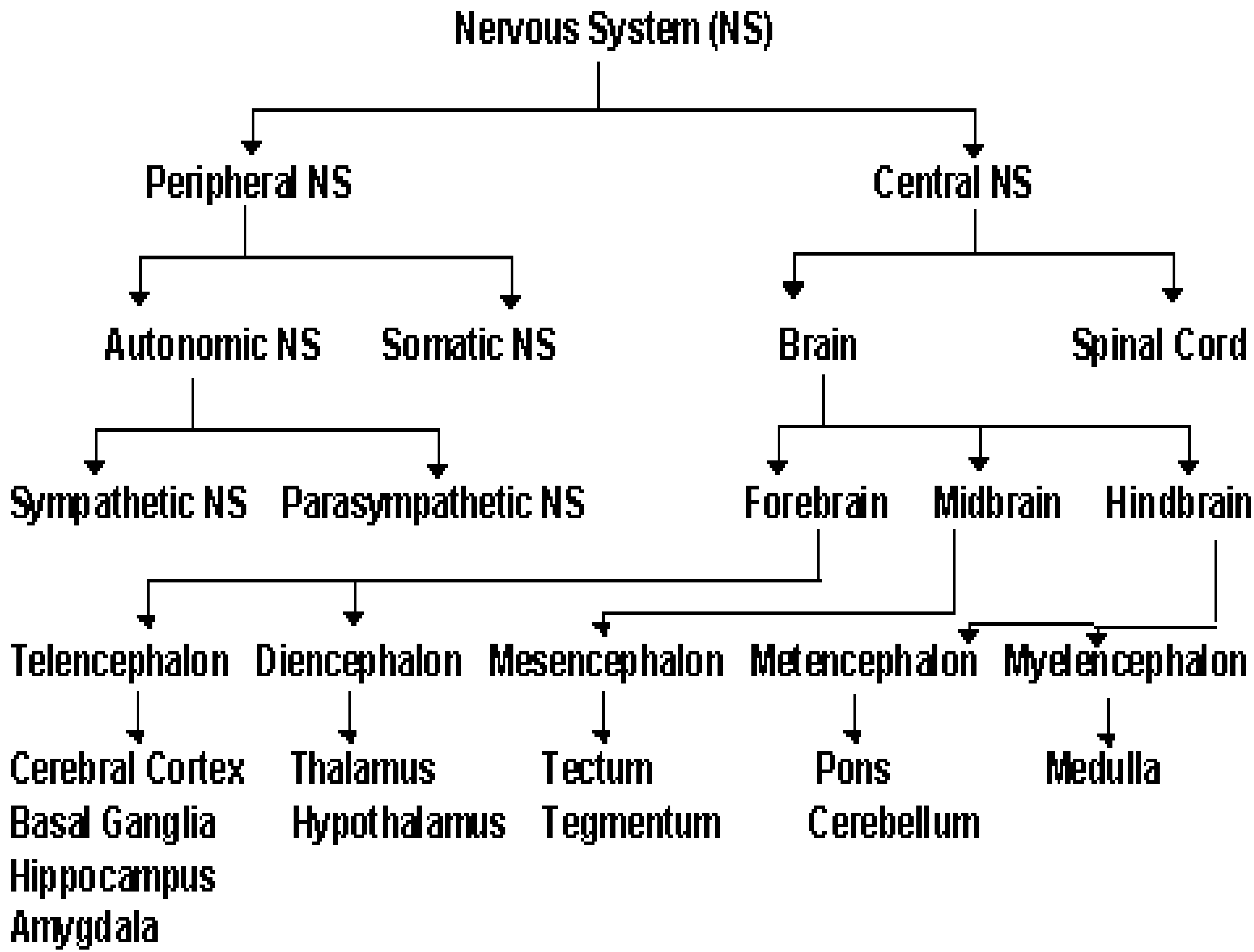
The Nervous System



- A network of billions of nerve cells linked together in a highly organized fashion to form the rapid control center of the body.
- Functions include:
  - Integrating center for homeostasis, movement, and almost all other body functions.
  - The mysterious source of those traits that we think of as setting humans apart from animals

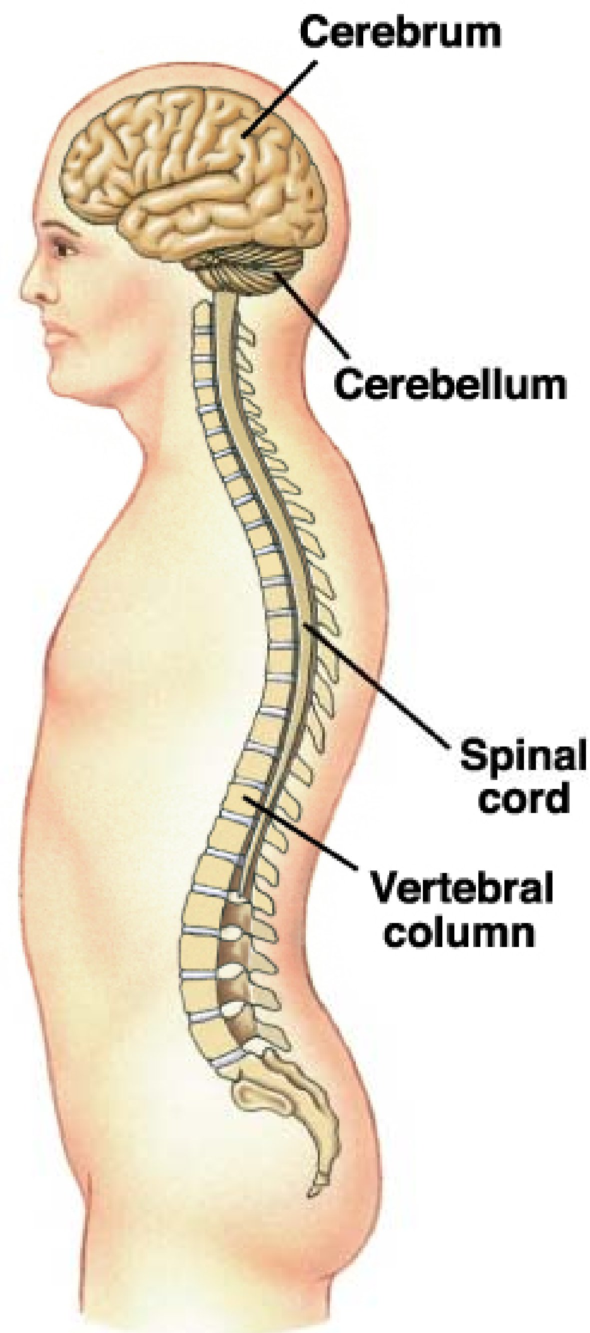
Human Nervous System

- **Central Nervous System (CNS)**
  Brain and spinal cord
  interneurones
- **Peripheral Nervous System (PNS)**
  Everything else
  sensory and motor neurones
  - **Somatic Nervous System**
    Voluntary
    Input from sense organs
    Output to skeletal muscles
  - **Autonomic Nervous System**
    Involuntary
    Input from internal receptros
    Output to smooth muscles & glands
    - **Sympathetic Motor System**
      'Fight or flight' responses
      Neurotransmitter: noradrenaline
      'Adrenergic System'
    - **Parasympathetic Motor System**
      Relaxing responses
      Neurotransmitter: acetylcholine
      'Cholinergic System'


Nervous System (NS)
Peripheral NS
Central NS
Autonomic NS
Somatic NS
Brain
Spinal Cord
Sympathetic NS
Parasympathetic NS
Forebrain
Midbrain
Hindbrain
Telencephalon
Diencephalon
Mesencephalon
Metencephalon
Myelencephalon
Cerebral Cortex
Basal Ganglia
Hippocampus
Amygdala
Thalamus
Hypothalamus
Tectum
Tegmentum
Pons
Cerebellum
Medulla

Organization of the Nervous System

- 2 big initial divisions:
  1. **Central Nervous System**
     - The brain + the spinal cord
       - The center of integration and control
  2. **Peripheral Nervous System**
     - The nervous system outside of the brain and spinal cord
     - Consists of:
       - **31 Spinal nerves**
         - » Carry info to and from the spinal cord
       - **12 Cranial nerves**
         - » Carry info to and from the brain



The central nervous system (CNS) is formed by :

- the brain
- spinal cord.

- These elements are enclosed within the <u>skull and spinal vertebral canal.</u>

- They are covered by the meninges,
  - **the dura,**
  - **arachnoid**
  - **pia.**

- Cerebrospinal fluid flows over the surface and fills the chambers (ventricles, central canal of the spinal cord).

- Two primary cell types make up the CNS - the neurons, and the glia [NEUROGLIA].

The organs of the nervous system include:

- **the brain**
- **the spinal cord**
- **sensory receptors of sense organs (eye, ears, etc.)**
- **the nerves that connect the nervous system with other systems**

The CNS is responsible for processing and coordinating:

1. **sensory data from inside and outside the body.**

2. **motor commands that control activities of peripheral organs such as the skeletal muscles.**

3. **higher functions of the brain such as intelligence, memory, learning and emotion.**

The peripheral nervous system (PNS) includes all neural tissue outside the CNS.

- **The PNS is responsible for:**

1. delivering sensory information to the CNS
2. carrying motor command to peripheral tissues and systems

Sensory information and motor commands in the PNS are carried by bundles of axons (with their associated connective tissues and blood vessels) called peripheral nerves (nerves):

1. cranial nerves are connected to the brain
2. spinal nerves are attached to the spinal cord

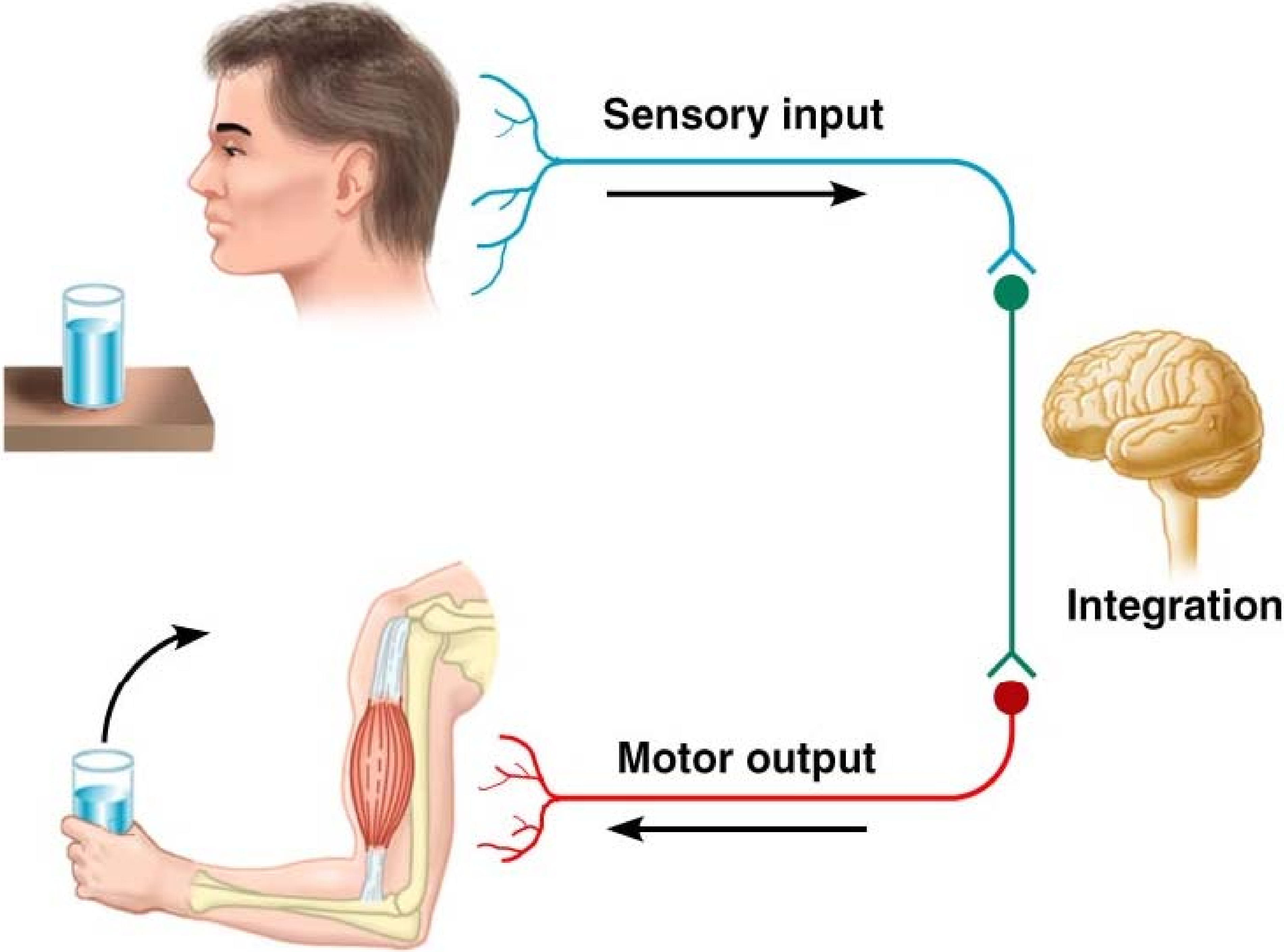
Peripheral Nervous System

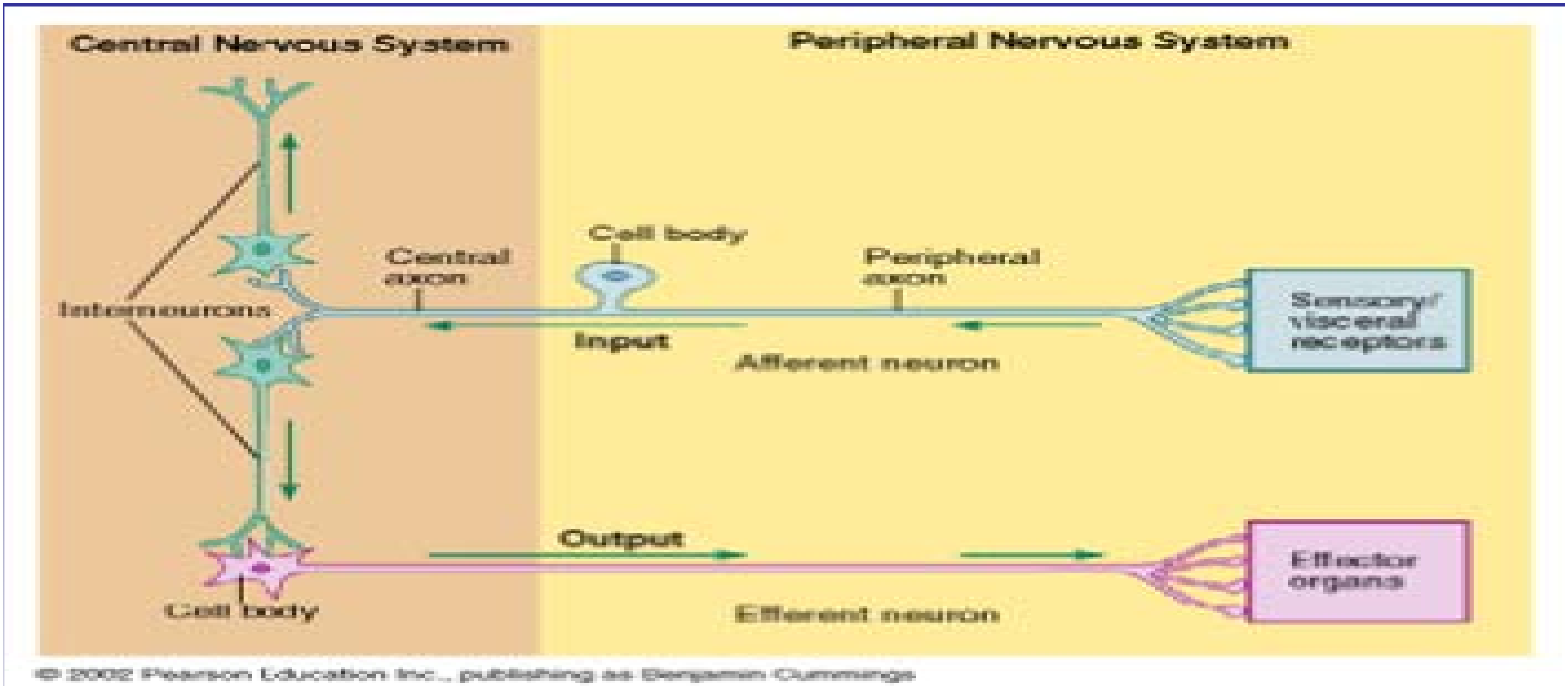
- Responsible for communication btwn the CNS and the rest of the body.
- Can be divided into:
  - **Sensory Division**
    - **Afferent division**
      - **Conducts impulses from receptors to the CNS**
      - **Informs the CNS of the state of the body interior and exterior**
      - **Sensory nerve fibers can be somatic (from skin, skeletal muscles or joints) or visceral (from organs w/i the ventral body cavity)**
  - **Motor Division**
    - **Efferent division**
      - **Conducts impulses from CNS to effectors (muscles/glands)**
      - **Motor nerve fibers**

Peripheral Nervous System (PNS): Two Functional Divisions

- **Sensory (afferent) division**
  - **Sensory afferent fibers** – carry impulses from skin, skeletal muscles, and joints to the brain
  - **Visceral afferent fibers** – transmit impulses from visceral organs to the brain

- **Motor (efferent) division**
  - Transmits impulses from the CNS to effector organs


Sensory input
Integration
Motor output


Central Nervous System
Peripheral Nervous System
Interneurons
Central axon
Cell body
Peripheral axon
Sensory/ visceral receptors
Input
Afferent neuron
Output
Effector organs
Cell body
Efferent neuron
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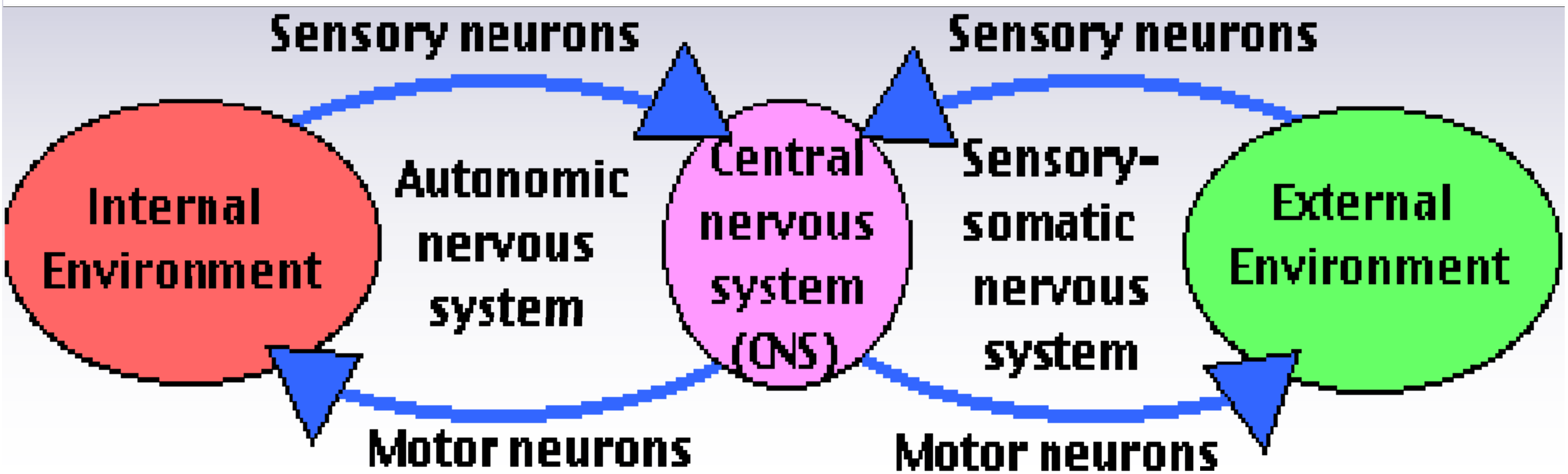

Sensory neurons
Sensory neurons
Internal Environment
Autonomic nervous system
Central nervous system (CNS)
Sensory-somatic nervous system
External Environment
Motor neurons
Motor neurons

Basic Functions of the Nervous System

1. **Sensation**
   - Monitors changes/events occurring in and outside the body. Such changes are known as *stimuli* and the cells that monitor them are *receptors*.
2. **Integration**
   - The parallel processing and interpretation of sensory information to determine the appropriate response
3. **Reaction**
   - Motor output.
     - **The activation of muscles or glands (typically via the release of neurotransmitters (NTs))**

Nervous vs. Endocrine System

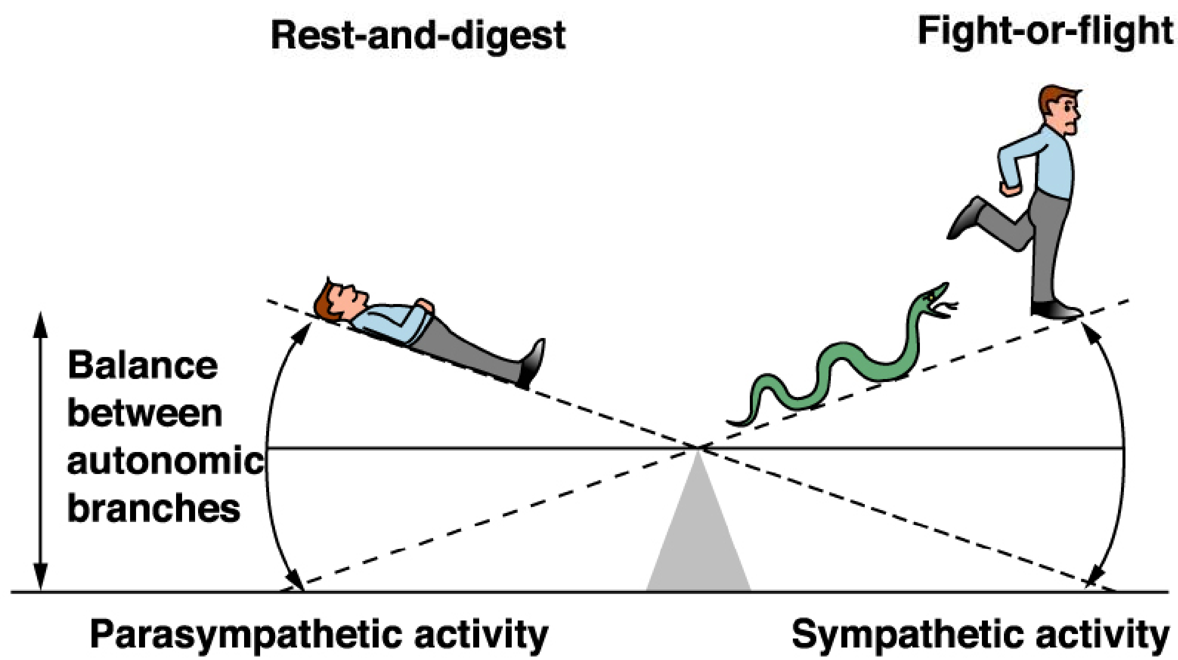
- Similarities:
  - They both monitor stimuli and react so as to maintain homeostasis.
- Differences:
  - The NS is a rapid, fast-acting system whose effects do not always persevere.
  - The ES acts slower (via blood-borne chemical signals called H ORMONES and its actions are usually much longer lasting.

Motor Efferent Division

- Can be divided further:
  - **Somatic nervous system**
    - VOLUNTARY (generally)
    - Somatic nerve fibers that conduct impulses from the CNS to skeletal muscles
  - **Autonomic nervous system**
    - INVOLUNTARY (generally)
    - Conducts impulses from the CNS to smooth muscle, cardiac muscle, and glands.

Autonomic Nervous System

- Can be divided into:
  - ***Sympathetic Nervous System***
    - "Fight or Flight"
  - ***Parasympathetic Nervous System***
    - "Rest and Digest"



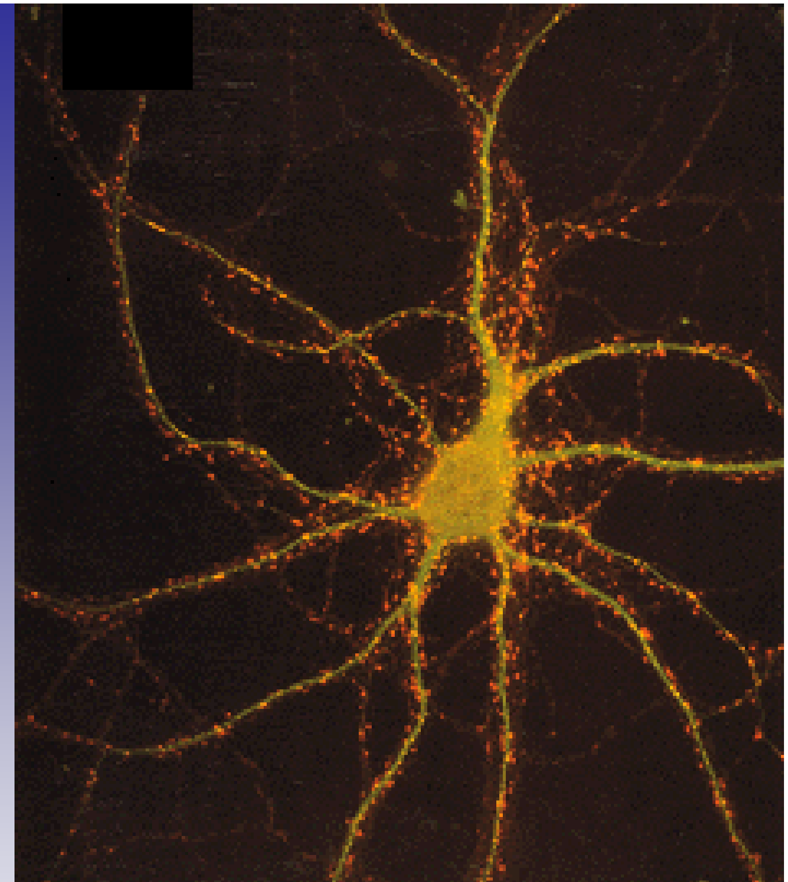
- These 2 systems are antagonistic.
- Typically, we balance these 2 to keep ourselves in a state of dynamic balance.

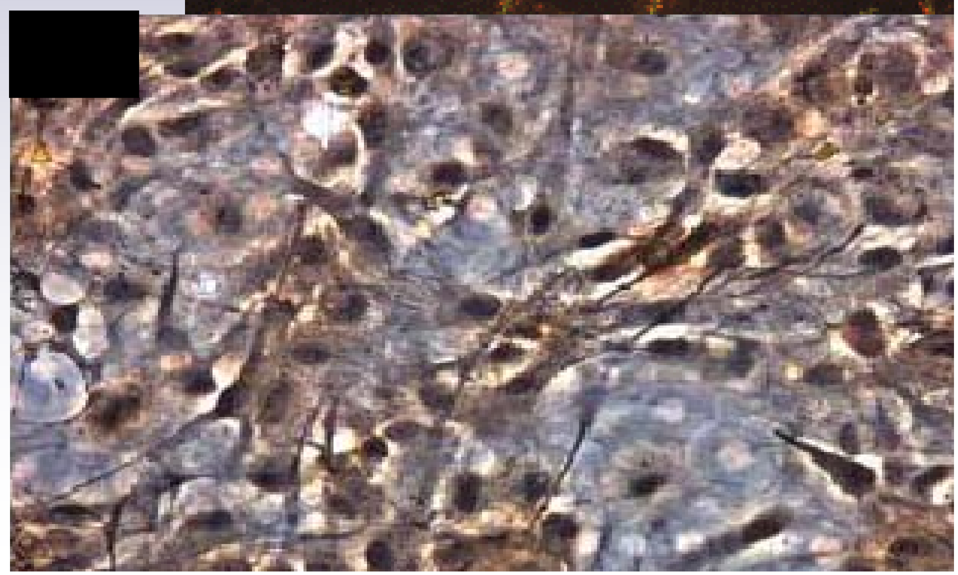
Histology

Nervous Tissue

- Highly cellular
- 2 cell types

1. **<u>Neurons</u>**
   - Functional, signal conducting cells
2. **<u>Neuroglia</u>**
   - Supporting cells





Neurons

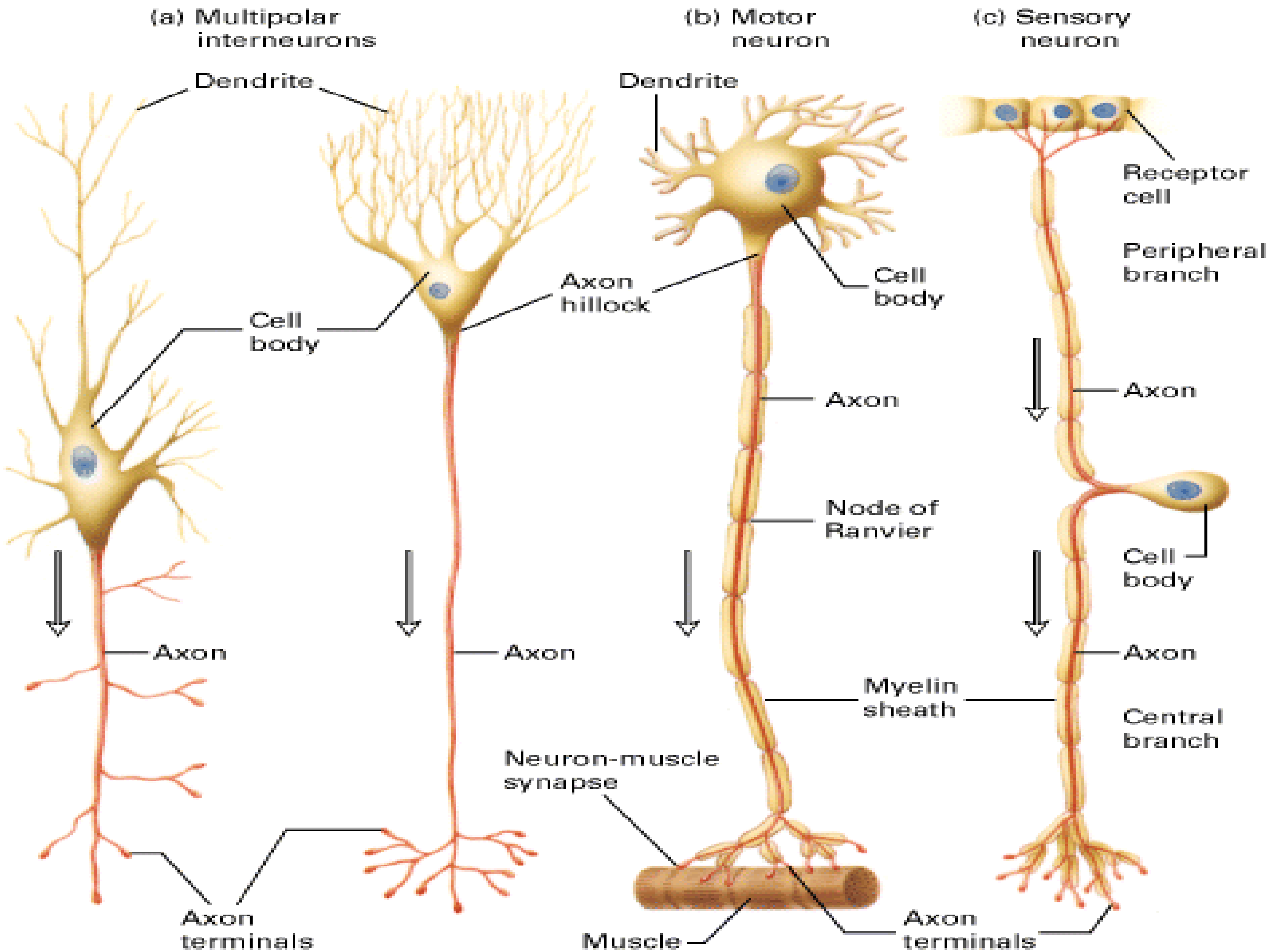
- There are many types of neuron based on the size and shape of the cell body and the arrangement of the processes.
- Based on their staining neurons could be seen to be unipolar, bipolar or multipolar.
- Most of the neurons within the CNS are multipolar.
- The processes extending from the cell body are either axons or dendrites.
- Neurons usually have only one axon but many dendrites.

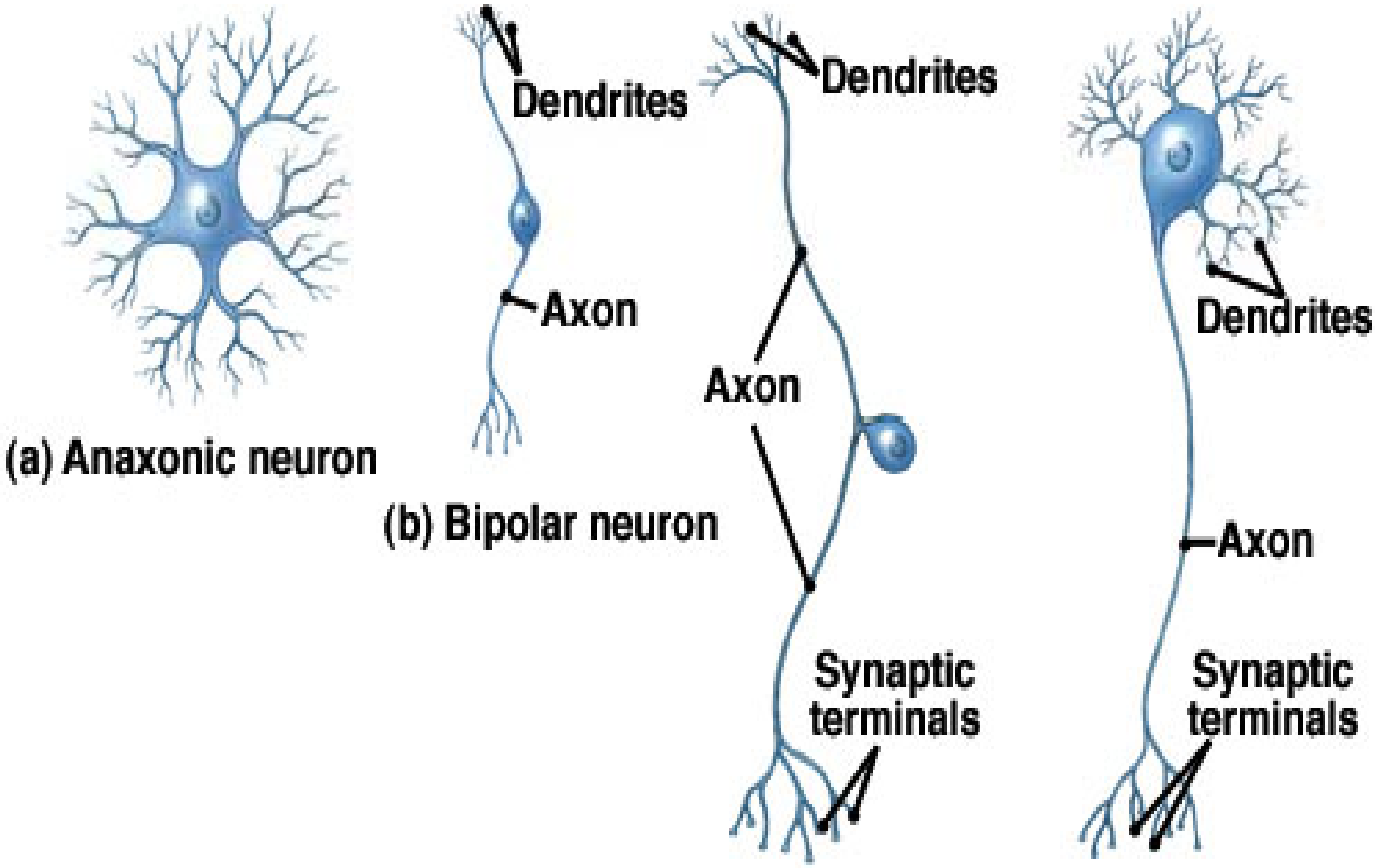
Neurons are similar to other cells in the body because:

1. Neurons are surrounded by a cell membrane.
2. Neurons have a nucleus that contains genes.
3. Neurons contain cytoplasm, mitochondria and other organelles.
4. Neurons carry out basic cellular processes such as protein synthesis and energy production.

Neurons differ from other cells in the body because:

1. Neurons have specialised extensions called dendrites and axons. Dendrites bring information to the cell body and axons take information away from the cell body.
2. Neurons communicate with each other through an electrochemical process.
3. Neurons contain some specialized structures (for example, synapses) and chemicals (for example, neurotransmitters).


(a) Multipolar interneurons
(b) Motor neuron
(c) Sensory neuron
Dendrite
Dendrite
Cell body
Axon hillock
Cell body
Receptor cell
Peripheral branch
Axon
Axon
Node of Ranvier
Axon
Axon
Cell body
Axon
Myelin sheath
Central branch
Neuron-muscle synapse
Axon terminals
Muscle
Axon terminals



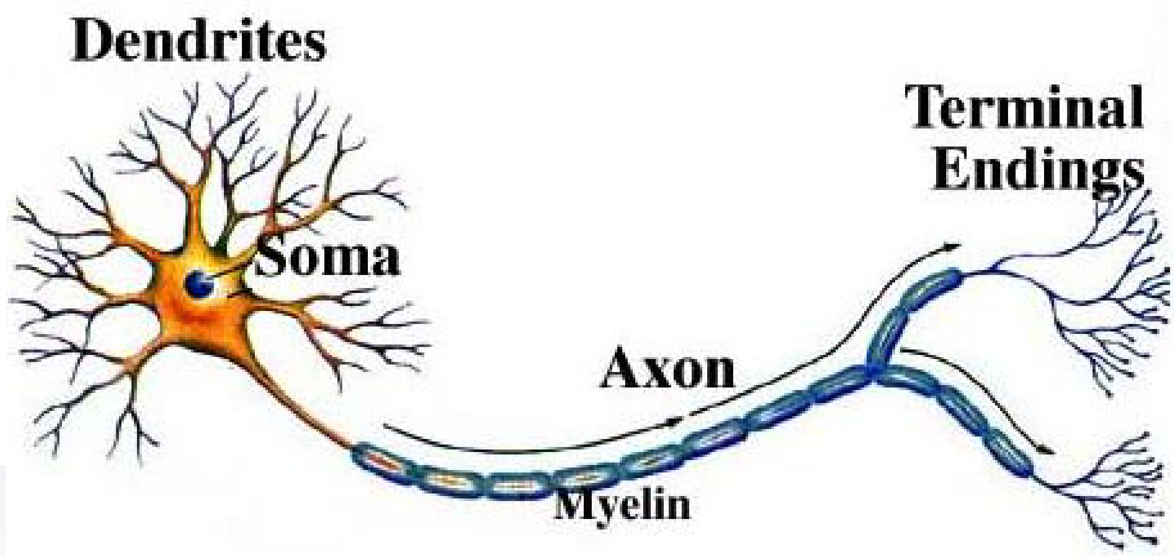
(a) Anaxonic neuron

(b) Bipolar neuron

(c) Unipolar neuron

(d) Multipolar neuron

- The functional and structural unit of the nervous system
- Specialized to conduct information from one part of the body to another
- There are many, many different types of neurons but most have certain structural and functional characteristics in common:
  - Cell body (soma)
  - One or more specialized, slender processes (axons/dendrites)
  - An input region (dendrites/soma)
  - A conducting component (axon)
  - A secretory (output) region (axon terminal)

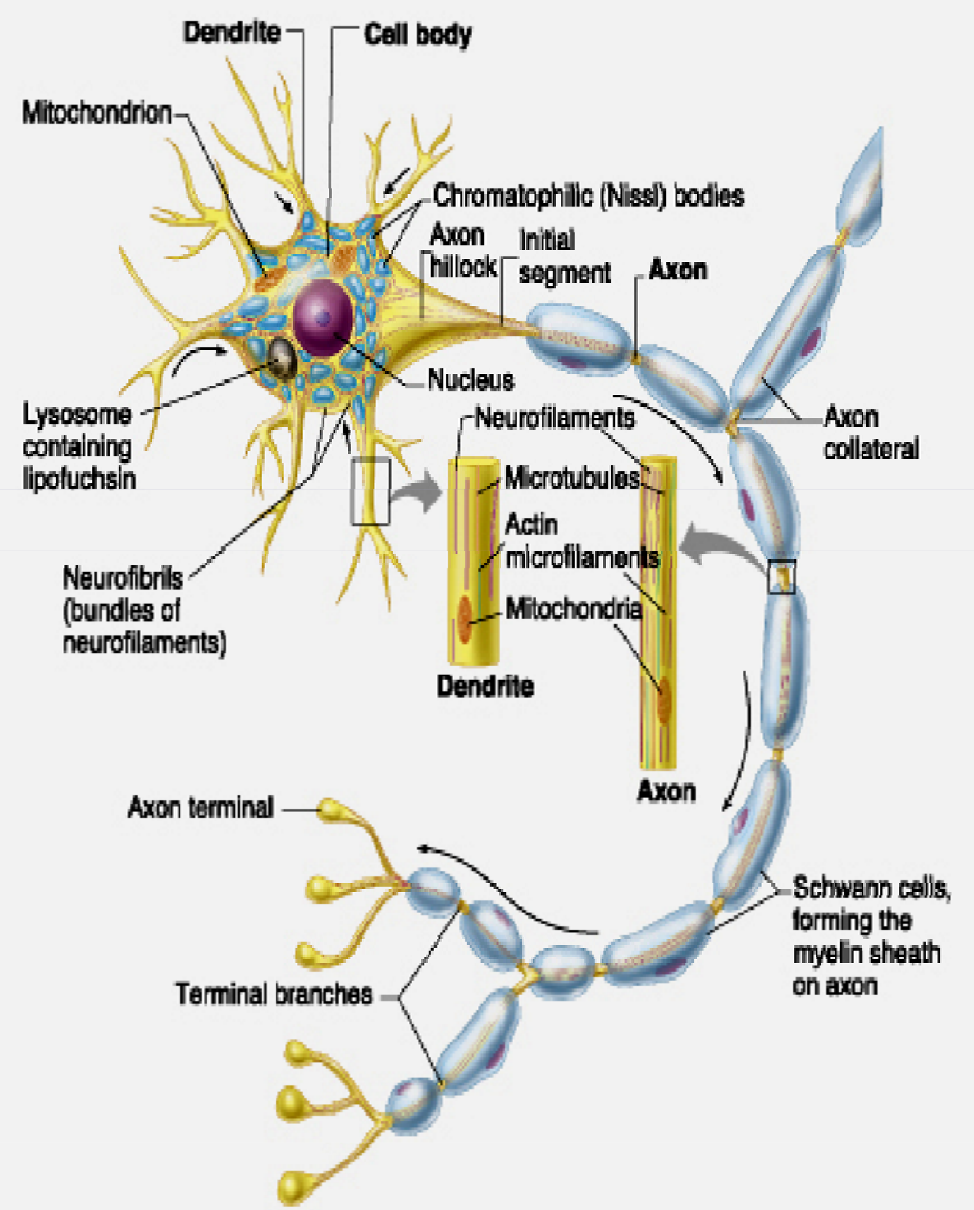


Neuron structure

- Typically large, complex cells, they all have the following structures
  - Cell body
    - Nuclei
    - Chromatophilic (Nissl) bodies
    - Neurofibrils
    - Axon hillock
  - Cell processes
    - Dendrites
    - Axon
    - Myelin sheath or neurilemma

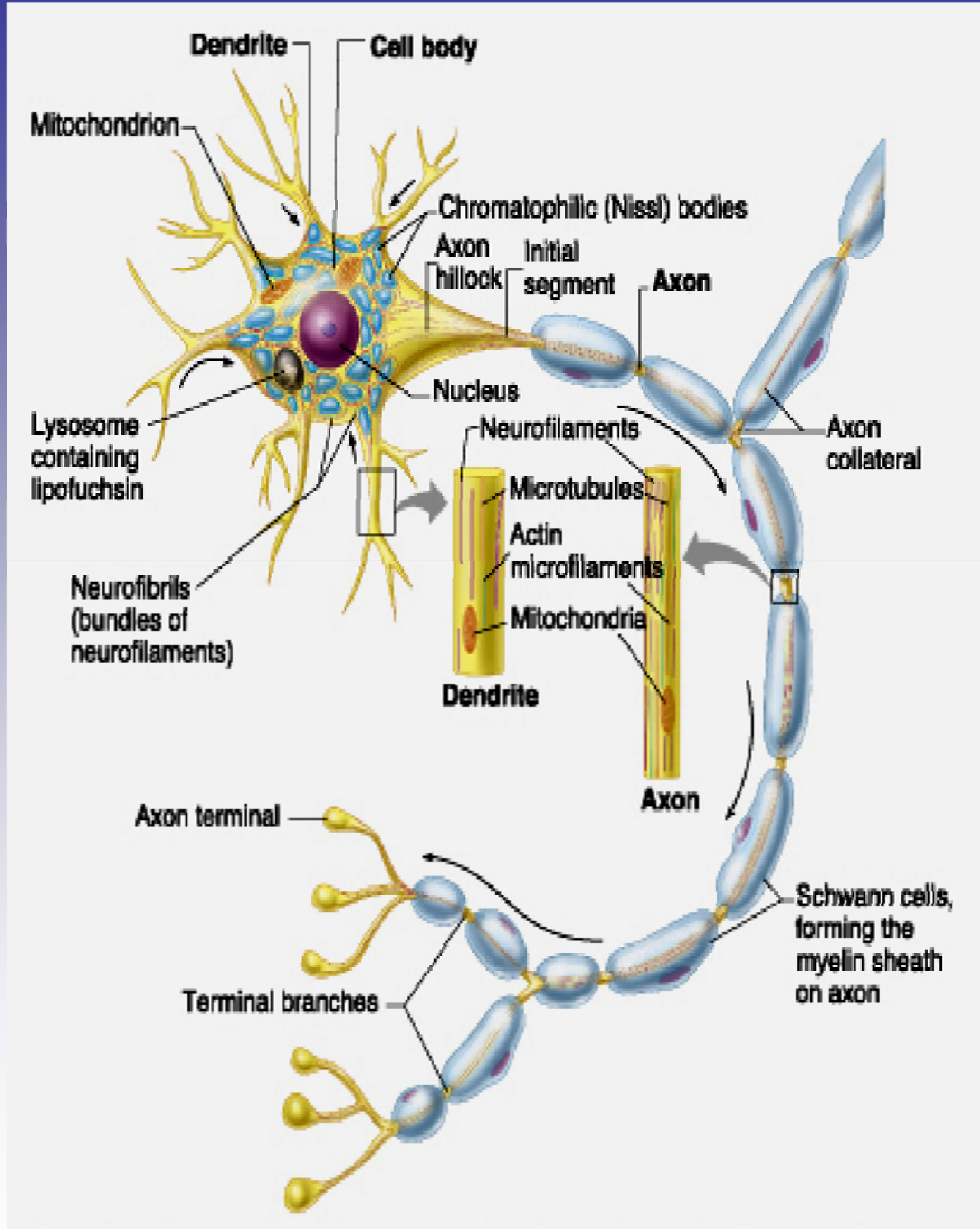
Neuron structure

- Cell Body
  - Nuclei
  - Chromatophilic (Nissl) bodies
  - Neurofibrils
  - Axon hillock
- Neuron Processes
  - Dendrites
  - Axons
  - Myelin sheaths
  - Axon terminals



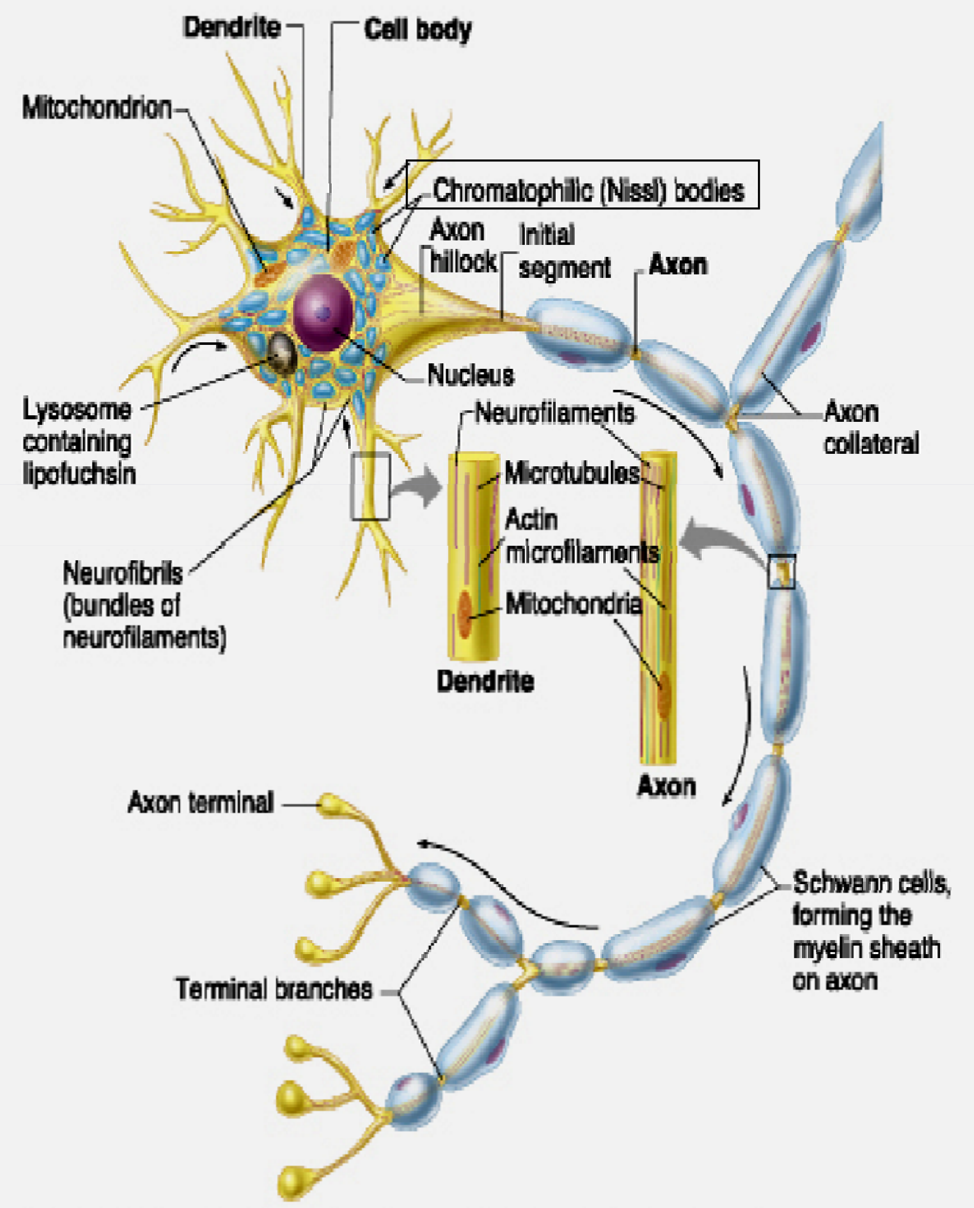
Neuron structure

- The cell body consists of a large, spherical nucleus with a prominent nucleolus surrounded by cytoplasm
- The cell ranges from 5 to 140μm in diameter
- The cell body is the biosynthetic center of the neuron



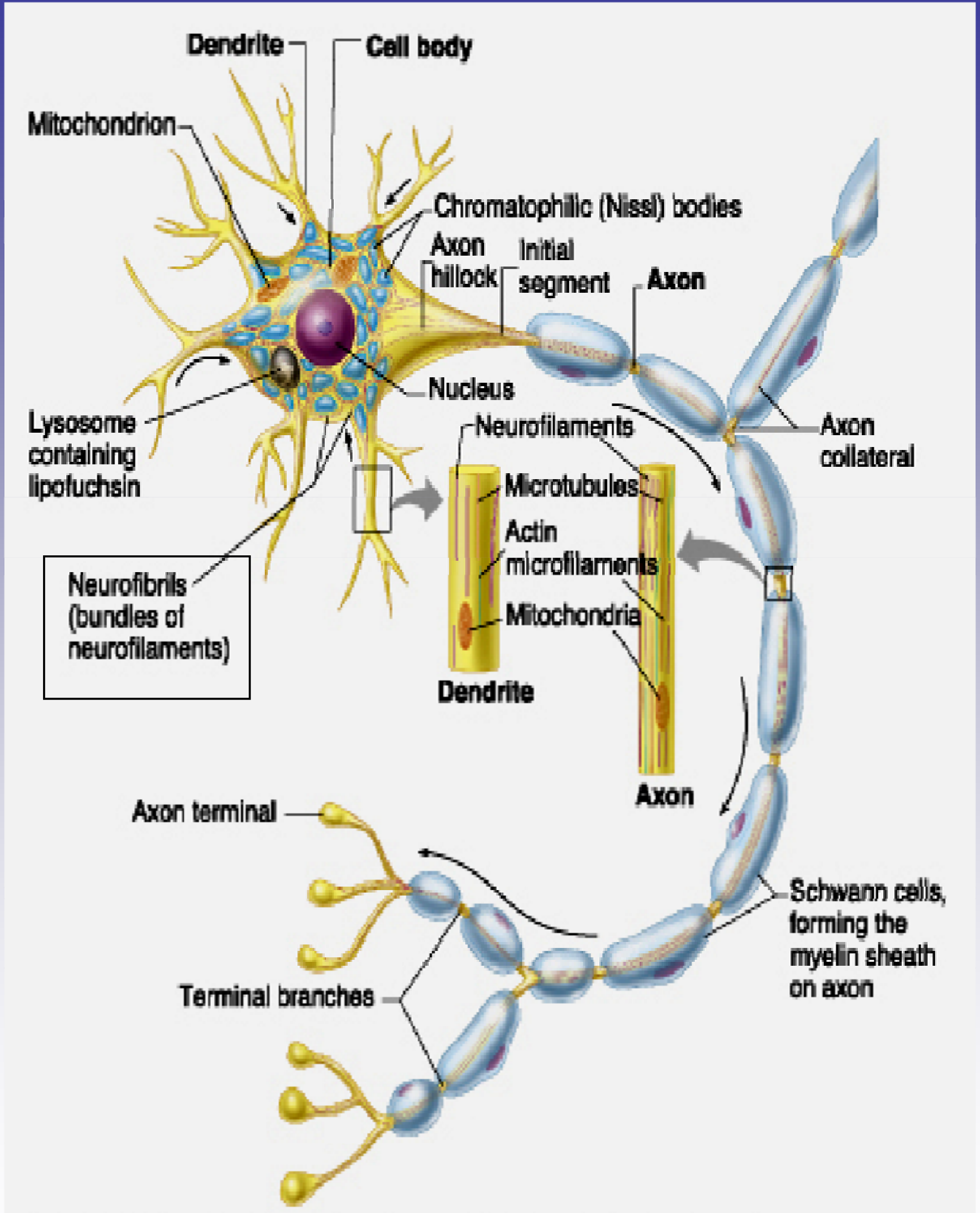
Neuron structure

- The cell body contains the usual organelles with the exception of centrioles (not needed in amitotic cells)
- The rough endoplasmic reticulum or Nissl bodies is the protein and membrane making machinery of the cell
- The cell body is the focal point for neuron growth in development



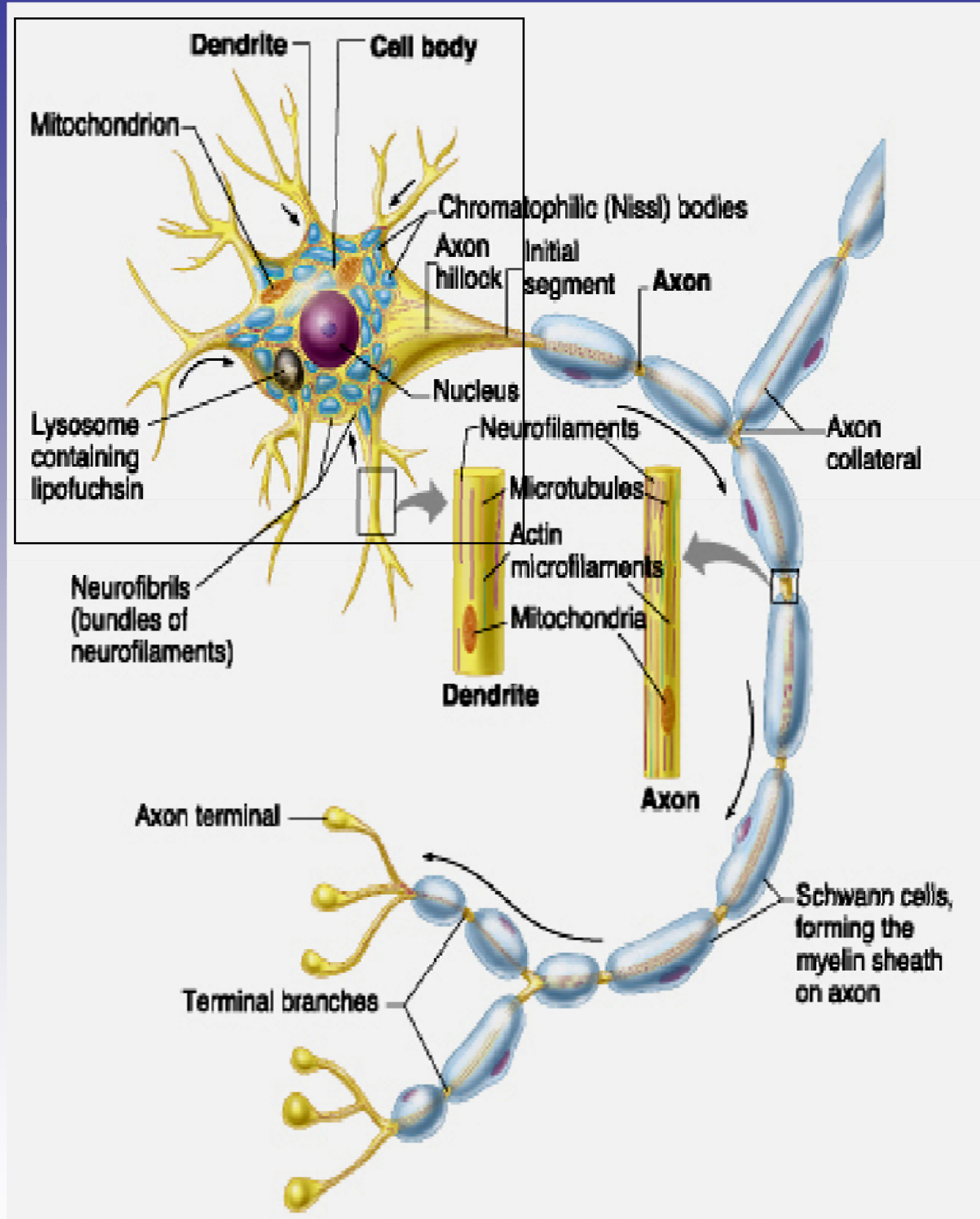
Neuron structure

- Neurofibrils are bundles of intermediate filaments (neurofilaments) that run in a network between the chromatophilic bodies
- Neurofibrils keep the cell from being pulled apart when it is subjected to tensile stresses



Neuron structure

- In most neurons, the plasma membrane of the cell body acts as a receptive surface that receives signals from other neurons



The cytoskeleton with neurofilaments and neurotubules (in place of microfilaments and microtubules) Bundles of neurofilaments called neurofibrils support the dendrites and axon.

- most nerve cells do not contain centrioles and cannot divide

The long axon carries the electrical signal (*action potential*) to its target.

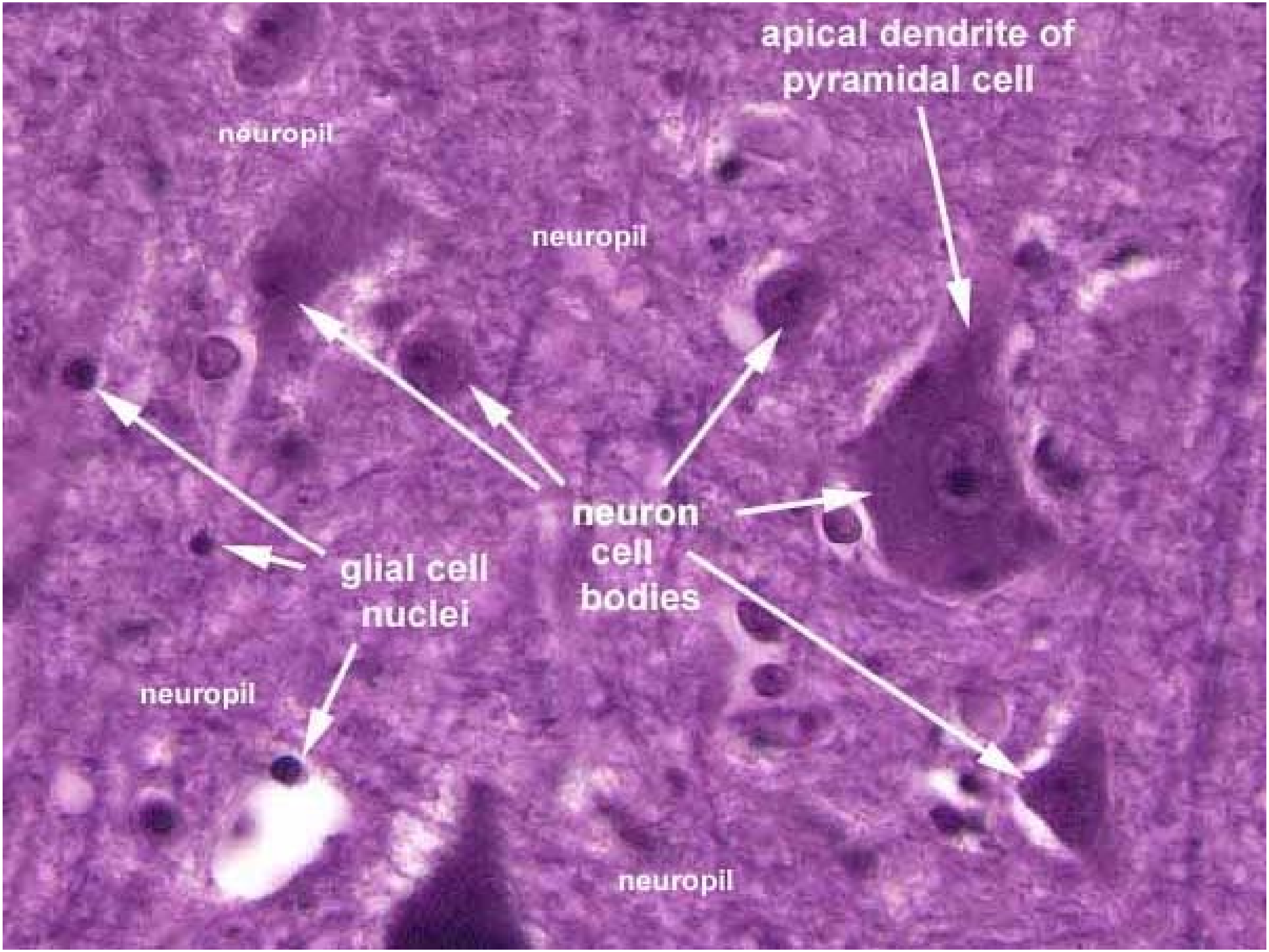
The structure of an axon is critical to its function.

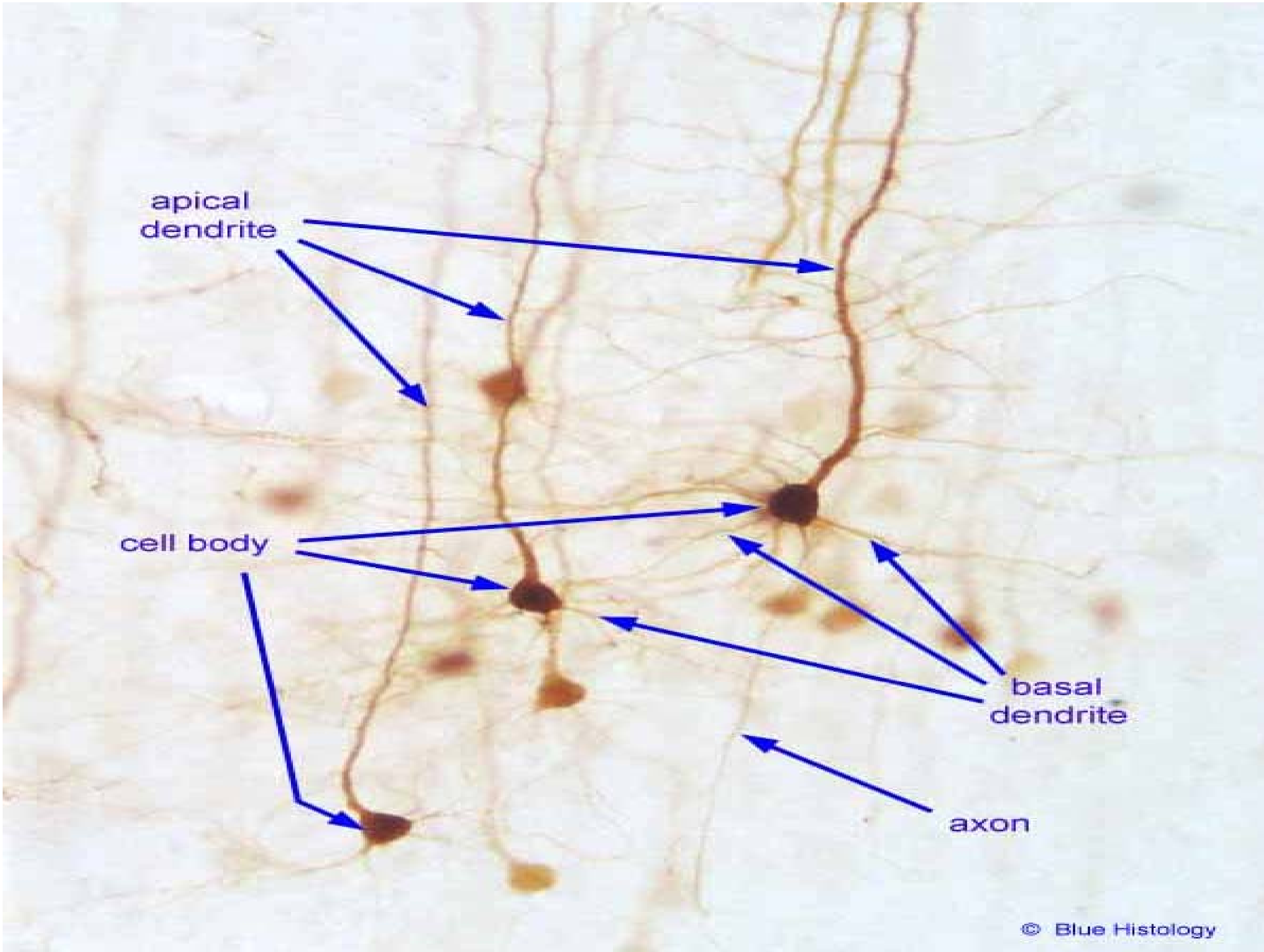
- <u>axoplasm:</u> the cytoplasm of the axon, which contains neurotubules, neurofibrils, enzymes and various organelles

-**<u>axolemma:</u> a specialized cell membrane, covers the axoplasm**

-**the initial segment of the axon attaches to the cell body at a thick section called the axon hillock**

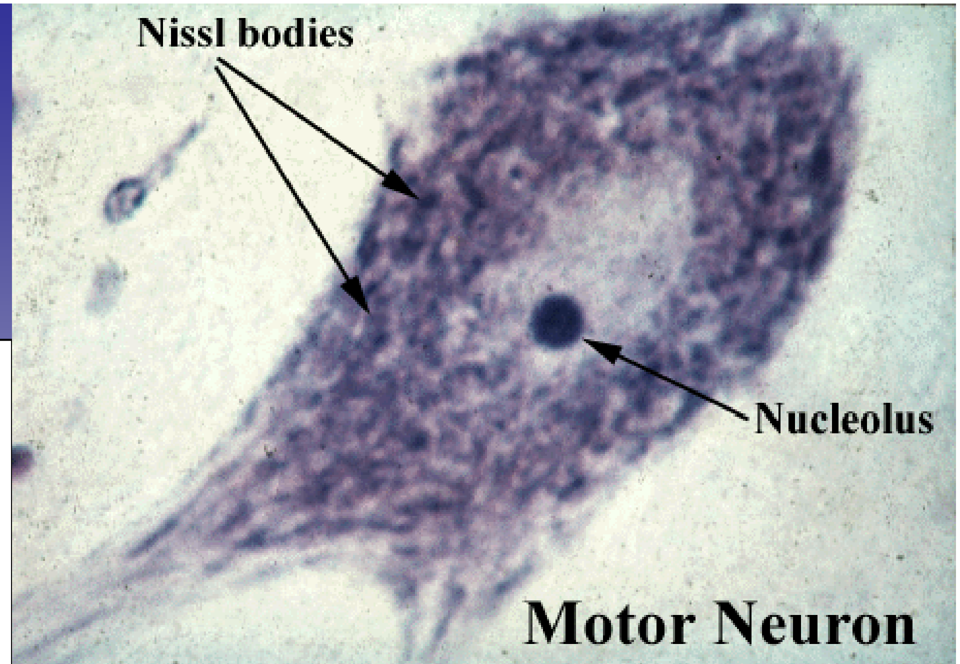
- collaterals are branches of a single axon
- <u>telodendria</u> are the fine extensions at the synaptic terminal of the axon


apical dendrite of
pyramidal cell
neuropil
neuropil
neuron
cell
bodies
glial cell
nuclei
neuropil
neuropil


apical
dendrite
cell body
basal
dendrite
axon
© Blue Histology

Soma

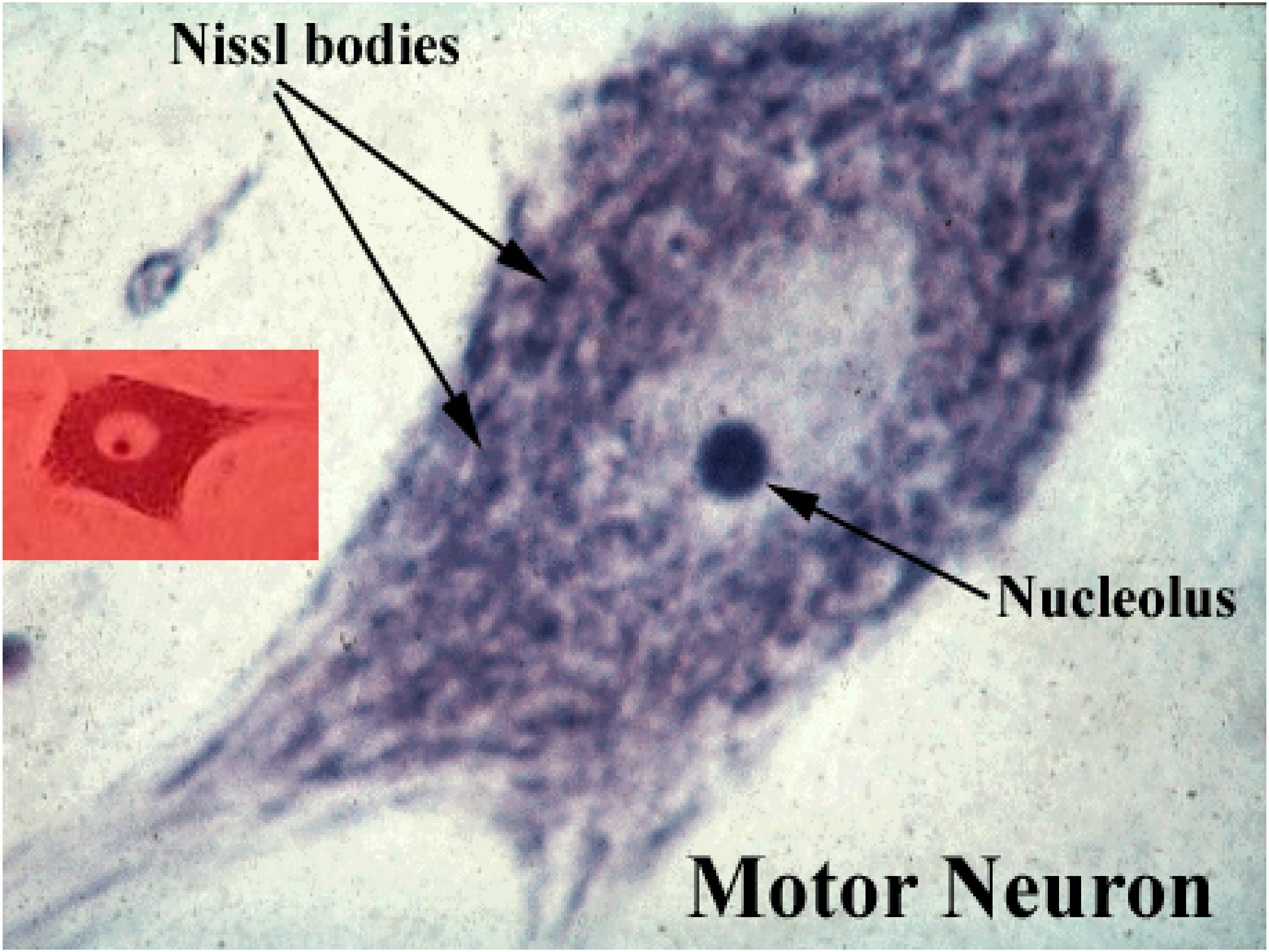
- Contains nucleus plus most normal organelles.
- Biosynthetic center of the neuron.
- Contains a very active and developed rough endoplasmic reticulum which is responsible for the synthesis of _________.
  - The neuronal rough ER is referred to as the Nissl body.
- Contains many bundles of protein filaments (neurofibrils) which help maintain the shape, structure, and integrity of the cell.



In the soma above, notice the small black circle. It is the nucleolus, the site of ribosome synthesis. The light circular area around it is the nucleus. The mottled dark areas found throughout the cytoplasm are the Nissl substance.

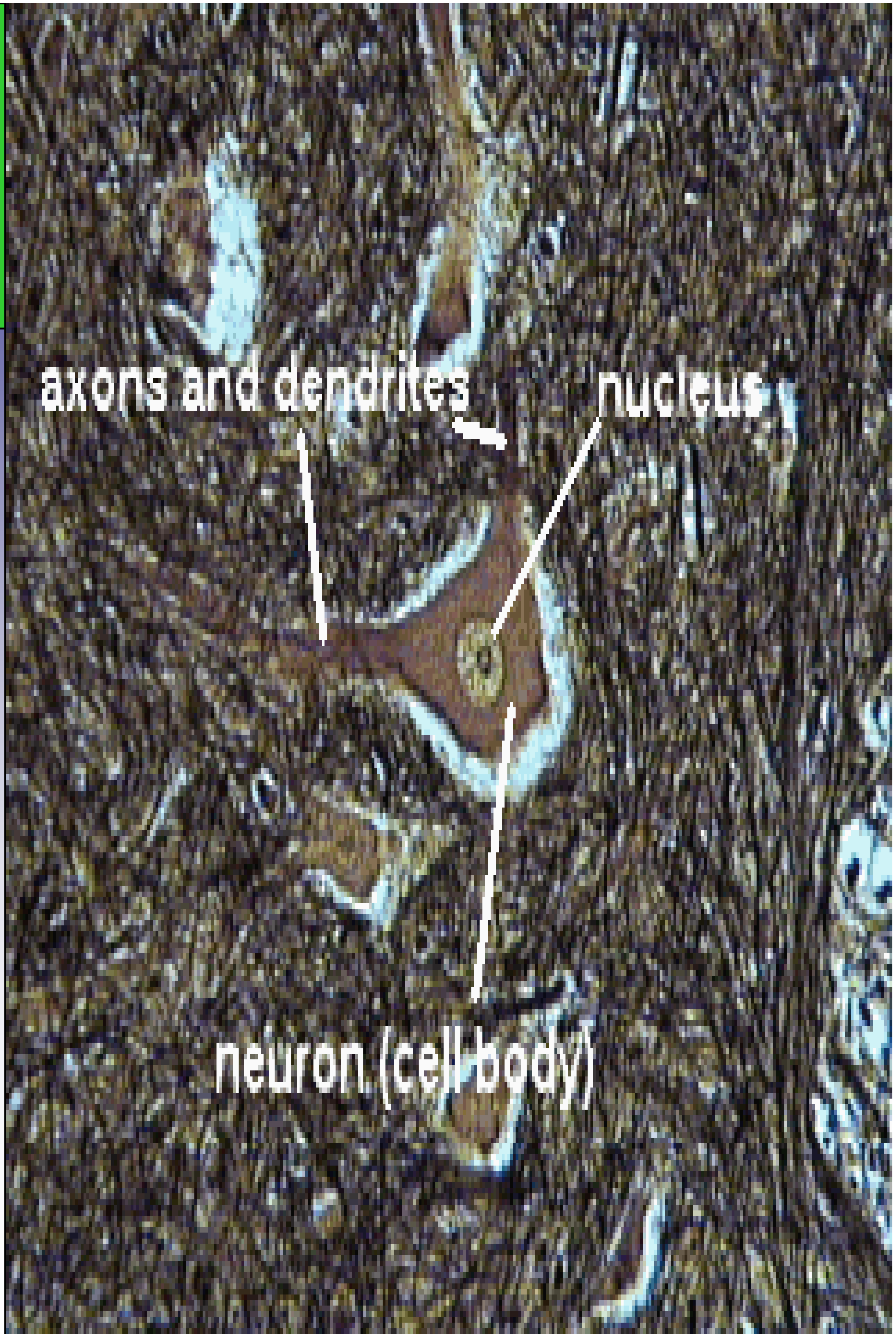
A Nissl body (or Nissl granule or tigroid body) is a large granular body found in nerve cells.

These granules are rough endoplasmic reticulum (with ribosomes) and are the site of protein synthesis.
Nissl bodies show changes under various physiological conditions and in pathological conditions they may dissolve and disappear (karyolysis).


Nissl bodies
Nucleolus
Motor Neuron

Somata

- Contain multiple mitochondria.
- Acts as a receptive service for interaction with other neurons.
- Most somata are found in the bony environs of the CNS.
- Clusters of somata in the CNS are known as nuclei.
- Clusters of somata in the PNS are known as ganglia.



The **axolemma** is the membrane of a neuron's axon.

It is responsible for maintaining the cell's membrane potential, and it contains channels through which ions can flow.

Neurons (gray matter): soma, axon (axon hillock, axoplasm, **axolemma**, neurofibril/neurofilament), dendrite (Nissl body, dendritic spine)
<u>types</u> (bipolar, pseudounipolar, multipolar, pyramidal, Purkinje, Renshaw, granule)

Synapses: neuropil, boutons, synaptic vesicle, neuromuscular junction, electrical synapse

Sensory receptors: Free nerve ending, Meissner's corpuscle, Merkel nerve ending, Muscle spindle, Pacinian corpuscle, Ruffini ending, Olfactory receptor neuron, Photoreceptor, Hair cell, Taste bud

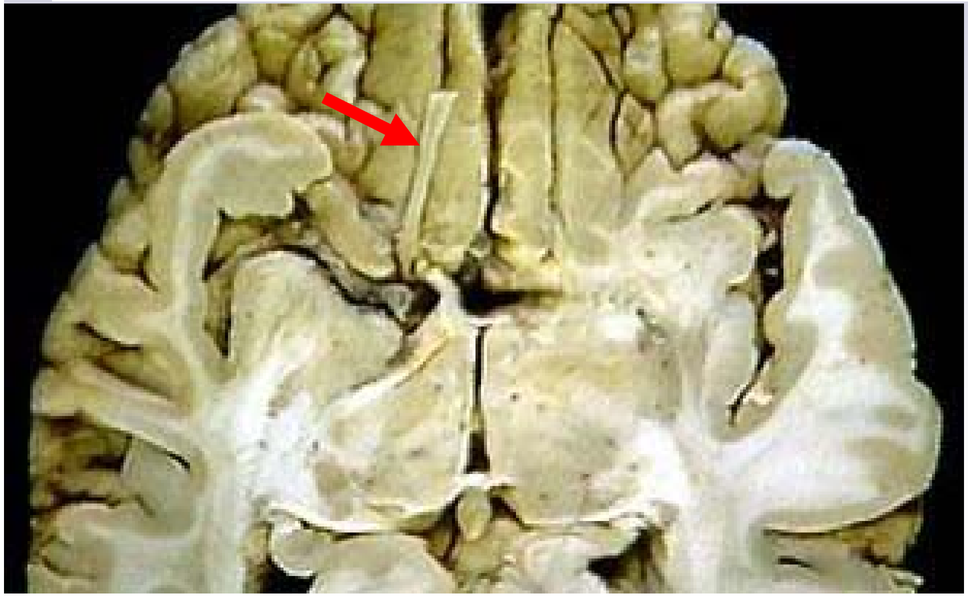
Glial cells: astrocyte, ependymal cells, microglia, radial glia

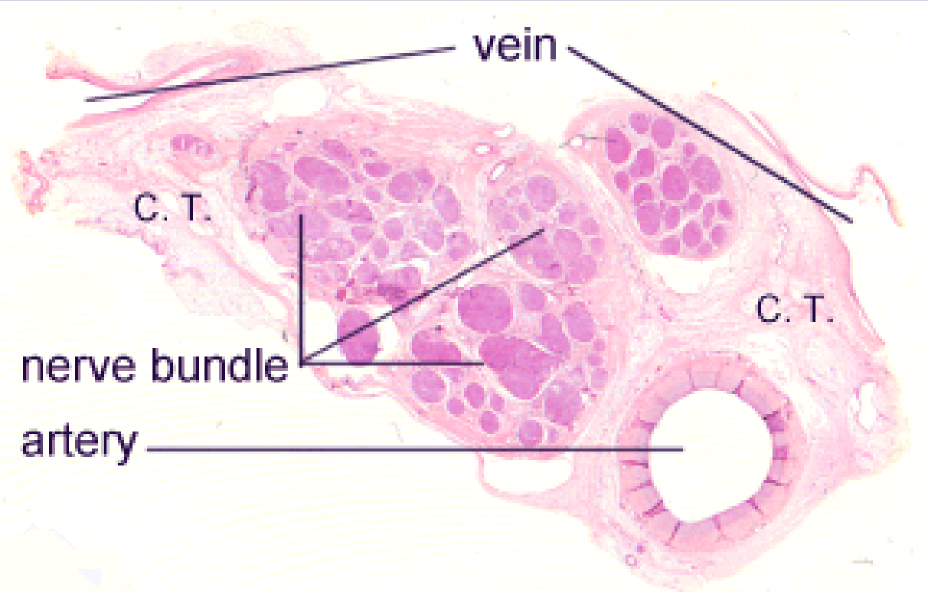
Myelination (white matter): Schwann cell, oligodendrocyte, nodes of Ranvier, internode, Schmidt-Lanterman incisures, neurolemma

Neuronal Processes

- Armlike extensions emanating from every neuron.
- The CNS consists of both somata and processes whereas the bulk of the PNS consists of processes.
- Tracts = Bundles of processes in the CNS (red arrow)

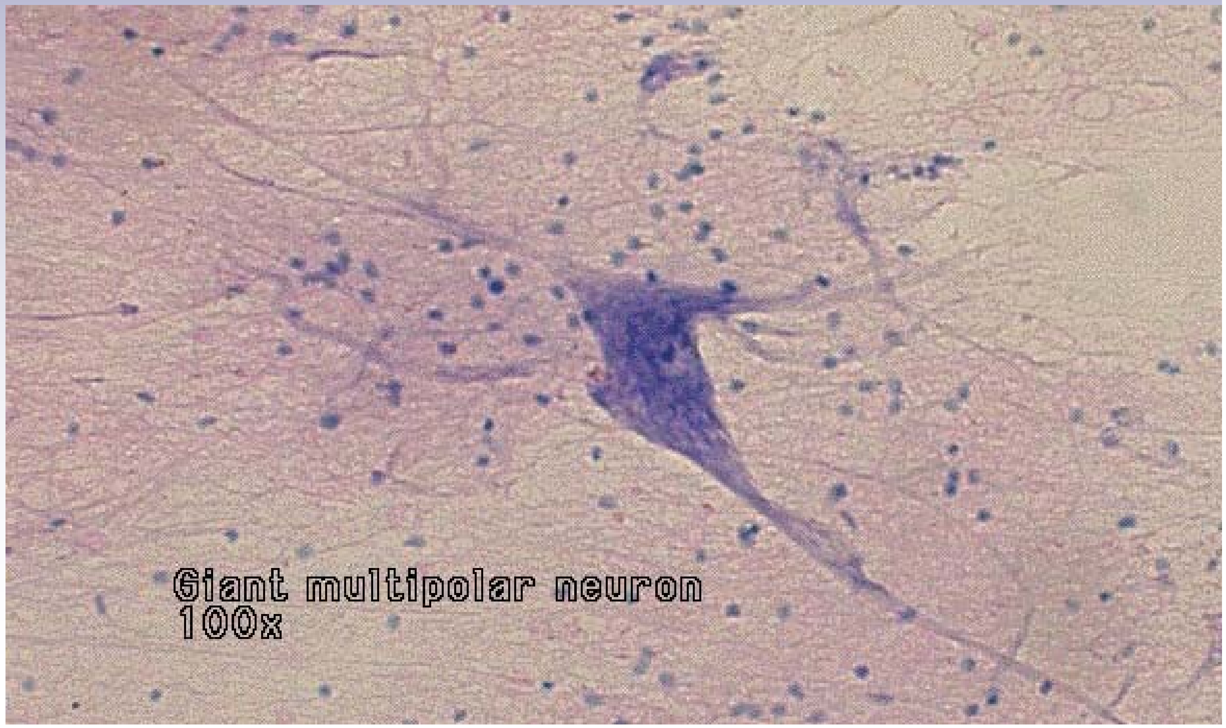
  Nerves = Bundles of processes in the PNS
- 2 types of processes that differ in structure and function:
  - Dendrites and Axons



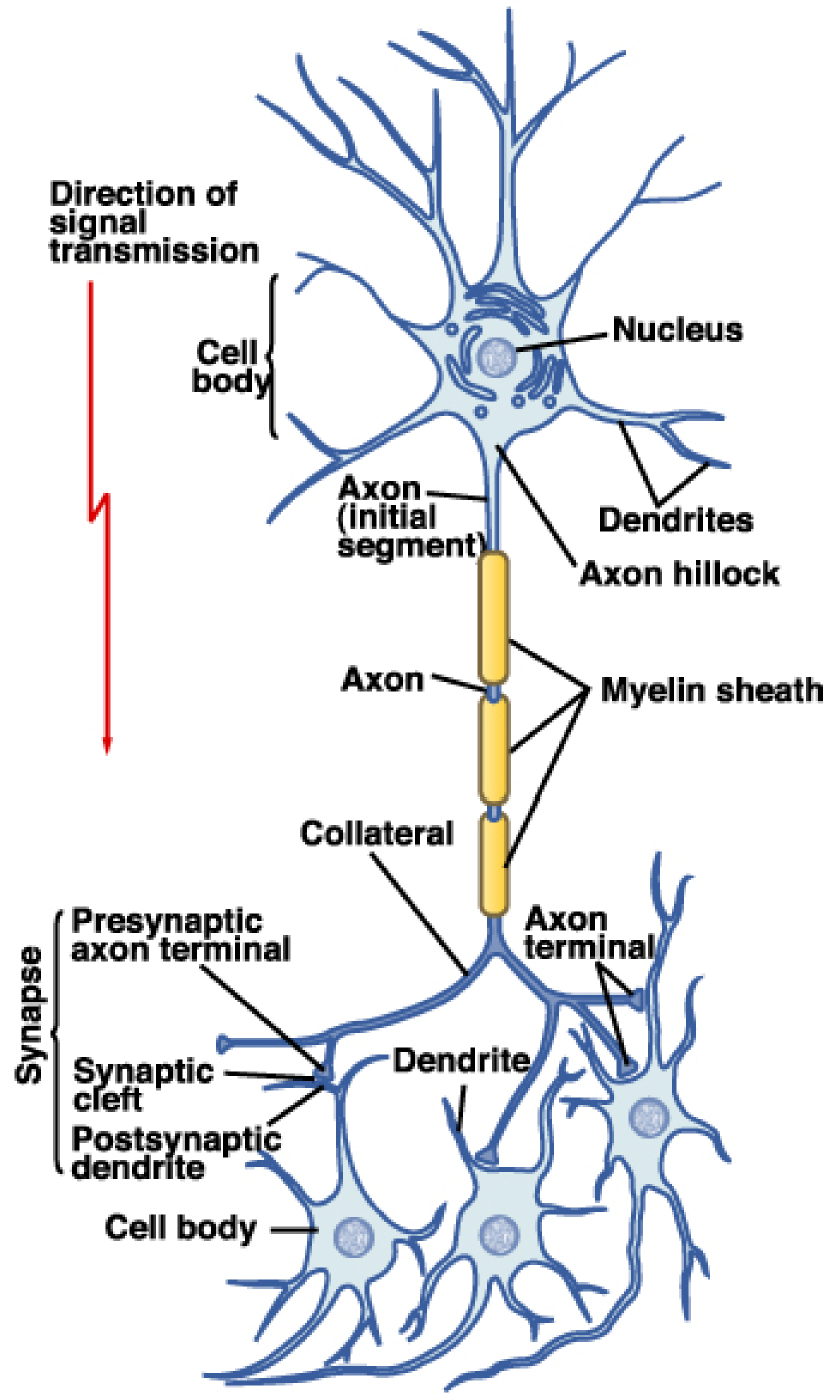


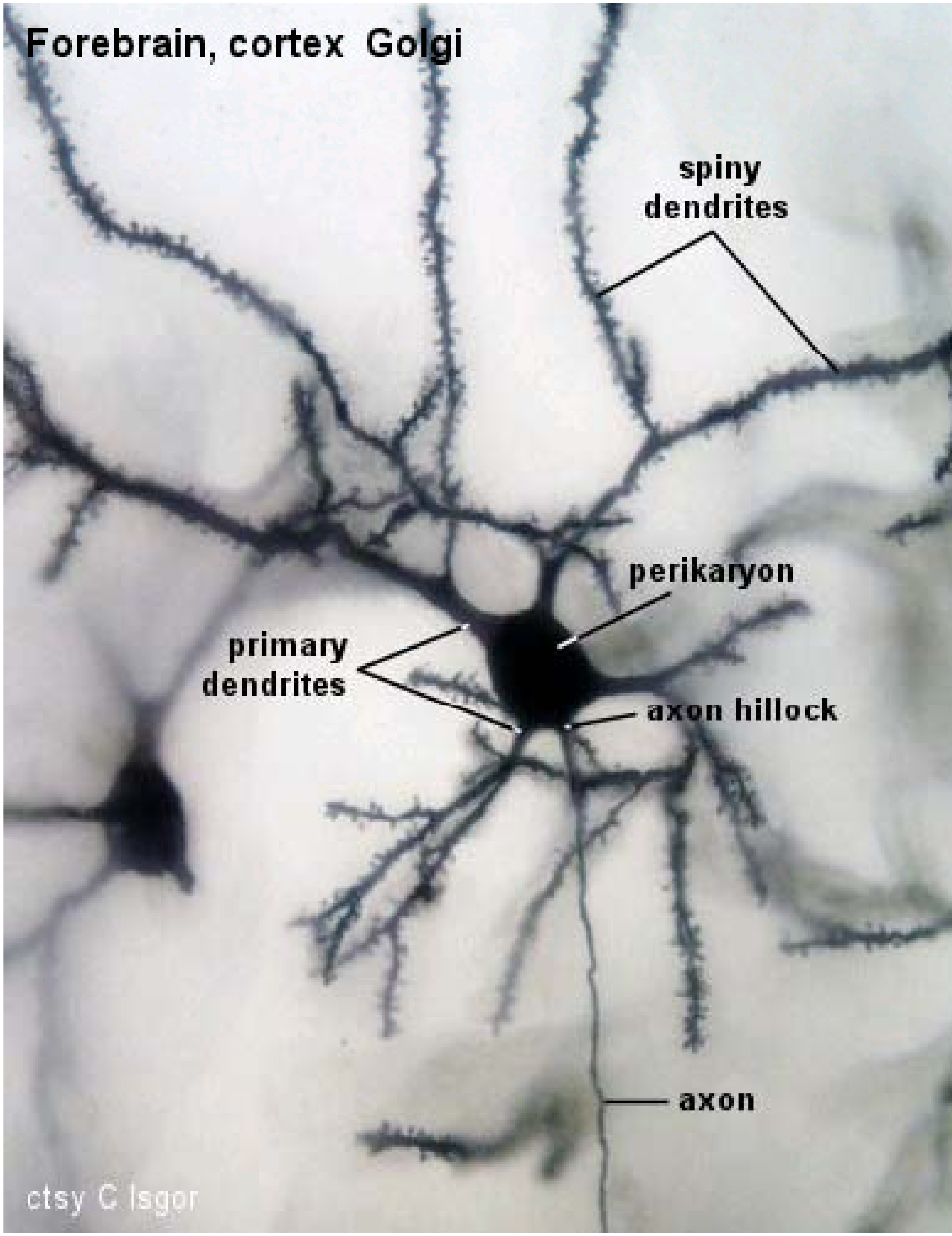
- Dendrites are thin, branched processes whose main function is to receive incoming signals.
- They effectively increase the surface area of a neuron to increase its ability to communicate with other neurons.
  - Small, mushroom-shaped dendritic spines further increase the SA
- Convey info towards the soma thru the use of graded potentials – which are somewhat similar to action potentials.

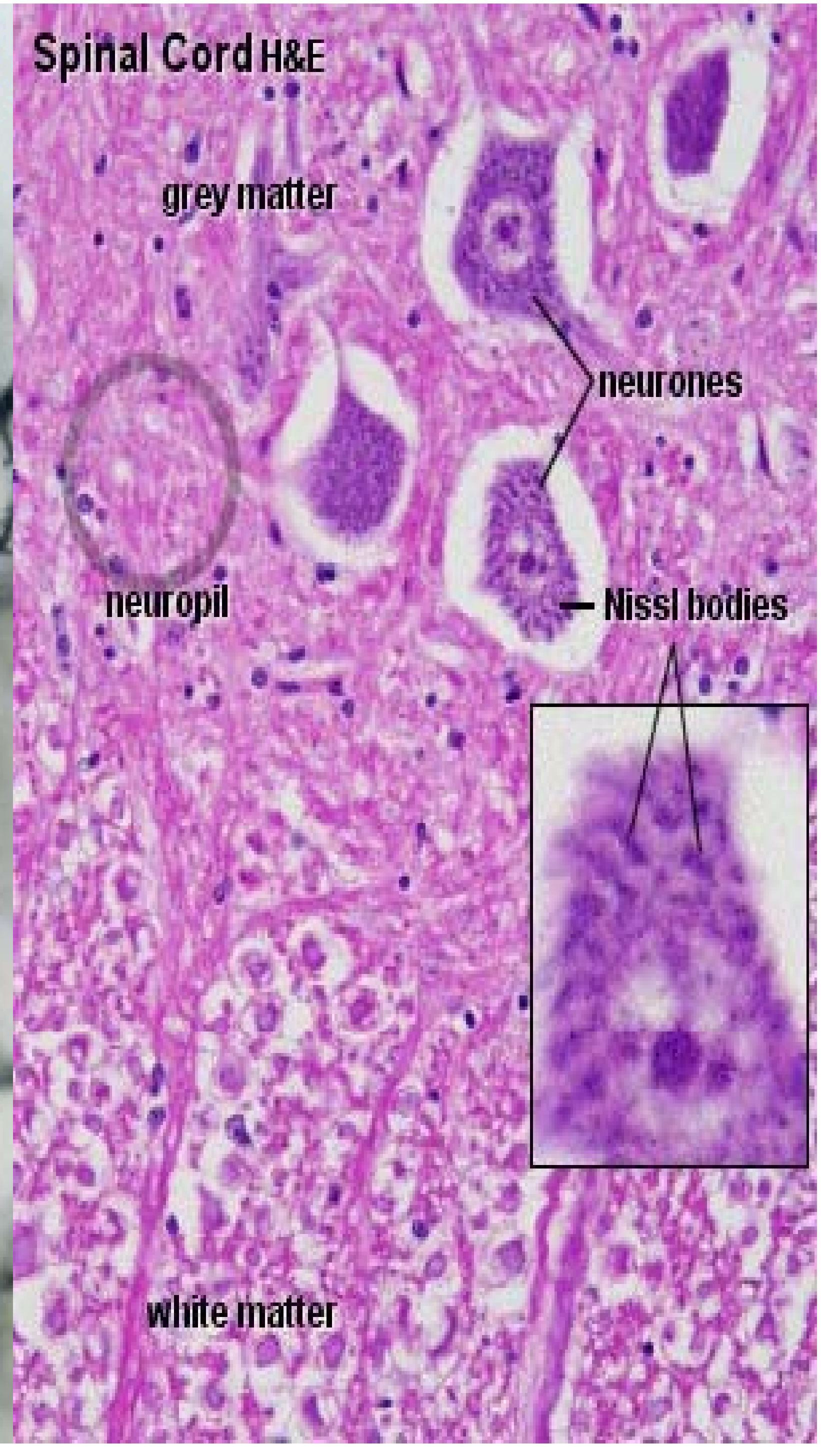
Notice the multiple processes extending from the neuron on the right. Also notice the multiple dark circular dots in the slide. They're not neurons, so they must be…

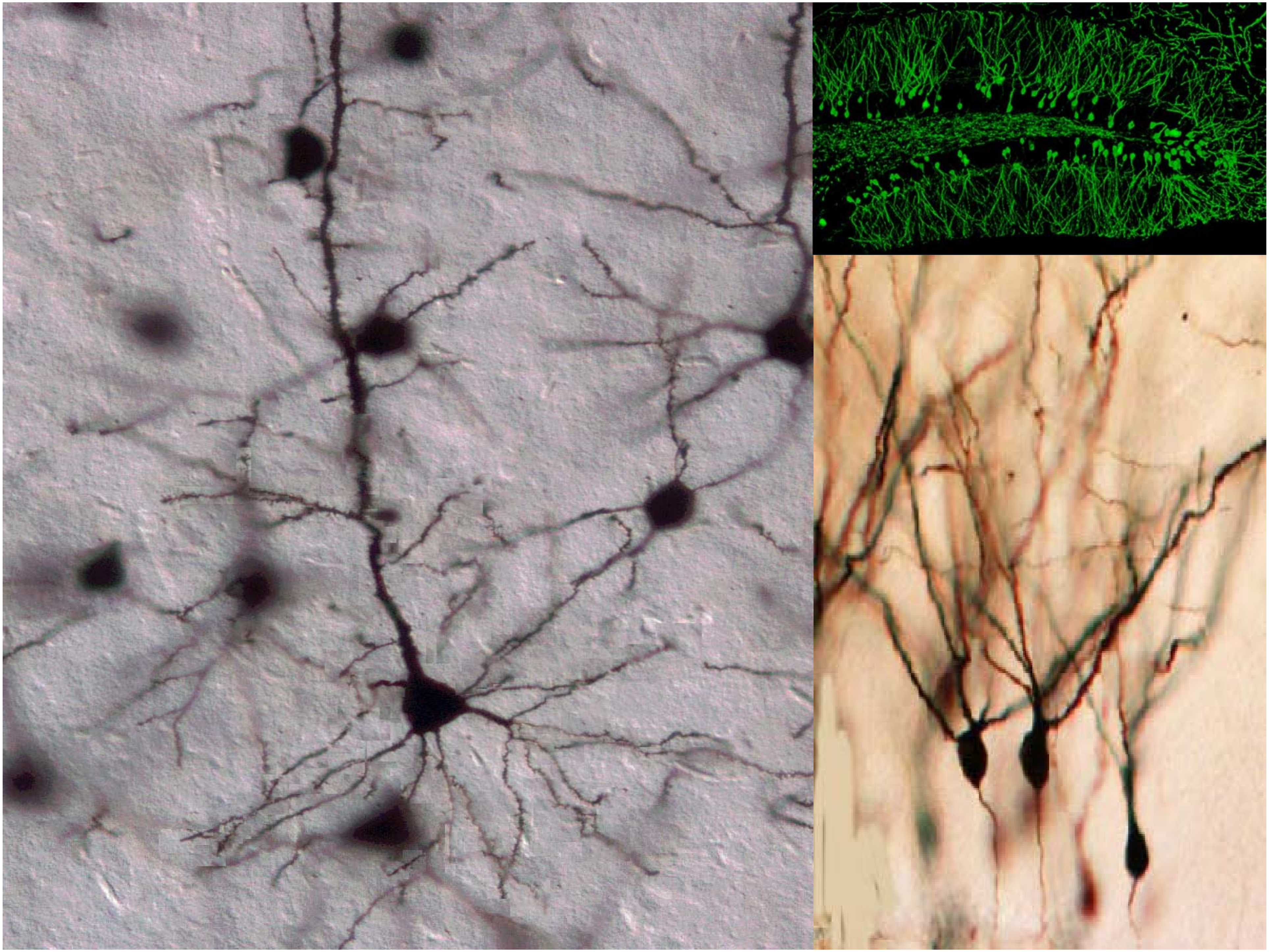


- Most neurons have a single <u>axon</u> – a long (up to 1m) process designed to convey info away from the cell body.
- Originates from a special region of the cell body called the axon hillock.
- Transmit APs from the soma toward the end of the axon where they cause NT release.
- Often branch sparsely, forming collaterals.
- Each collateral may split into telodendria which end in a synaptic knob, which contains synaptic vesicles – membranous bags of NTs.

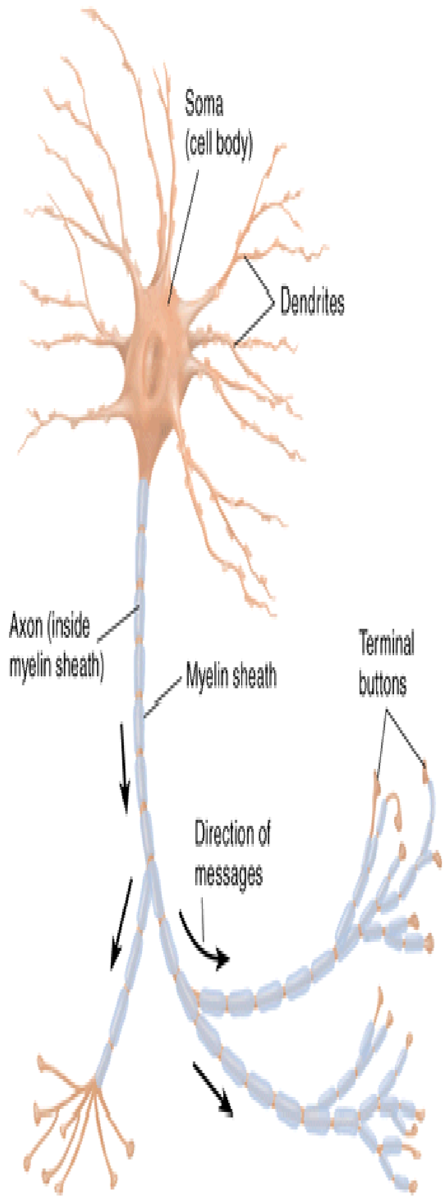


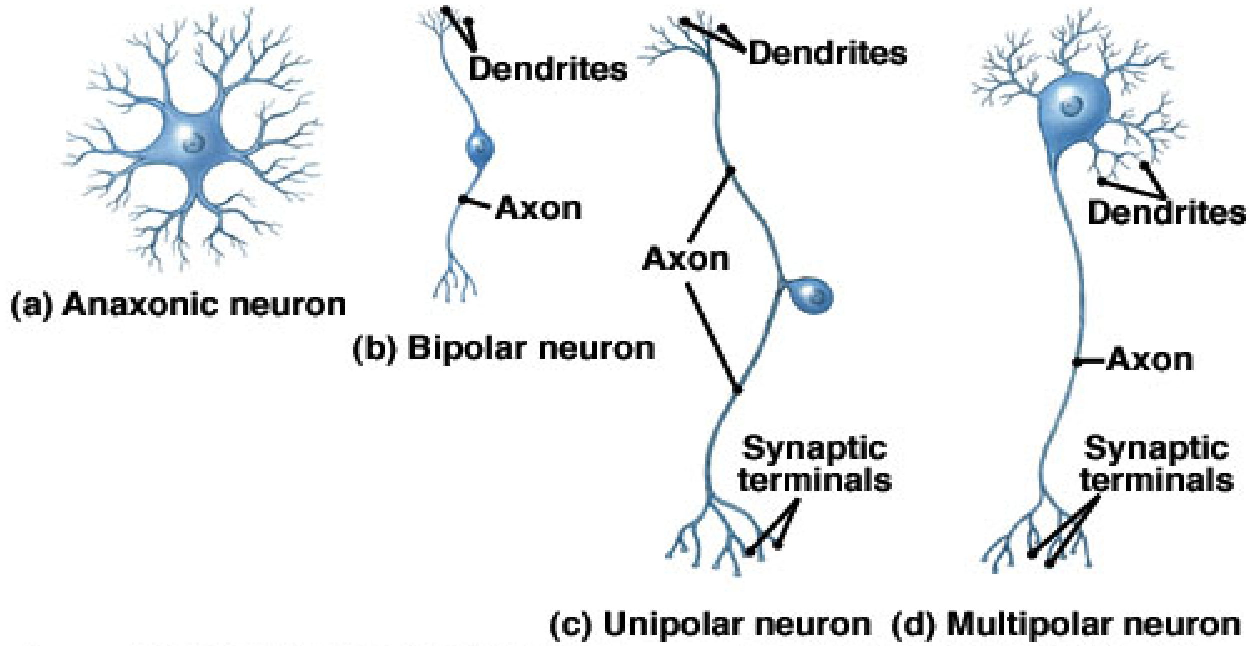

Forebrain, cortex Golgi
spiny
dendrites
perikaryon
primary
dendrites
axon hillock
axon
ctsy C Isgor

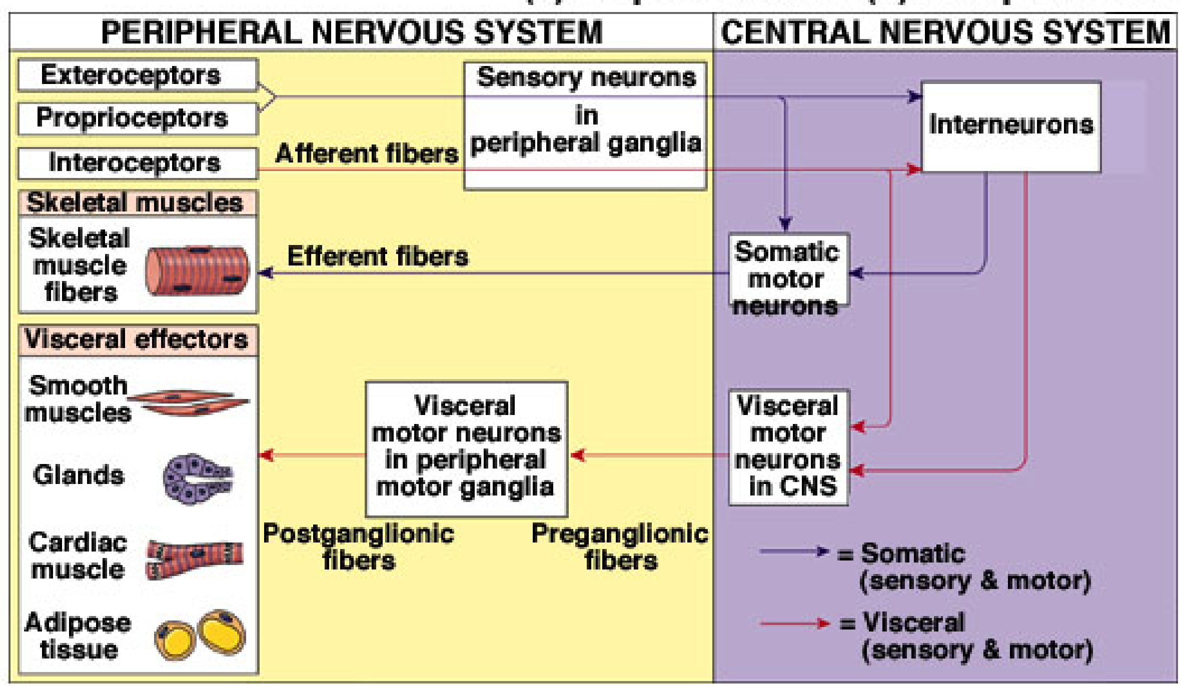

Spinal Cord H&E
grey matter
neurones
neuropil
Nissl bodies
white matter



▸ Multipolar Neuron

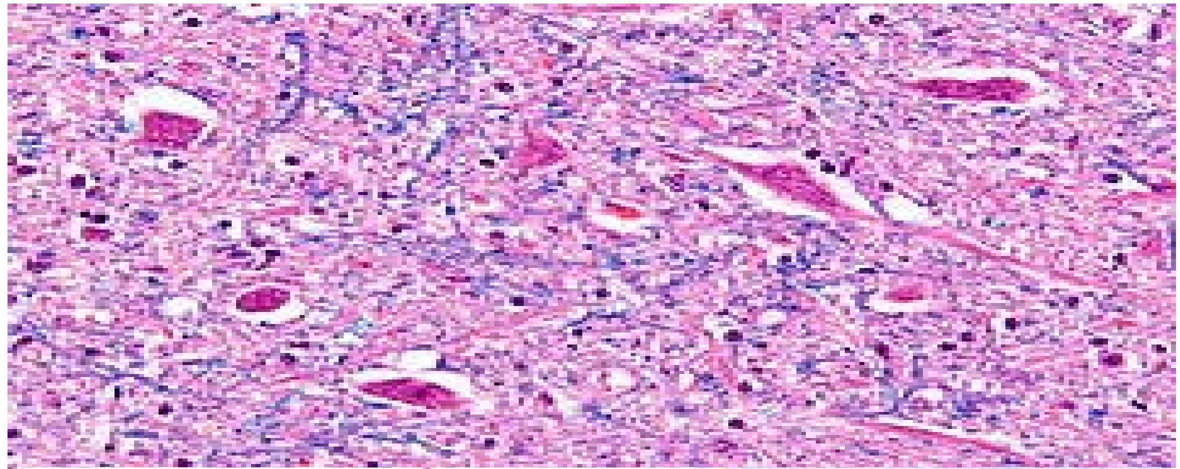


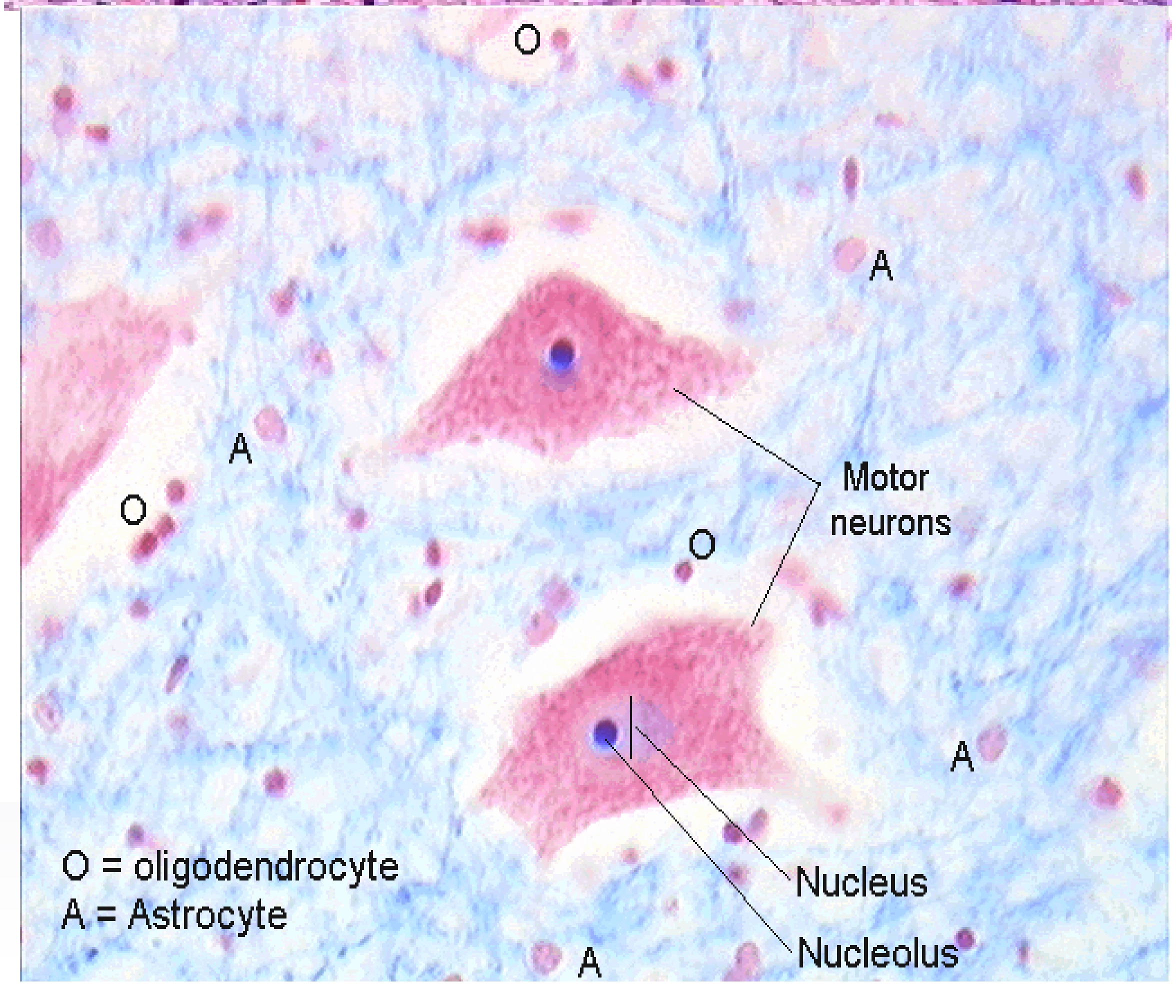




Motor neurons

- These transmit impulses from the central nervous system to the
  - muscles and
  - glands
- that carry out the response.
- Most motor neurons are stimulated by interneurons, although some are stimulated directly by sensory neurons.

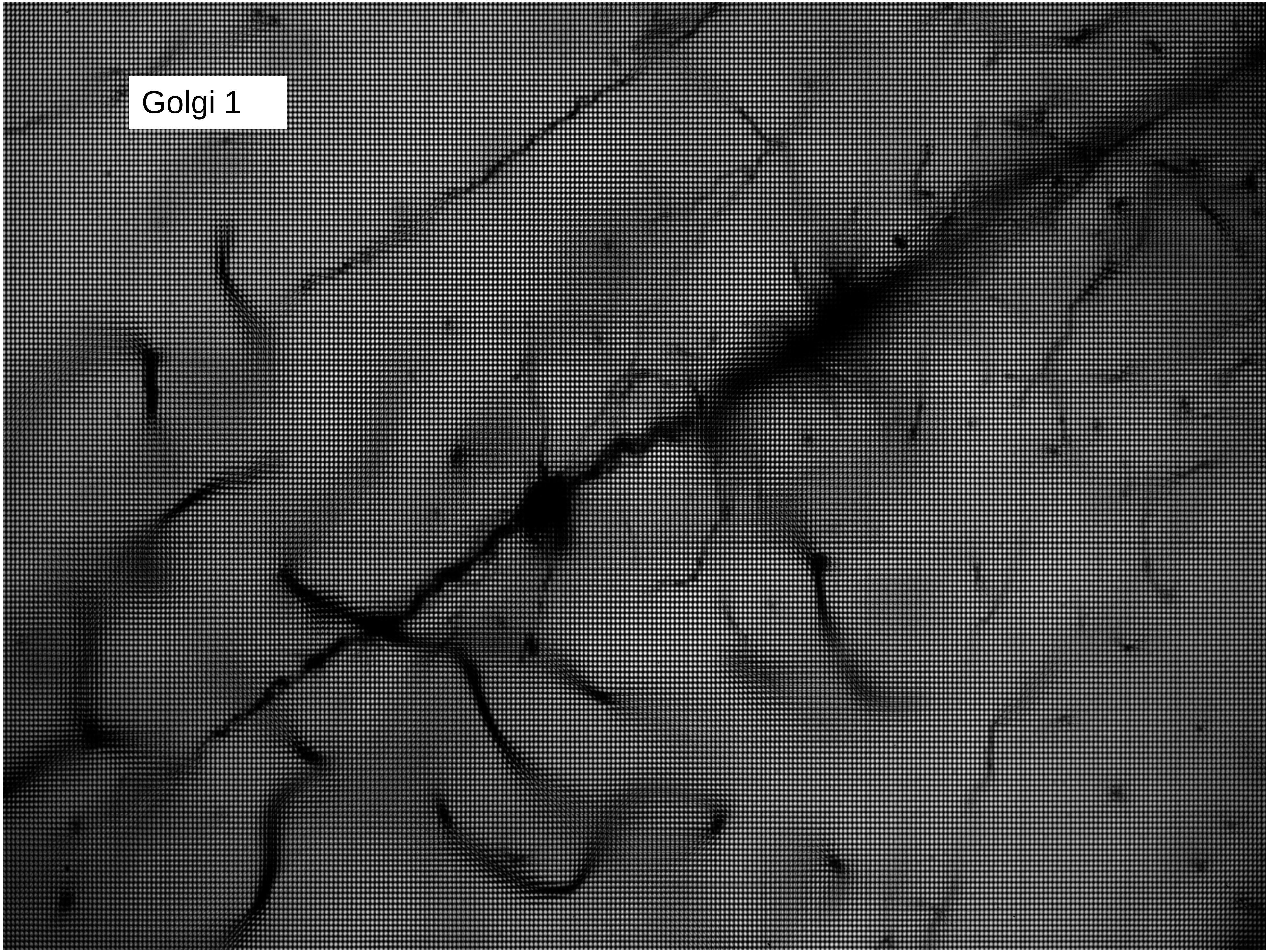




Structural classification

Most neurons can be anatomically characterized as:

- **Unipolar or Pseudounipolar-** dendrite and axon emerging from same process.
- **Bipolar -** single axon and single dendrite on opposite ends of the soma.
- **Multipolar** - more than two dendrites
  - **Golgi I-** neurons with long-projecting axonal processes.
  - **Golgi II-** neurons whose axonal process projects locally.


Golgi 1

Functional classification

- **Afferent neurons** convey information from tissues and organs into the central nervous system.

- **Efferent neurons** transmit signals from the central nervous system to the effector cells and are sometimes called motor neurons.

- **Interneurons** connect neurons within specific regions of the central nervous system.

Afferent and *efferent* can also refer to neurons which convey information from one region of the brain to another.

Sensory receptors

may be the processes of specialized sensory neurons or cells monitored by sensory neurons.

Receptors are broadly categorized as follows:

Exteroceptors provide information about the external environment in the form of touch, temperature, or pressure sensations and the more complex senses of sight, smell, and hearing.

Proprioceptors monitor the position and movement of skeletal muscles and joints.

Interoceptors monitor the digestive, respiratory, cardiovascular, urinary, and reproductive systems and provide sensations of taste, deep pressure, and pain.

Classification by action on other neurons

- **Excitatory neurons**
  - evoke excitation of their target neurons.
  - Excitatory neurons in the brain are often **glutamatergic**. Spinal motoneurons use acetylcholine as their neurotransmitter.

- **Inhibitory neurons**
  - evoke inhibition of their target neurons. Inhibitory neurons are often interneurons.
  - The output of some brain structures (neostriatum, globus pallidus, cerebellum) are inhibitory.
  - The primary inhibitory neurotransmitters are **GABA** and glycine.

- **Modulatory neurons**
  - evoke more complex effects termed neuromodulation.
  - These neurons use such neurotransmitters as dopamine, acetylcholine, serotonin and others.

Classification by discharge patterns

Neurons can be classified according to their electrophysiological characteristics:

- **Tonic or regular spiking.** Some neurons are typically constantly (or tonically) active. Example: interneurons in neurostriatum.

- **Phasic or bursting.** Neurons that fire in bursts are called phasic.

- **Fast spiking.** Some neurons are notable for their fast firing rates, for example some types of cortical inhibitory interneurons, cells in globus pallidus.

- **Thin-spike.** Action potentials of some neurons are more narrow compared to the others. For example, interneurons in prefrontal cortex are thin-spike neurons.

.

Classification by neurotransmitter released

Some examples are

- **cholinergic,**
- **GABA-ergic,**
- **glutamatergic**
- **dopaminergic neurons.**

Neurosecretory Cells:Secrete hormones and similar substances

Hypothalamus of brain, adrenal medulla gland, etc some unique neuronal types can be identified according to their location in the nervous system and distinct shape.

Some examples are:

•**Basket cells,** interneurons that form a dense plexus of terminals around the soma of target cells, found in the cortex and cerebellum.

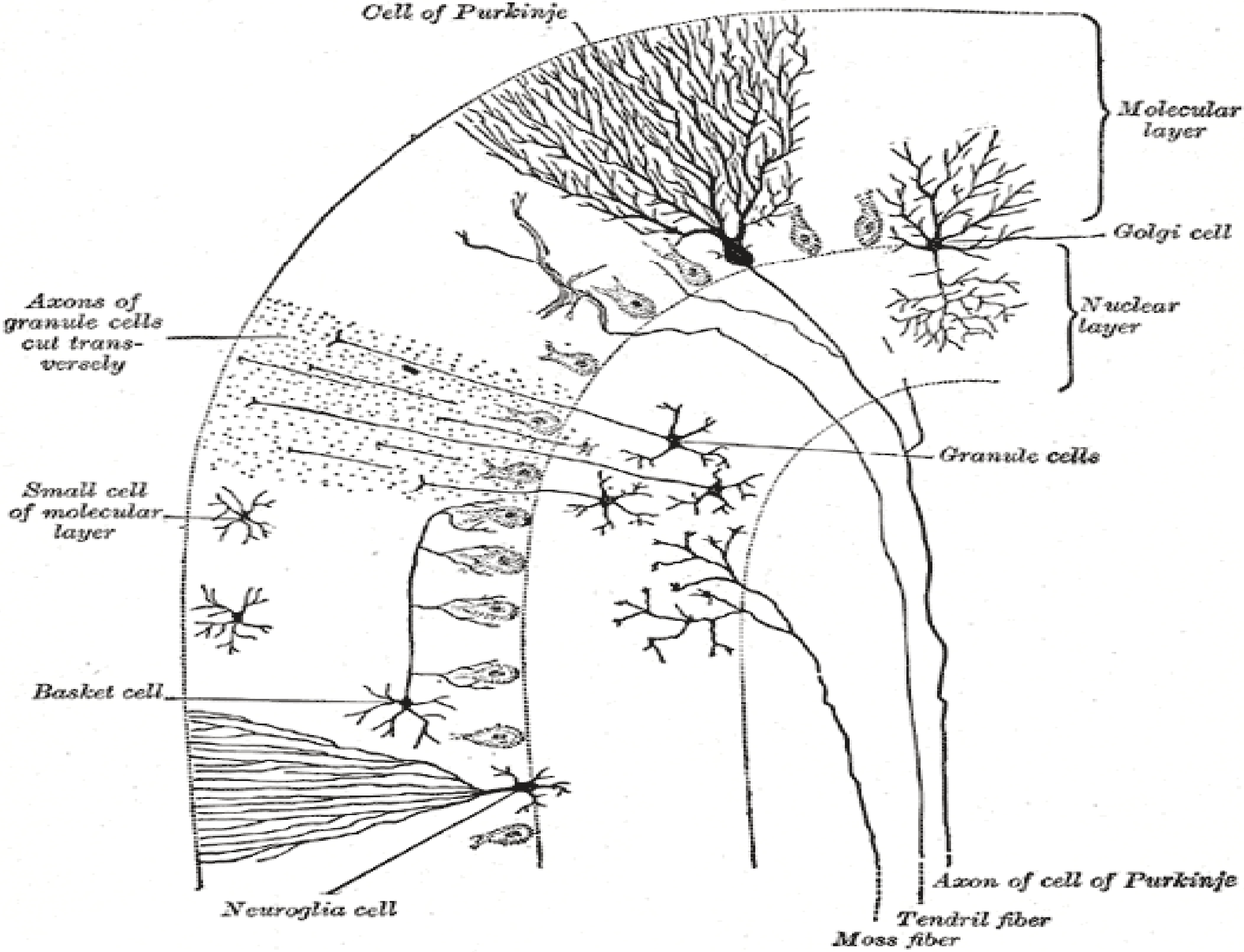
•**Betz cells**, large motor neurons.

•**Medium spiny neurons,** most neurons in the corpus striatum.

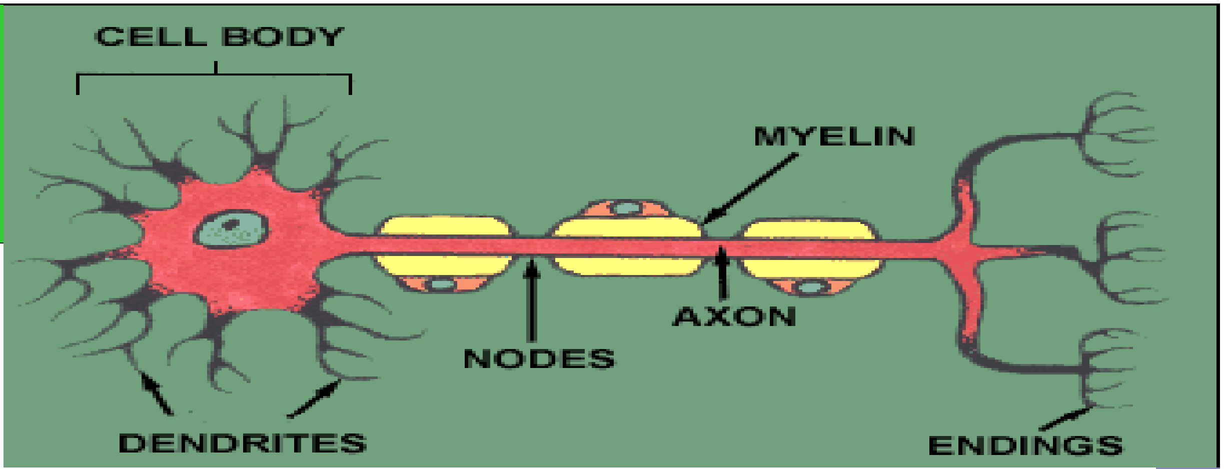
•**Purkinje cells,** huge neurons in the cerebellum, a type of Golgi I multipolar neuron.
•**Pyramidal cells,** neurons with triangular soma, a type of Golgi I.

•**Renshaw cells,** neurons with both ends linked to alpha motor neurons.
•Granule cells, a type of Golgi II neuron.

•**Anterior horn cells**, motoneurons located in the spinal cord.


Cell of Purkinje
Molecular layer
Golgi cell
Nuclear layer
Axons of granule cells cut transversely
Granule cells
Small cell of molecular layer
Basket cell
Neuroglia cell
Axon of cell of Purkinje
Tendril fiber
Moss fiber

Axons

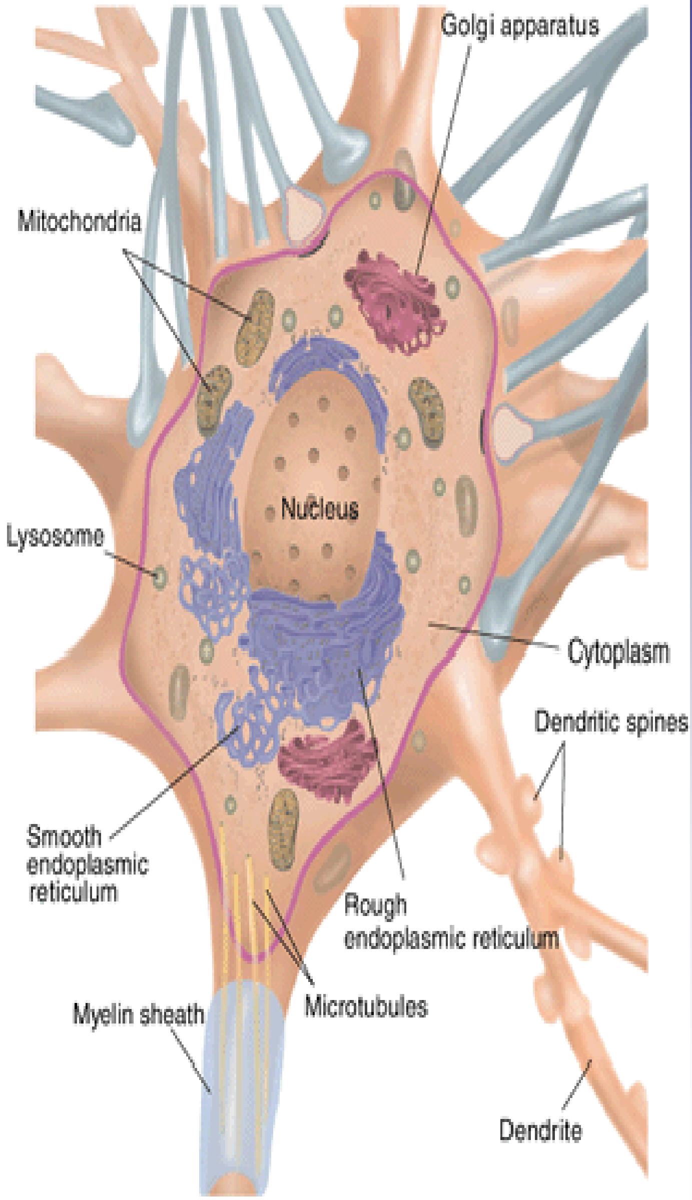


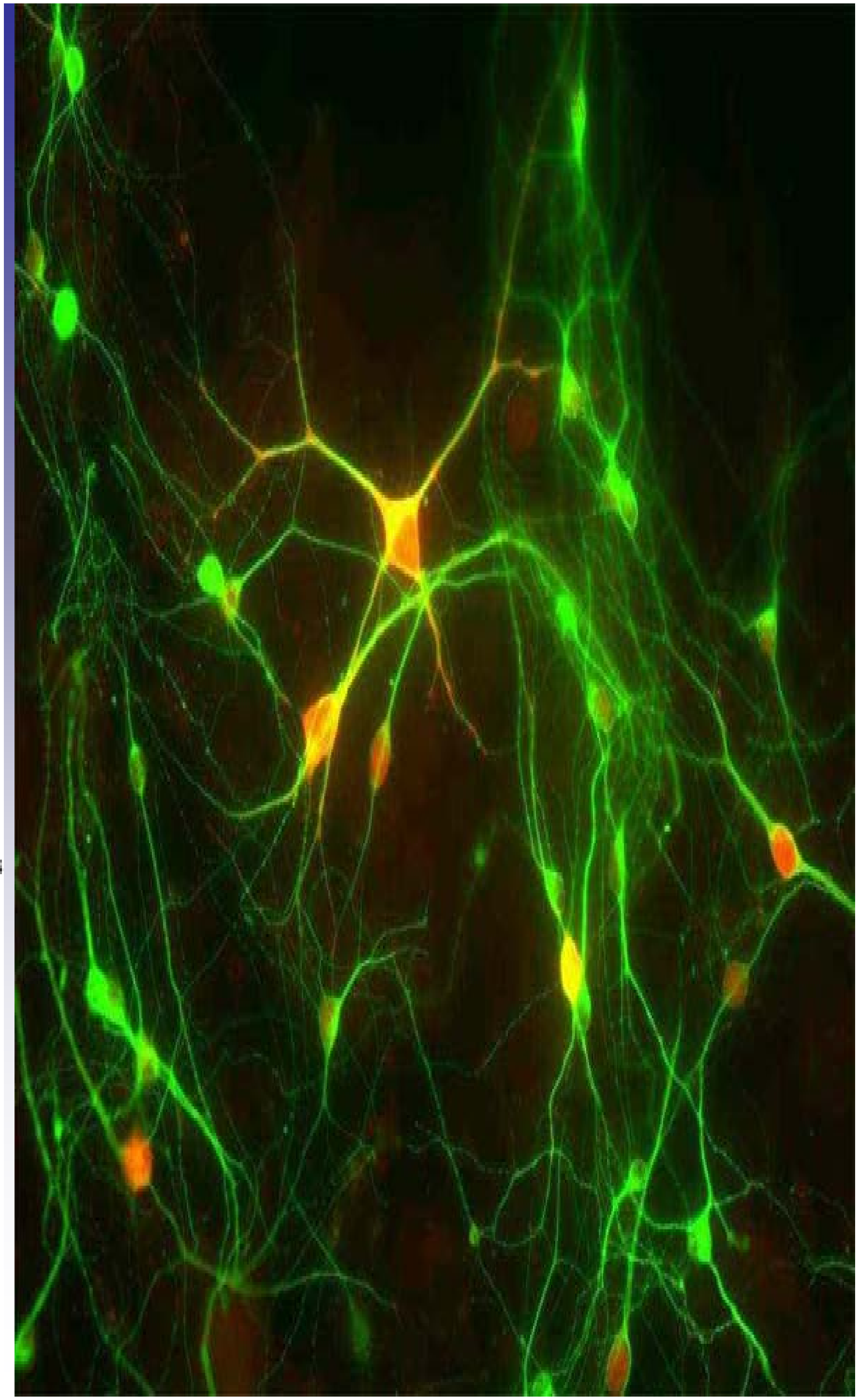
- Axolemma = axon plasma membrane.
- Surrounded by a myelin sheath, a wrapping of lipid which:
  - Protects the axon and electrically isolates it
  - Increases the rate of AP transmission
- The myelin sheath is made by _________ in the CNS and by __________ in the PNS.
- This wrapping is never complete. Interspersed along the axon are gaps where there is no myelin – these are nodes of Ranvier.
- In the PNS, the exterior of the Schwann cell surrounding an axon is the neurilemma

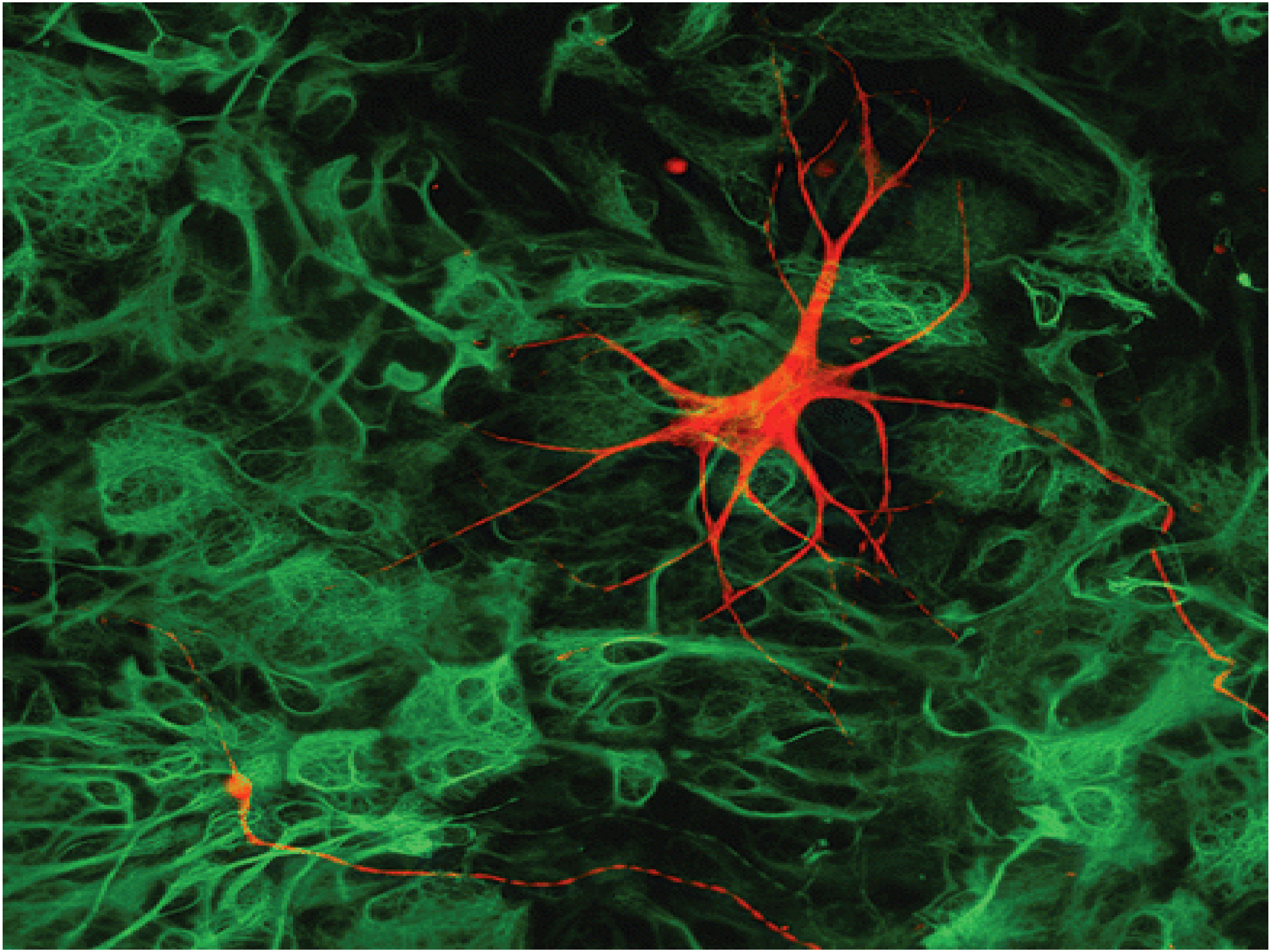
Axons: Function

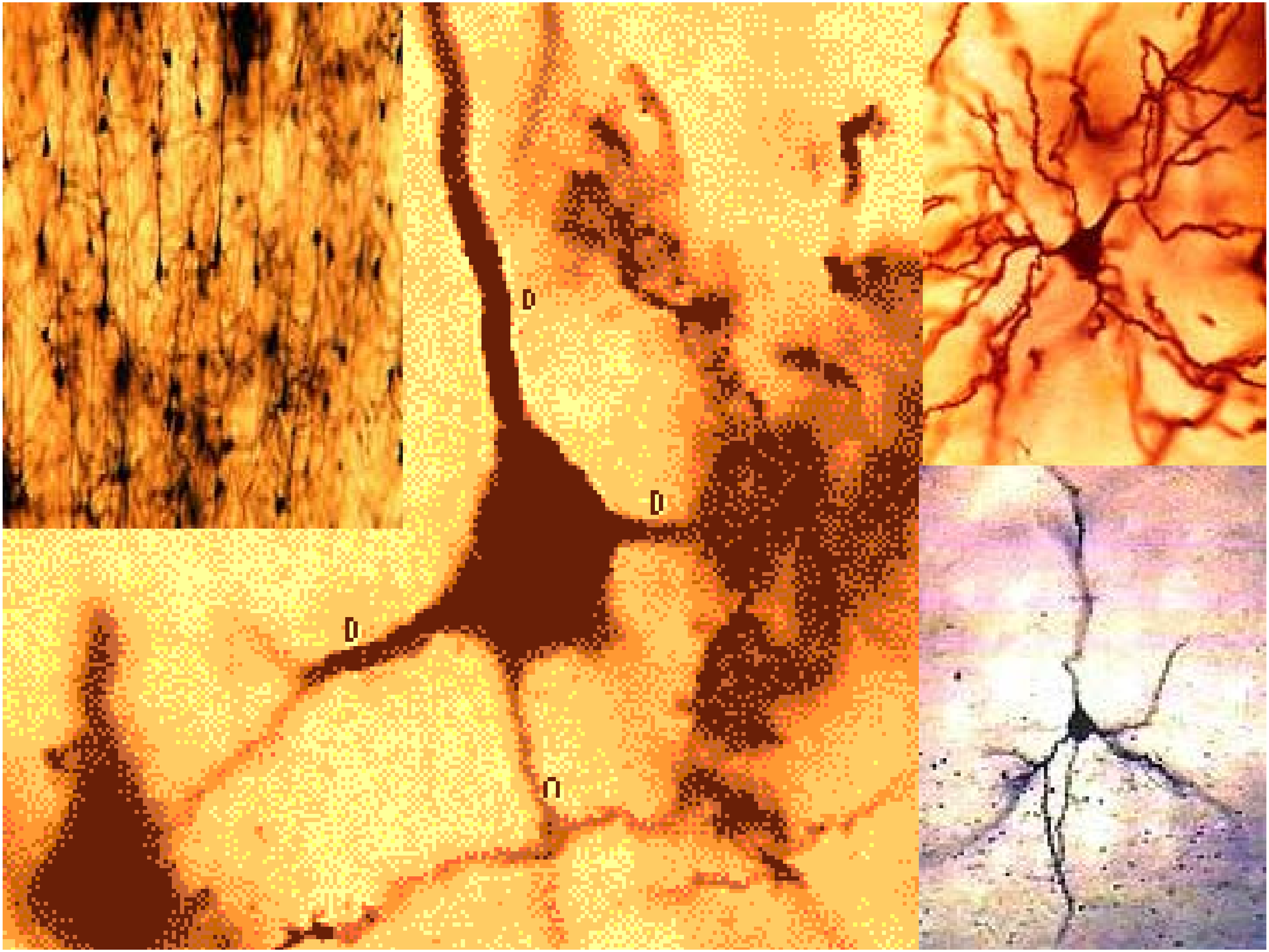
- Generate and transmit action potentials
- Secrete neurotransmitters from the axonal terminals
- Movement along axons occurs in two ways
  - Anterograde — toward axonal terminal
  - Retrograde — away from axonal terminal

▸ **Principal Internal Structures of a Multipolar Neuron**





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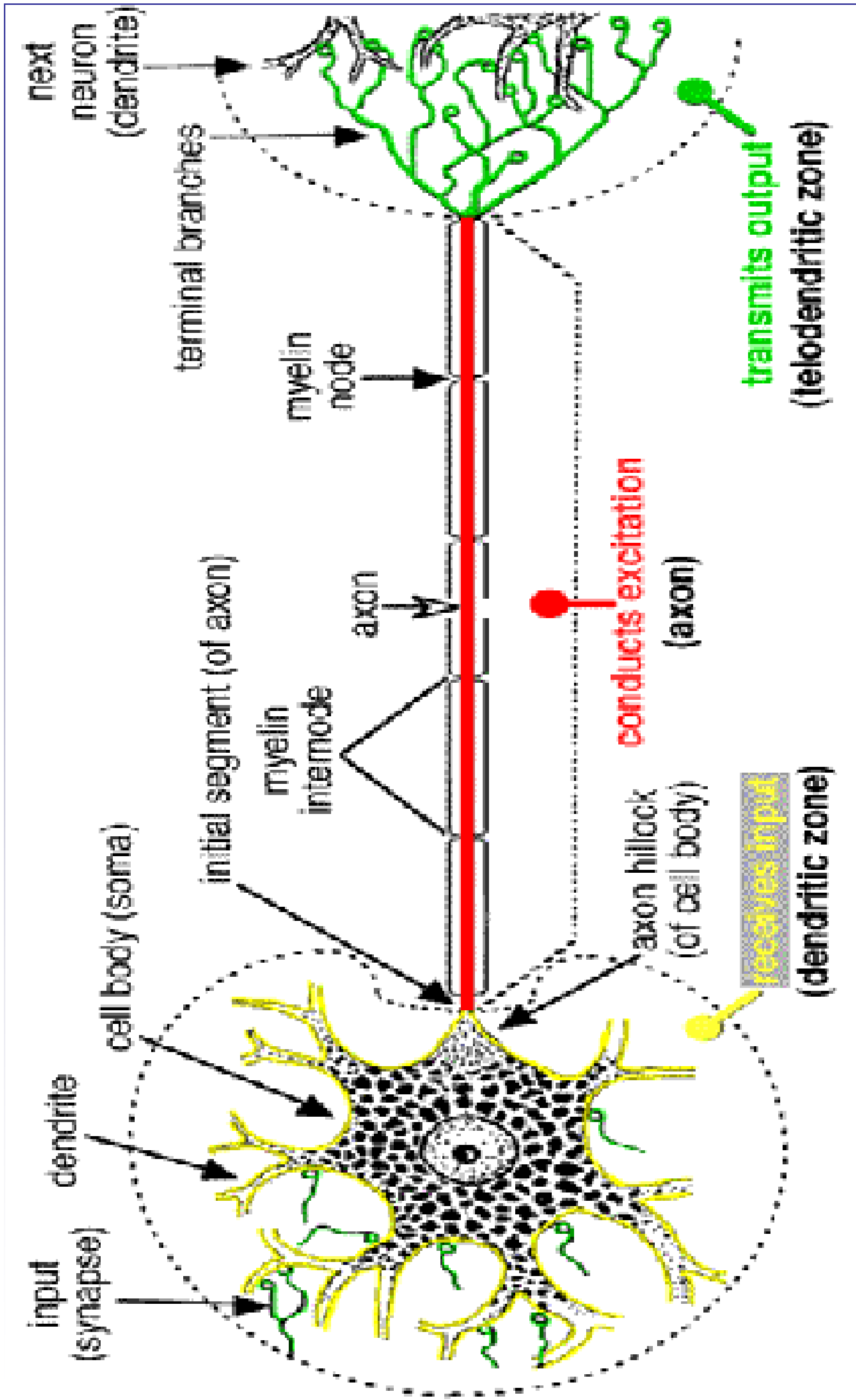


<u>Cell body (perikaryon)</u>

– "Nutrition center"

– Cell bodies within CNS clustered into nuclei, and in PNS in ganglia

• Dendrites

– Provide receptive area

– Transmit electrical impulses to cell body

<u>• Axon</u>

– Conducts impulses away from cell body

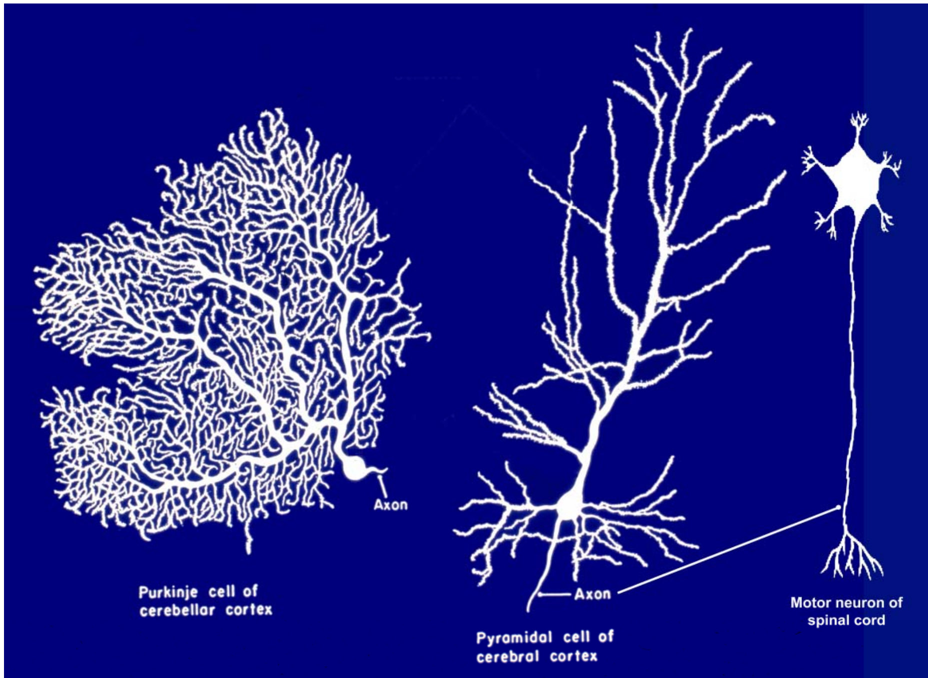
– Axoplasmicflow:

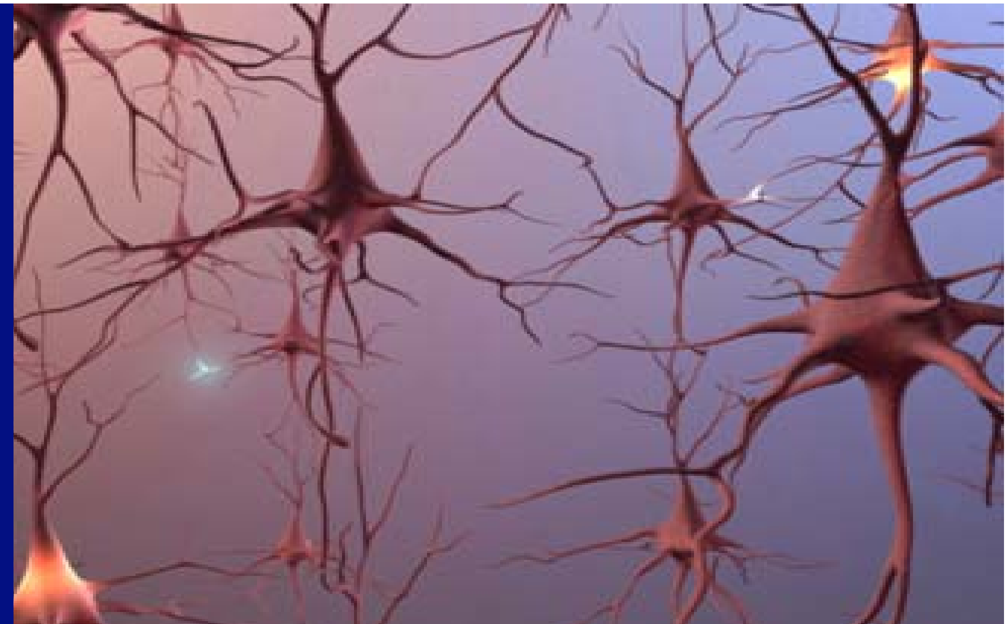
• Proteins and other molecules are transported by rhythmic contractions to nerve endings

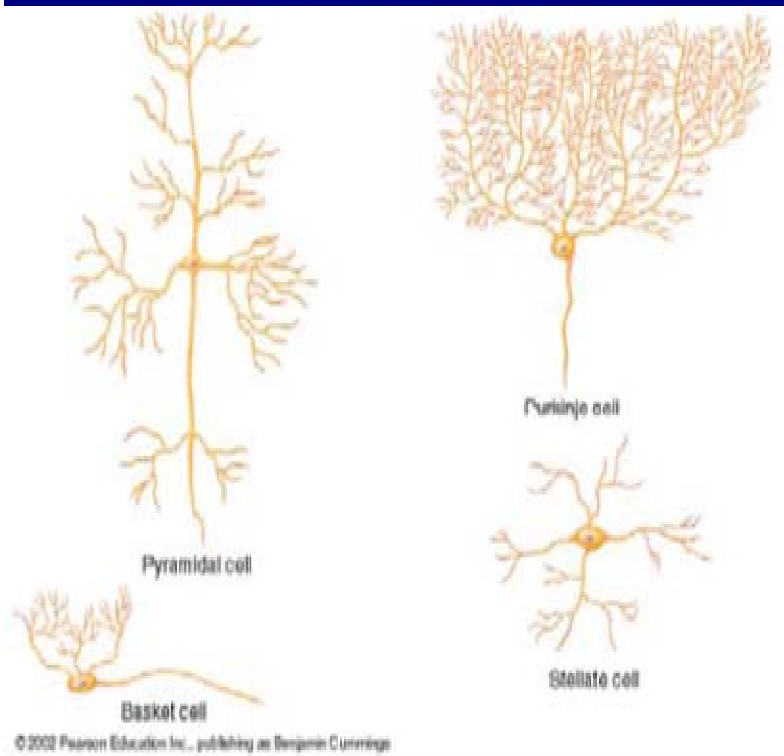
– <u>Axonal transport:</u>

• Employs microtubules for transport

• May occur in orthograde or retrograde direction


Axon
Purkinje cell of cerebellar cortex
Axon
Pyramidal cell of cerebral cortex
Motor neuron of spinal cord




Purkinje cell
Pyramidal cell
Stellate cell
Basket cell
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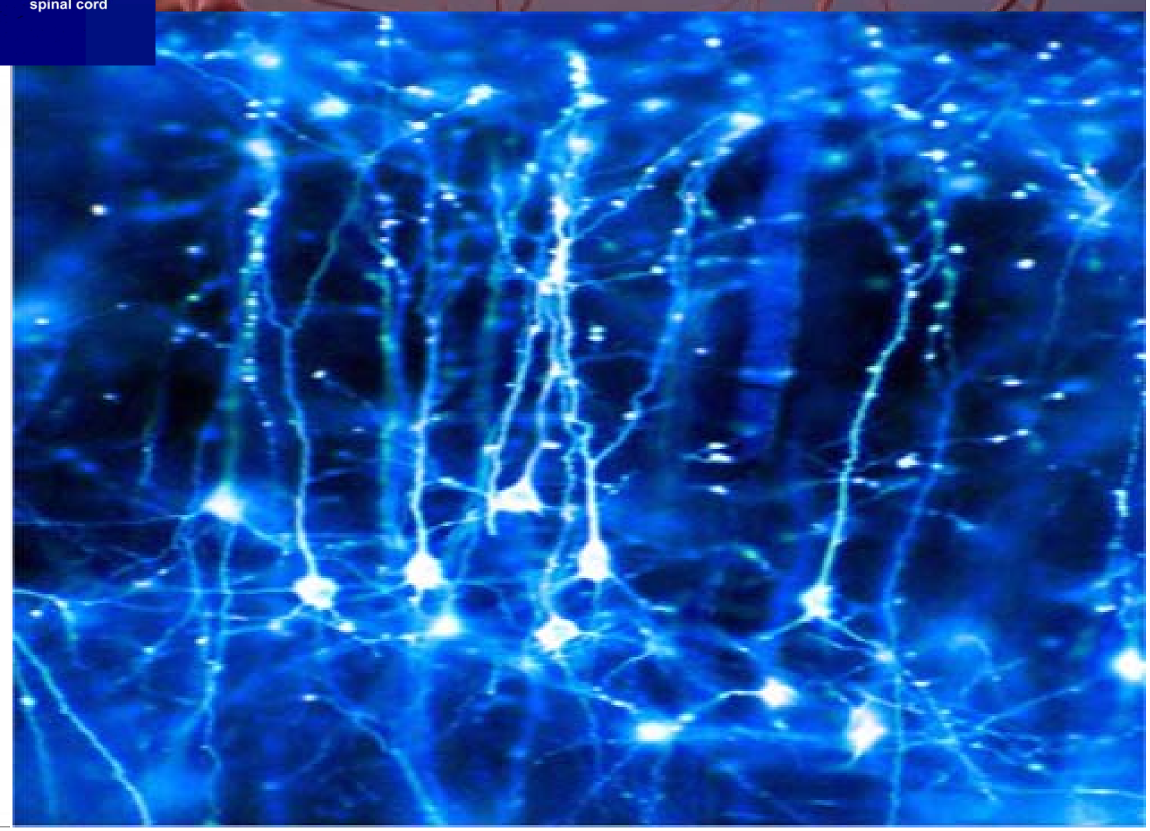


Axons	Dendrites
•Take information away from the cell body •Smooth Surface •Generally only 1 axon per cell •No ribosomes •Can have myelin •Branch further from the cell body	•Bring information to the cell body •Rough Surface (dendritic spines) •Usually many dendrites per cell •Have ribosomes •No myelin insulation •Branch near the cell body

***There are 4 classifications of neurons based on structure*:**

1. Anaxonic neurons:
- small
- all cell processes look alike
-found in brain and sense organs

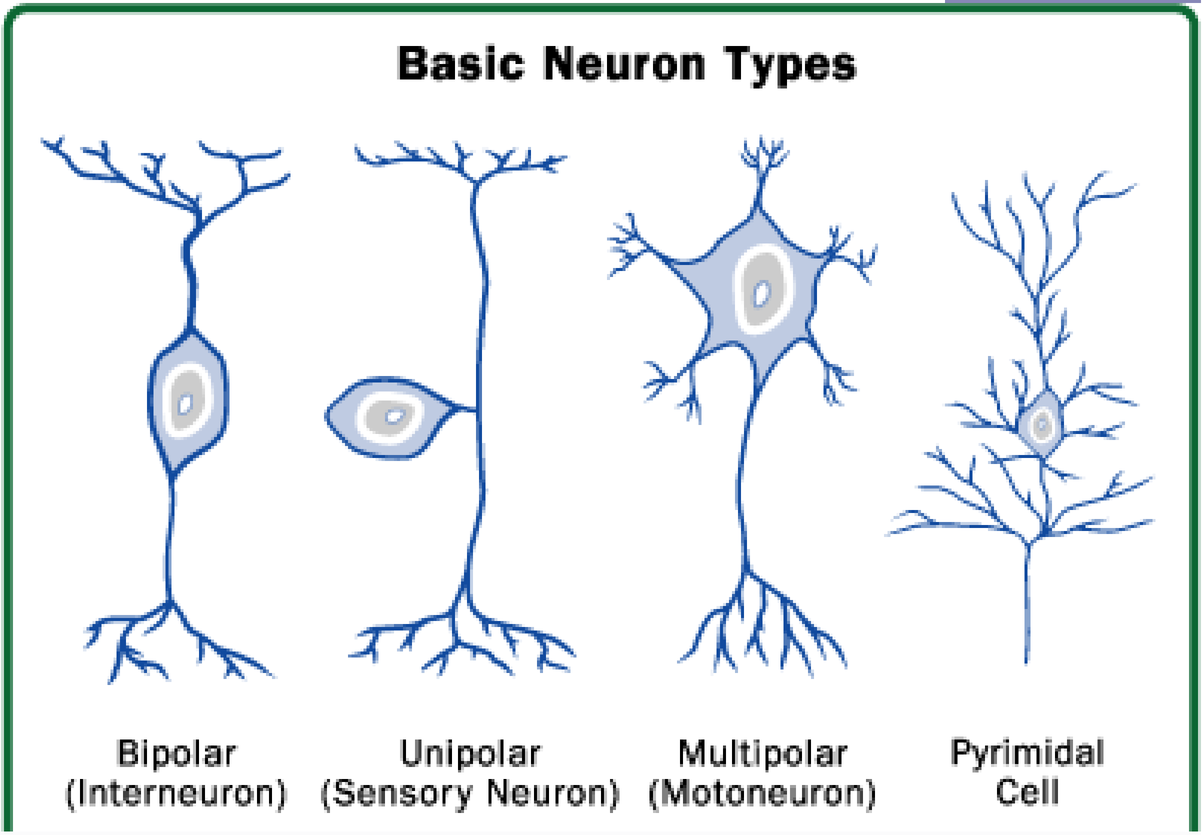
2. Bipolar neurons:
- small
- one dendrite and one axon
-found in special sensory organs (sight, smell, hearing)

3. Unipolar neurons:
- very long axons
- dendrites and axon are fused, with cell body to one side
-found in sensory neurons of the peripheral nervous system

4. Multipolar neurons:
- very long axons
- 2 or more dendrites and 1 axon
- common in the CNS
- includes all motor neurons of skeletal muscles

Type of Neurons

- Sensory neurons:
- Interneurons
- Motor neurons



There are 3 classifications of neurons based on function:

1. **Sensory neurons or *afferent neurons*, (the afferent division of the PNS):**

- Cell bodies of sensory neurons are grouped in ***sensory ganglia***.
- Sensory neurons collect information about our internal environment (visceral sensory neurons) and our relationship to the external environment (somatic sensory neurons).
- Sensory neurons are unipolar. Their processes, called afferent fibers, extend (deliver messages) from sensory receptors to the CNS.

- Sensory receptors are categorized as:

a. **interoceptors:**
- monitor digestive, respiratory, cardiovascular, urinary and reproductive systems
- provide internal senses of taste, deep pressure and pain

b. **exteroceptors:**
- external senses of touch, temperature, and pressure
- distance senses of sight, smell and hearing

c. **proprioceptors:**
- monitor position and movement of skeletal muscles and joints

2. **Motor neurons or *efferent neurons* (the efferent division of the PNS):**

- carry instructions from the CNS to peripheral effectors of tissues and organs via axons called efferent fibers.
- **the 2 major efferent systems are:**

1. the somatic nervous system (SNS), including all the somatic motor neurons that innervate skeletal muscles.

2. the autonomic nervous system (ANS), including the visceral motor neurons that innervate all other peripheral effectors (smooth muscle, cardiac muscle, glands and adipose tissue).

- signals from CNS motor neurons to visceral effectors pass through synapses at *autonomic ganglia*, dividing efferent axons into 2 groups:

1. *preganglionic fibers*
2. *postganglionic fibers*

3. **<u>Interneurons or *association neurons*</u>:**

-located in the brain, spinal cord and some autonomic ganglia, between sensory neurons and motor neurons

-responsible for distribution of sensory information and coordination of motor activity

- involved in higher functions such as memory, planning and learning

Classification of Neurons

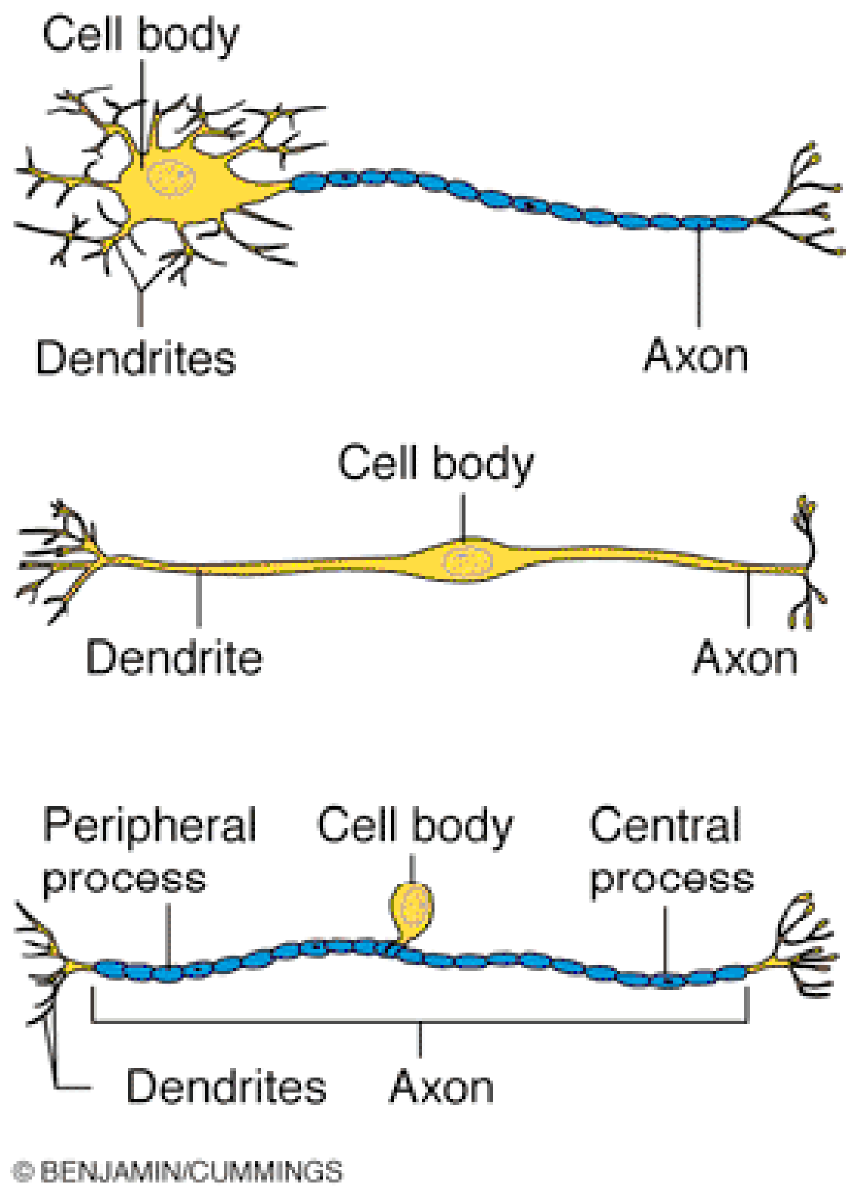
- Neurons can be classified structurally or functionally
- According to the **structural classification** system there are three types of neurons;
  - **Multipolar**
  - **Bipolar**
  - **Unipolar**

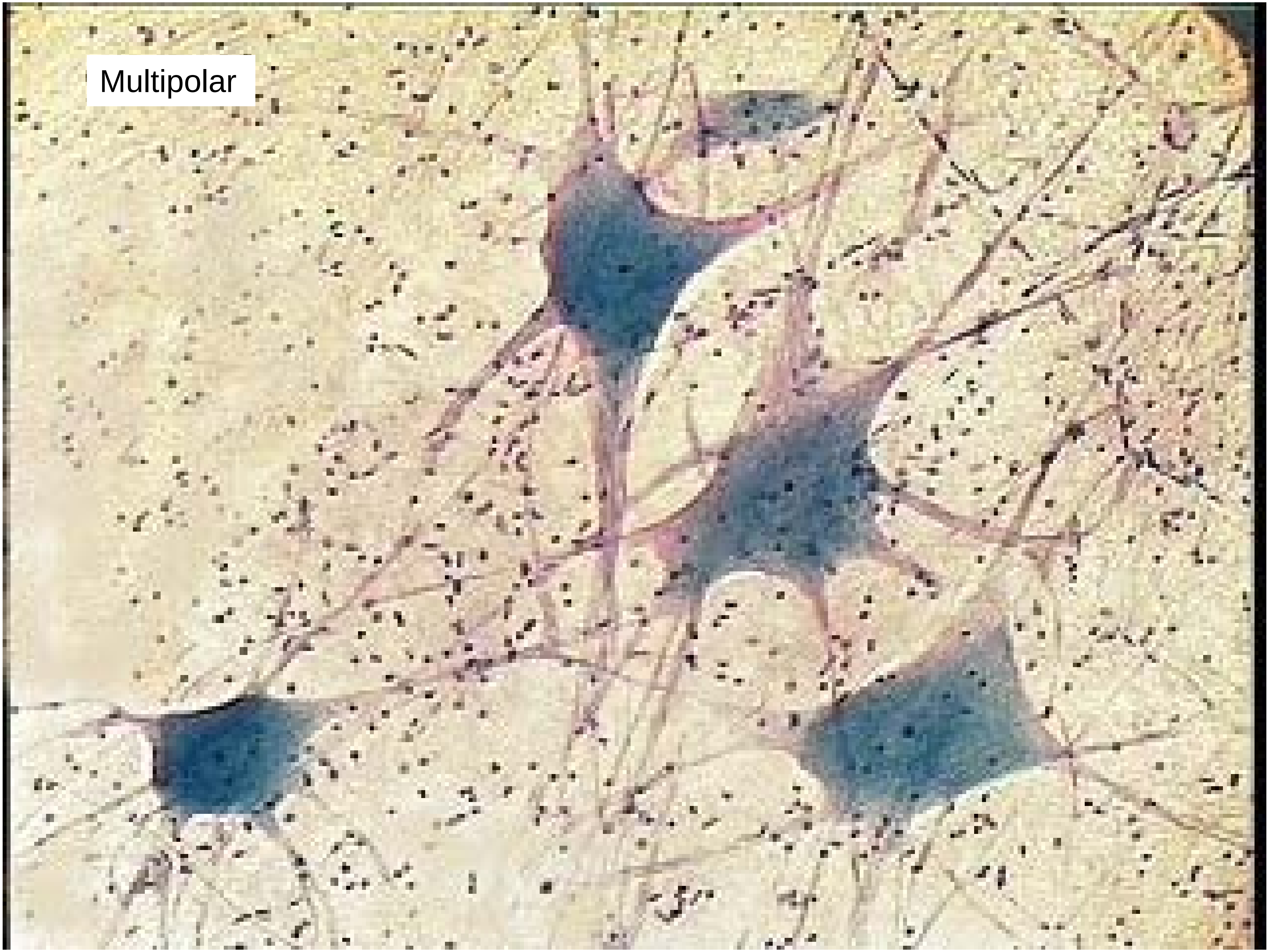
Structural Classification

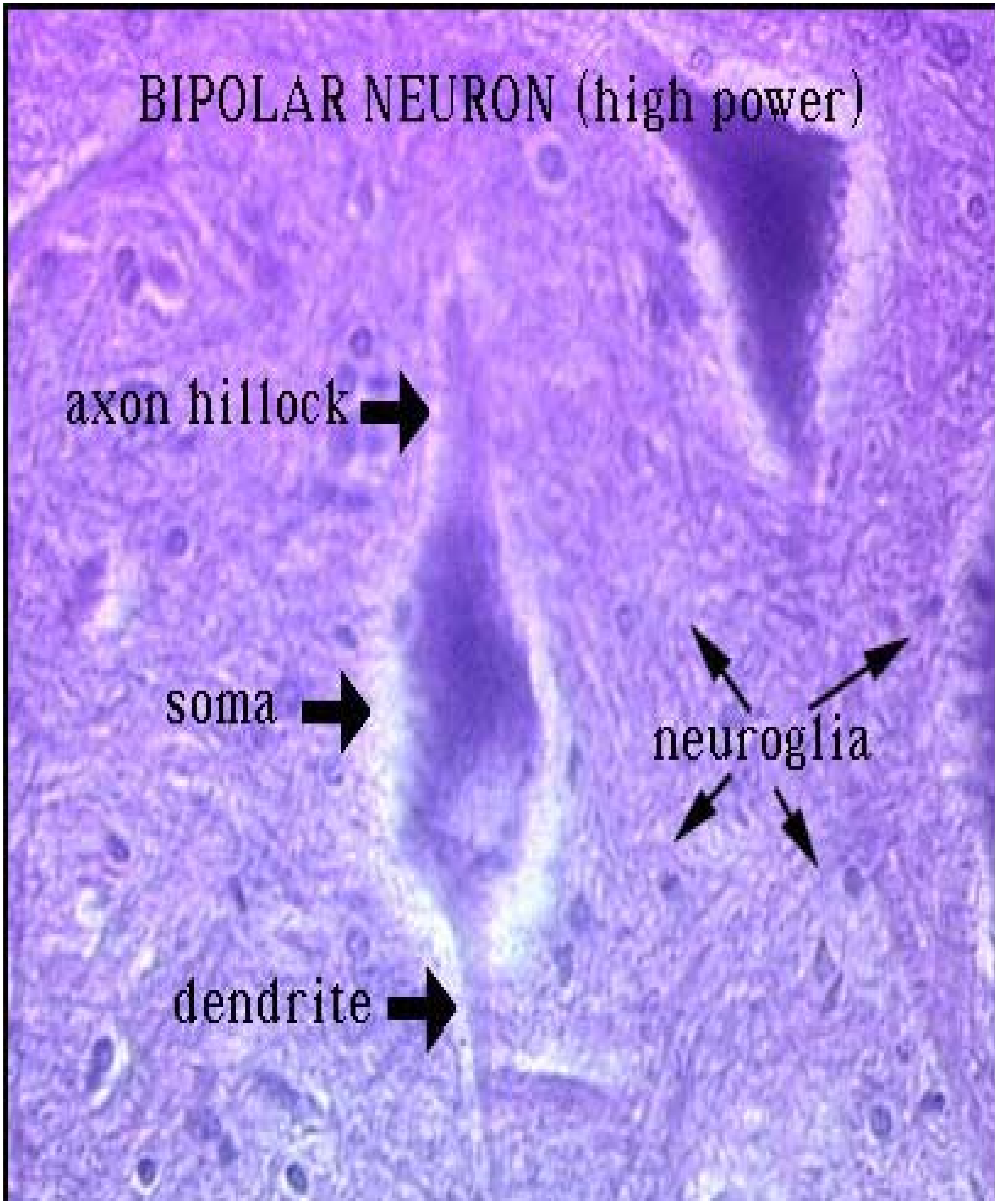
- **Multipolar** - many processes extend from cell body, all dendrites except one axon

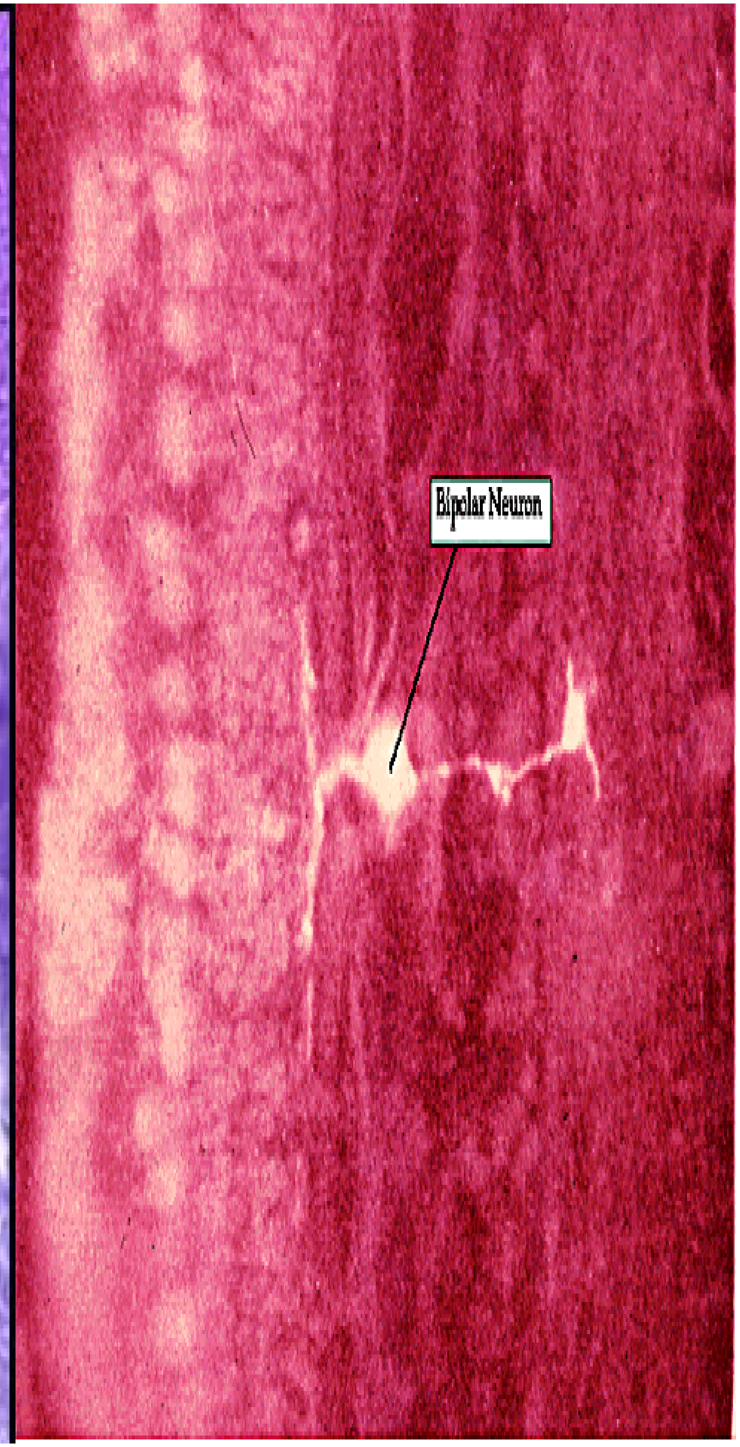
- **Bipolar** - Two processes extend from cell, one a fused dendrite, the other an axon

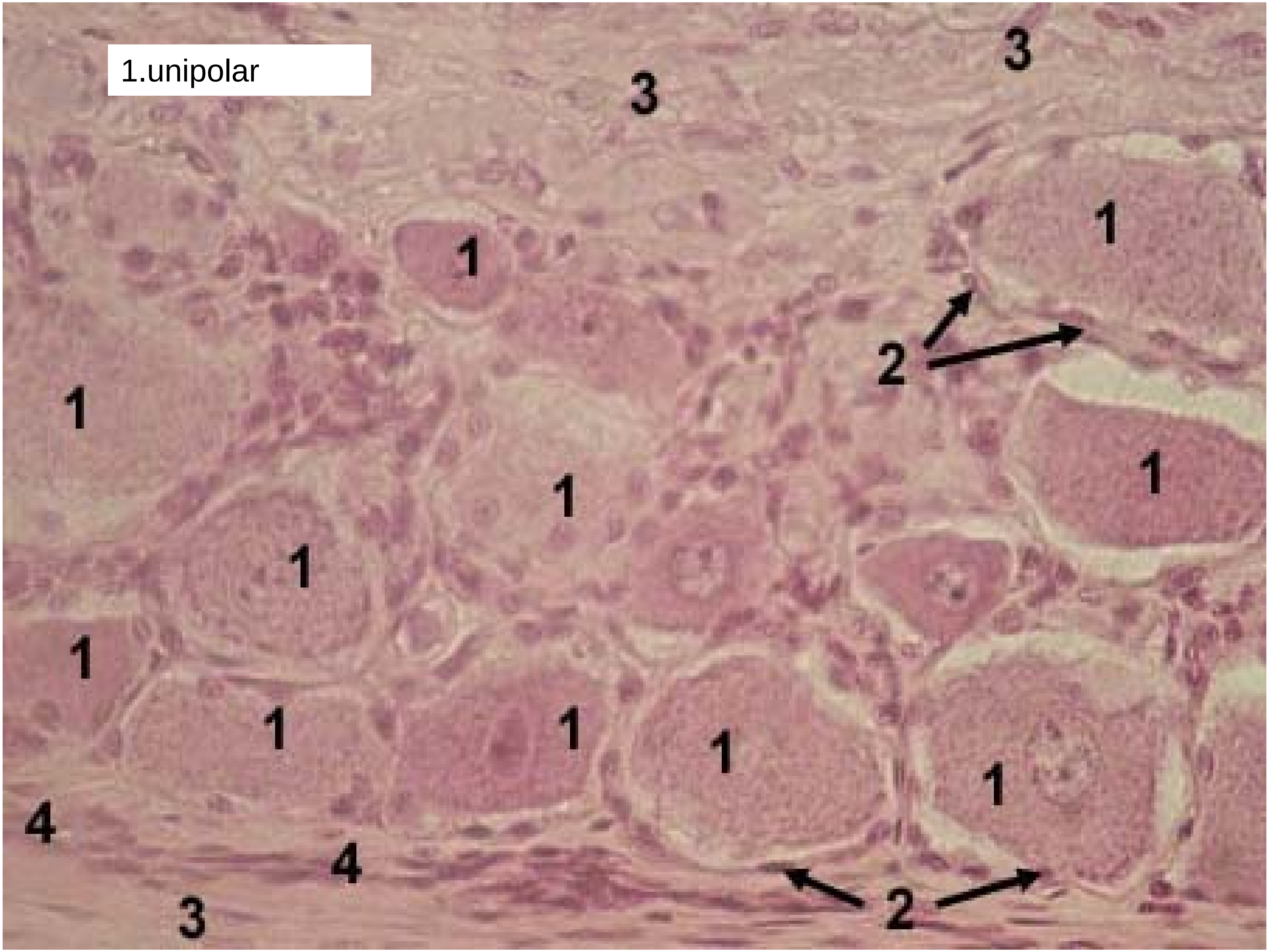
- **Unipolar** - One process extends from the cell body and forms the peripheral and central process of the axon




Multipolar


BIPOLAR NEURON (high power)
axon hillock
soma
neuroglia
dendrite


Bipolar Neuron


1.unipolar
3
3
1
1
2
1
1
1
1
1
1
1
1
1
4
4
3
2

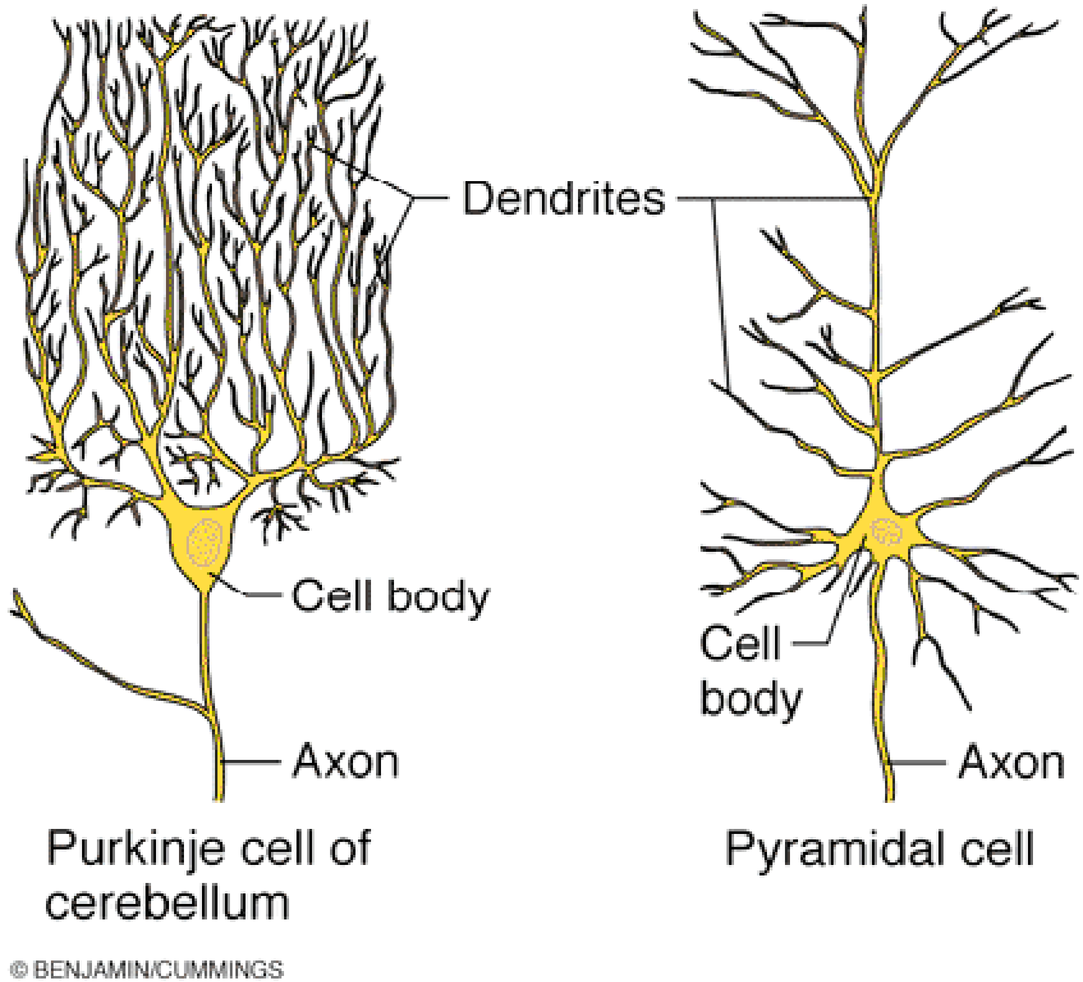
- **Multipolar neurons have more than two processes**

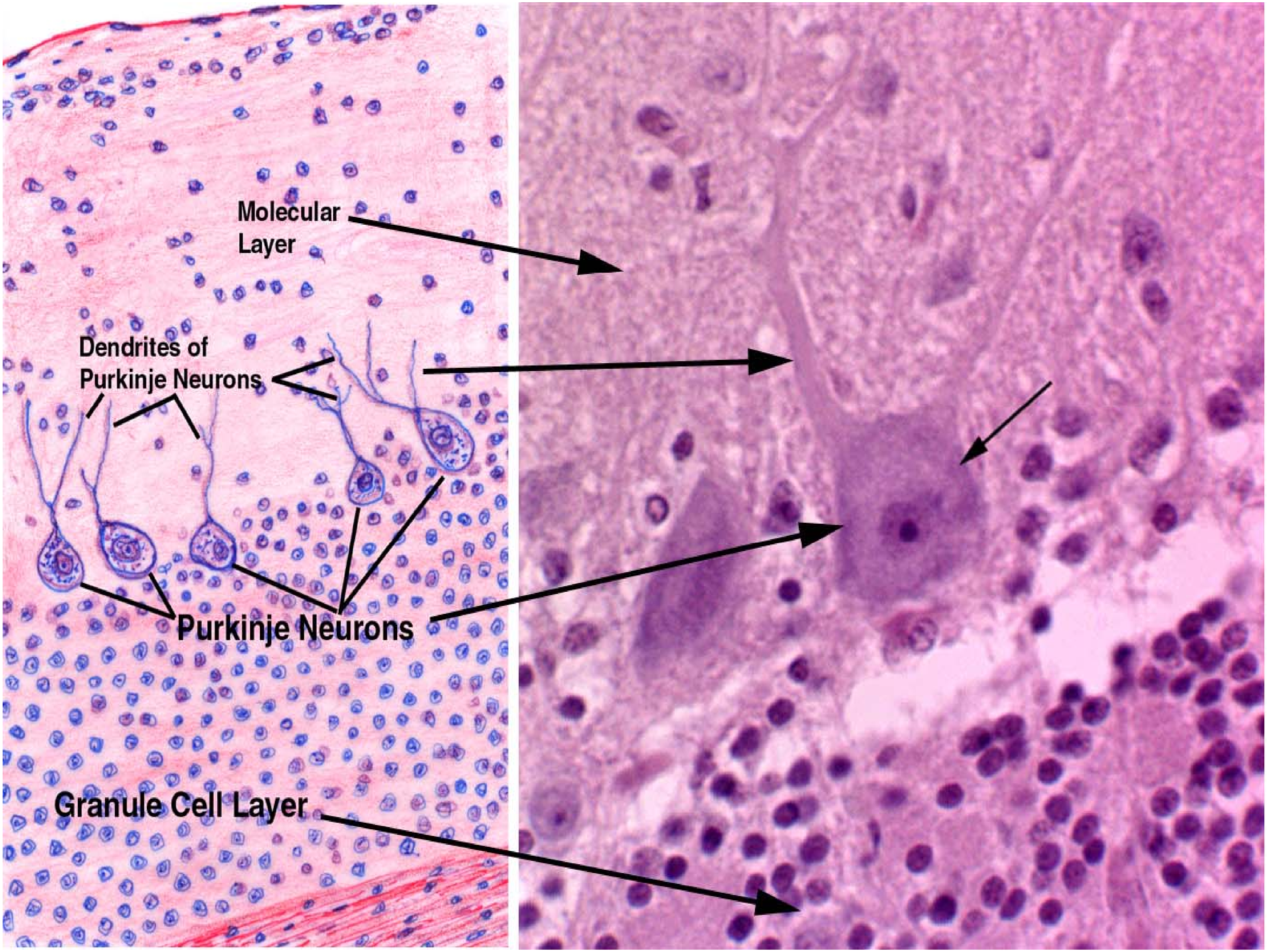
- **Most common type in humans**

- **Major neuron of the CNS**

- **Most have many dendrites and one axon, some neurons lack an axon**

Multipolar Neurons

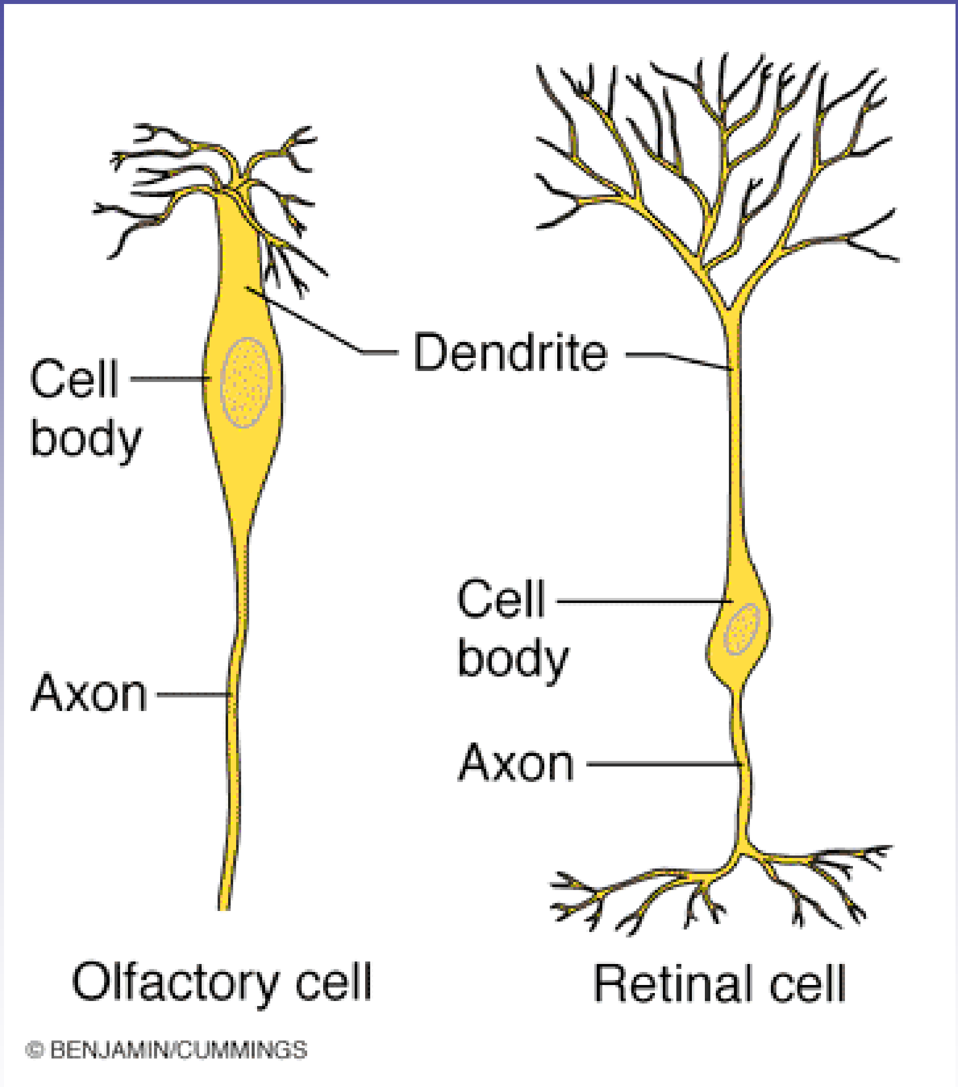



Molecular
Layer
Dendrites of
Purkinje Neurons
Purkinje Neurons
Granule Cell Layer


Pyramidal
cells

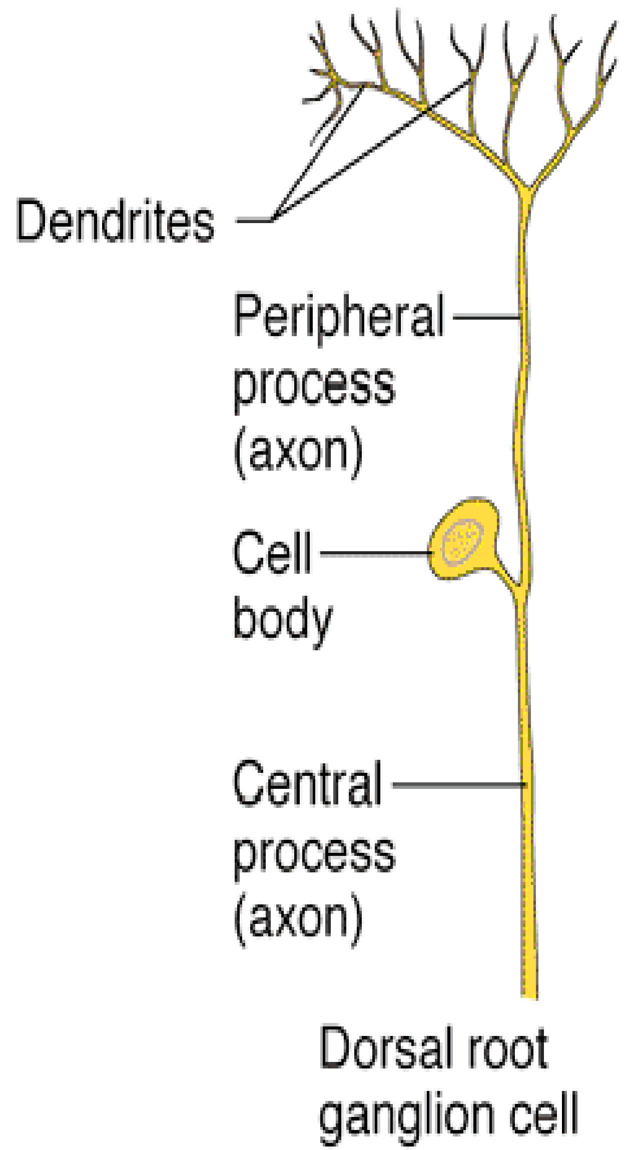
Bipolar Neurons

- Bipolar neurons are rare in the human body
- Found only in special sense organs where they function as receptor cells
- Examples include those found in the retina of the eye, inner ear, and in the olfactory mucosa
- They are primarily sensory neurons



Unipolar Neuron

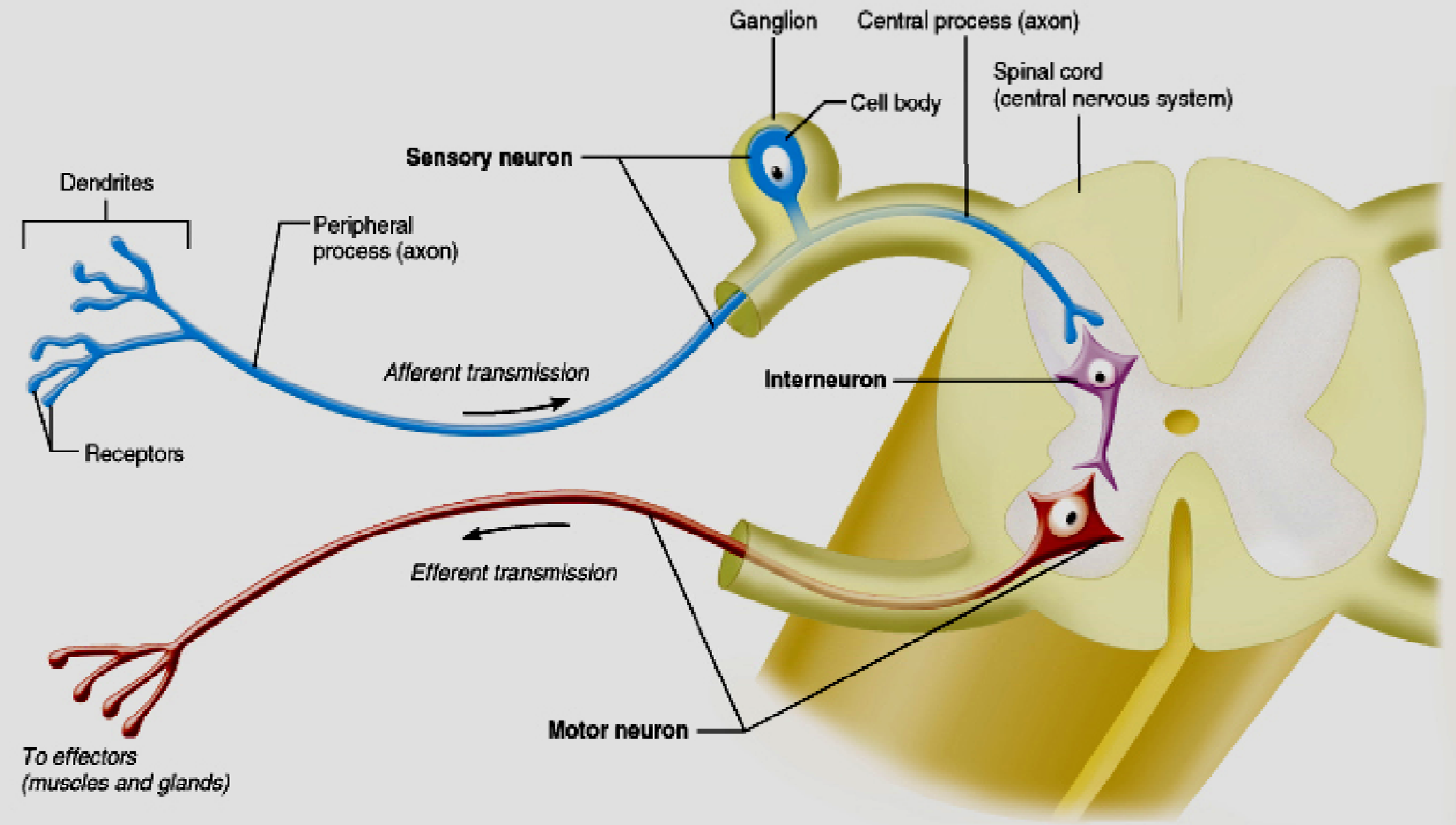
- Unipolar neurons have a single process that emerges from the cell body
- The central process (axon) is more proximal to the CNS and the peripheral is closer to the PNS
- Unipolar neurons are chiefly found in the ganglia of the peripheral nervous system
- Function as sensory neurons



Functional Classification

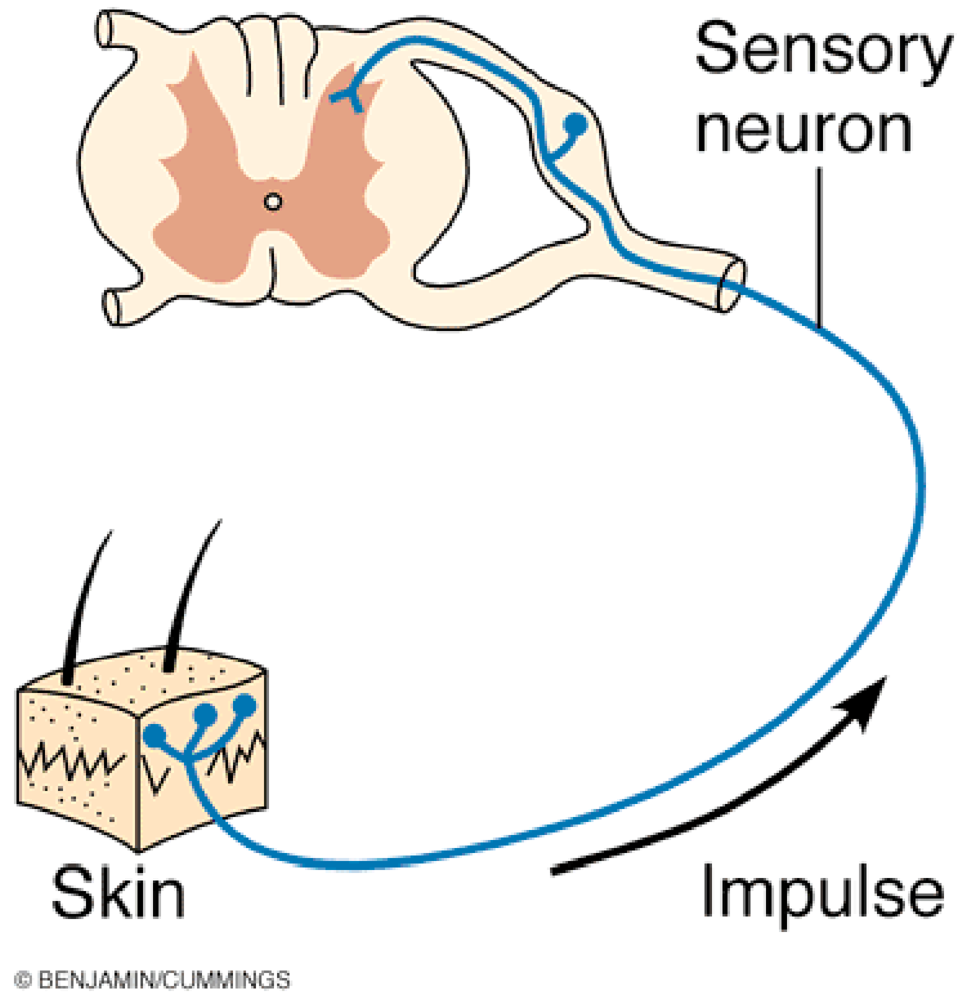
- The functional classification scheme groups neurons according to the direction in which the nerve impulse travels relative to the CNS
- Based on this criterion there are three neurons
  - **Sensory neurons**
  - **Motor neurons**
  - **Interneurons**

Functional Classification

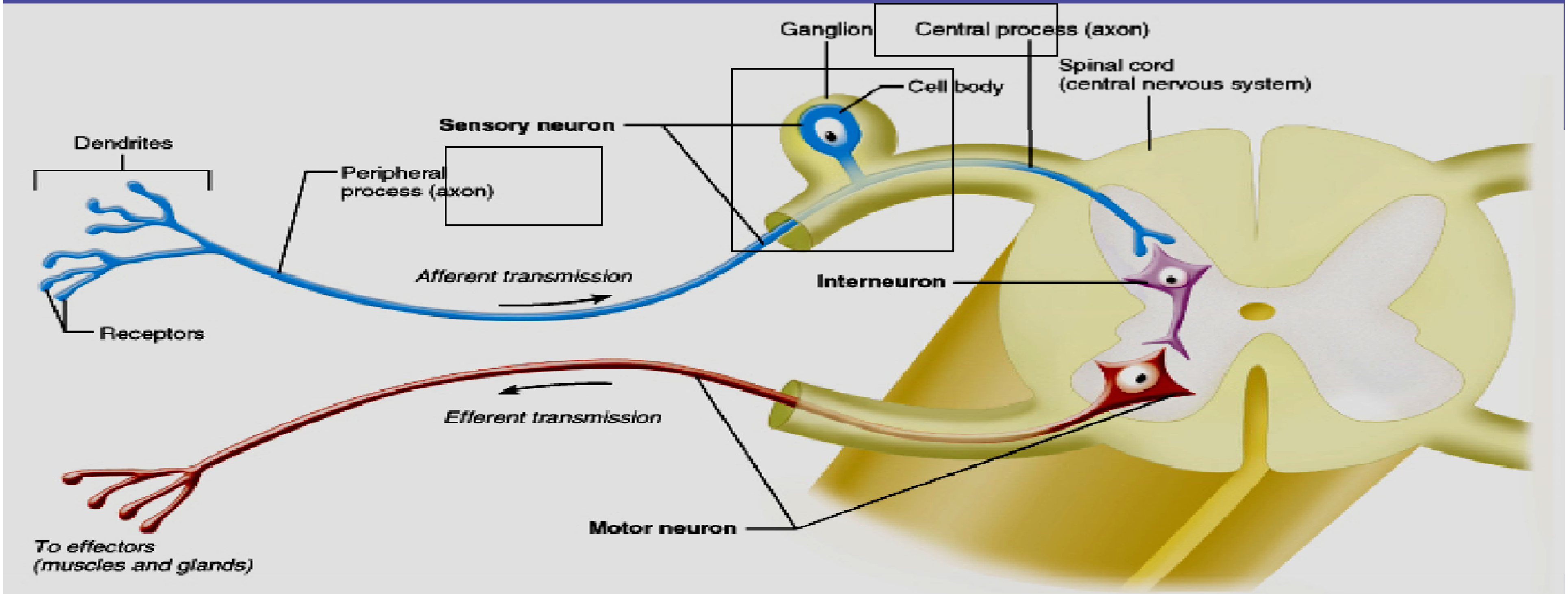


Sensory Neurons

- Neurons that transmit impulses from sensory receptors in the skin or internal organs toward or into the CNS are called sensory or afferent neurons
- Virtually all primary sensory neurons of the body are unipolar



Sensory Neurons



- Sensory neurons have their ganglia outside of the CNS
- The single (unipolar) process is divided into the central process and the peripherial process

Sensory Neuron

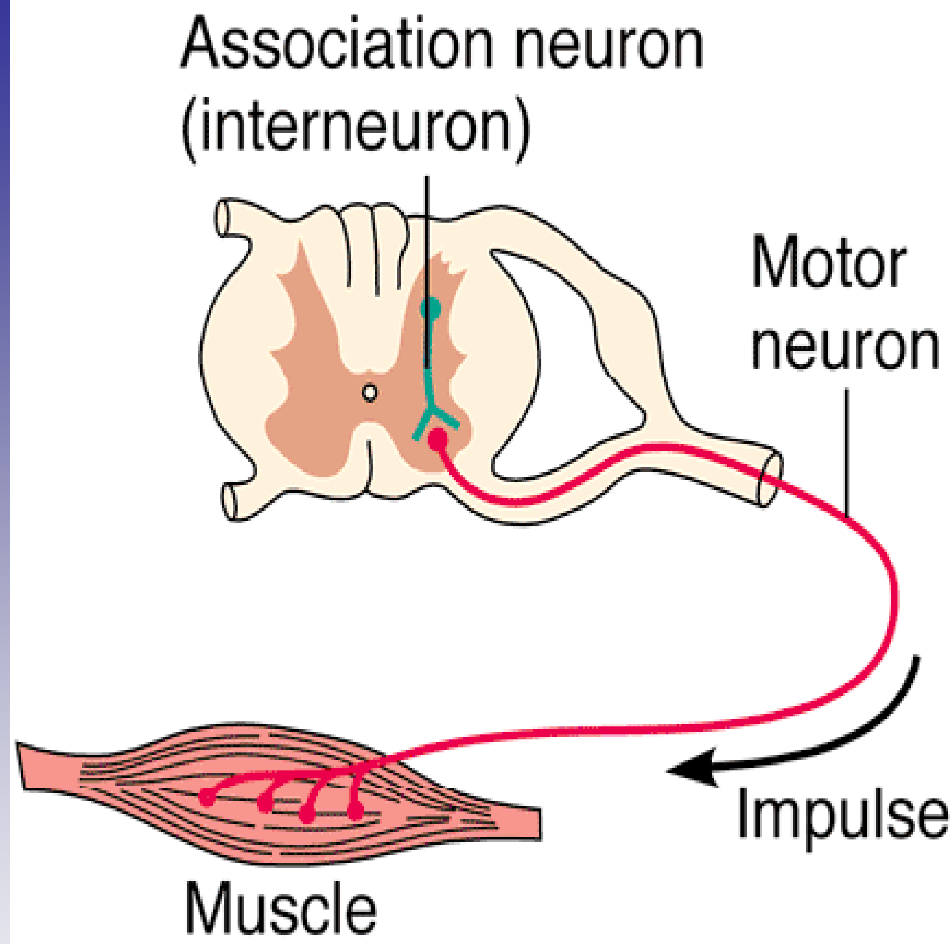
- The central process is clearly an axon because it carries a nerve impulse and carries that impulse away from the cell body which meet the criteria which define an axon
- The peripheral by contrast carries nerve impulses toward the cell body which suggests that it is a dendrite
- However, the basic convention is that the central process and the peripheral process are parts of a unipolar neuron

Motor Neurons

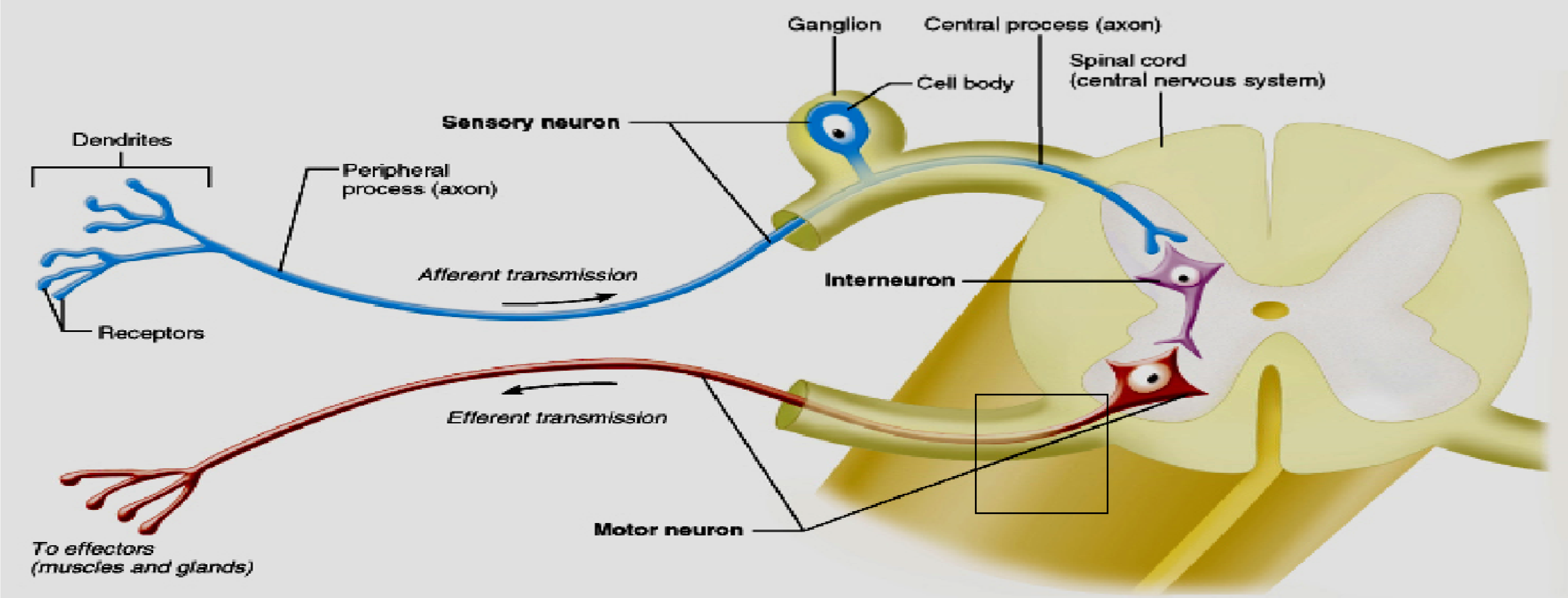
- Neurons that carry impulses away from the CNS to effector organs (muscles and glands) are called motor or efferent neurons

- Upper motor neurons are in the brain

- Lower motor neurons are in PNS



Motor Neurons

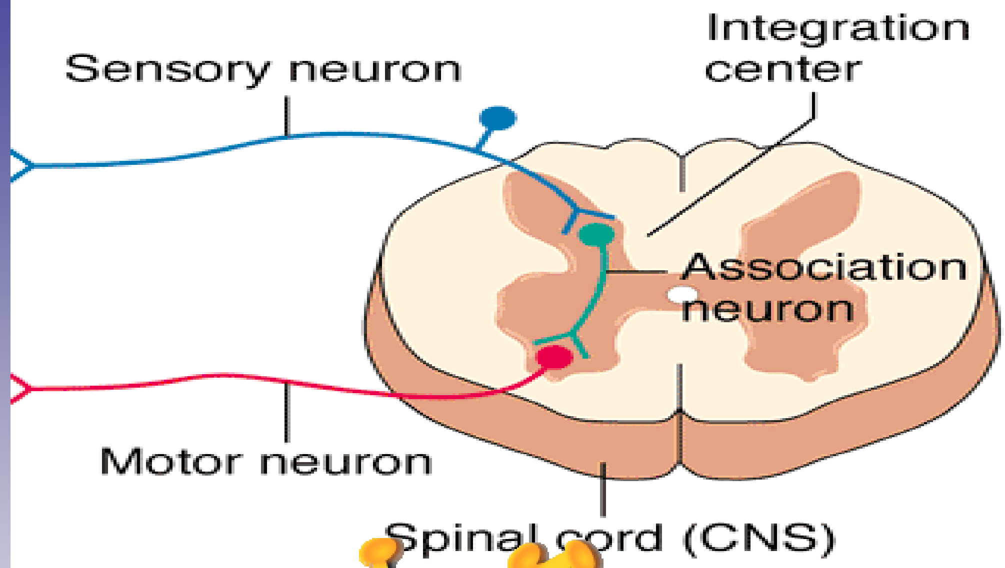


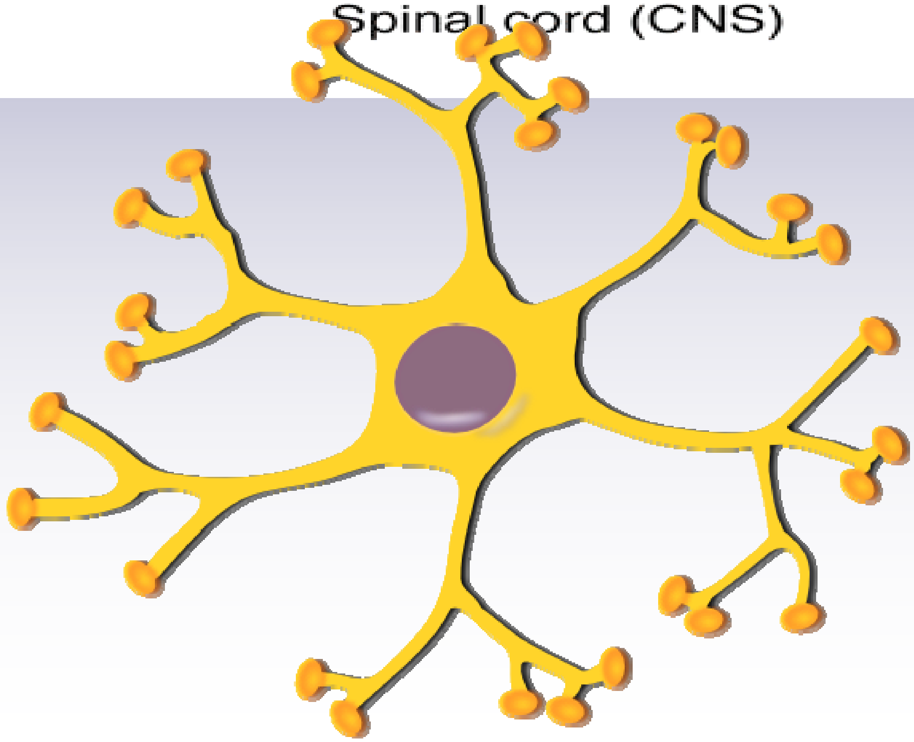
- **Motor neurons are multipolar and their cell bodies are located in the CNS (except autonomic)**

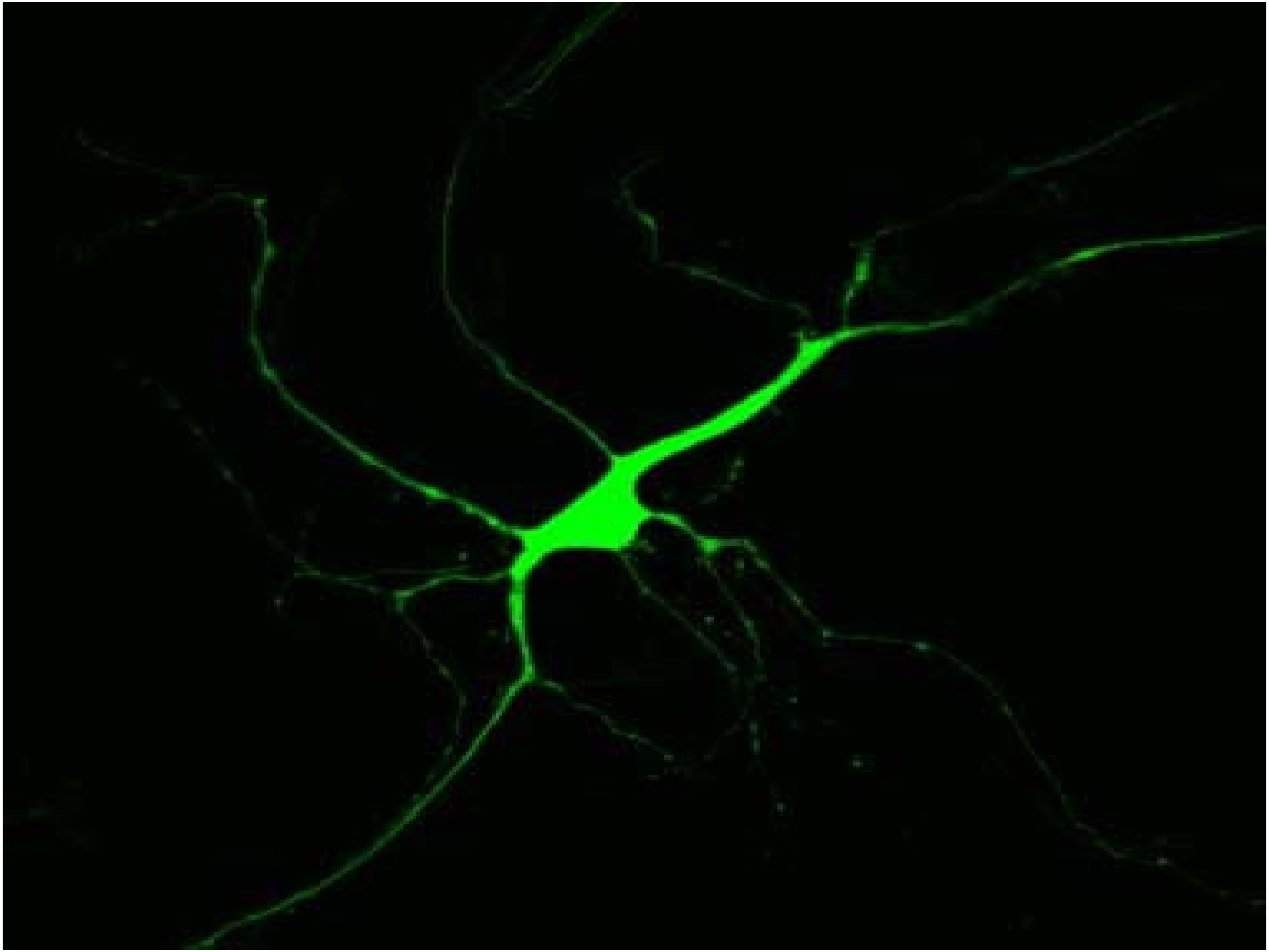
- **Motor neurons form junctions with effector cells, signaling muscle to contract or glands to secrete**

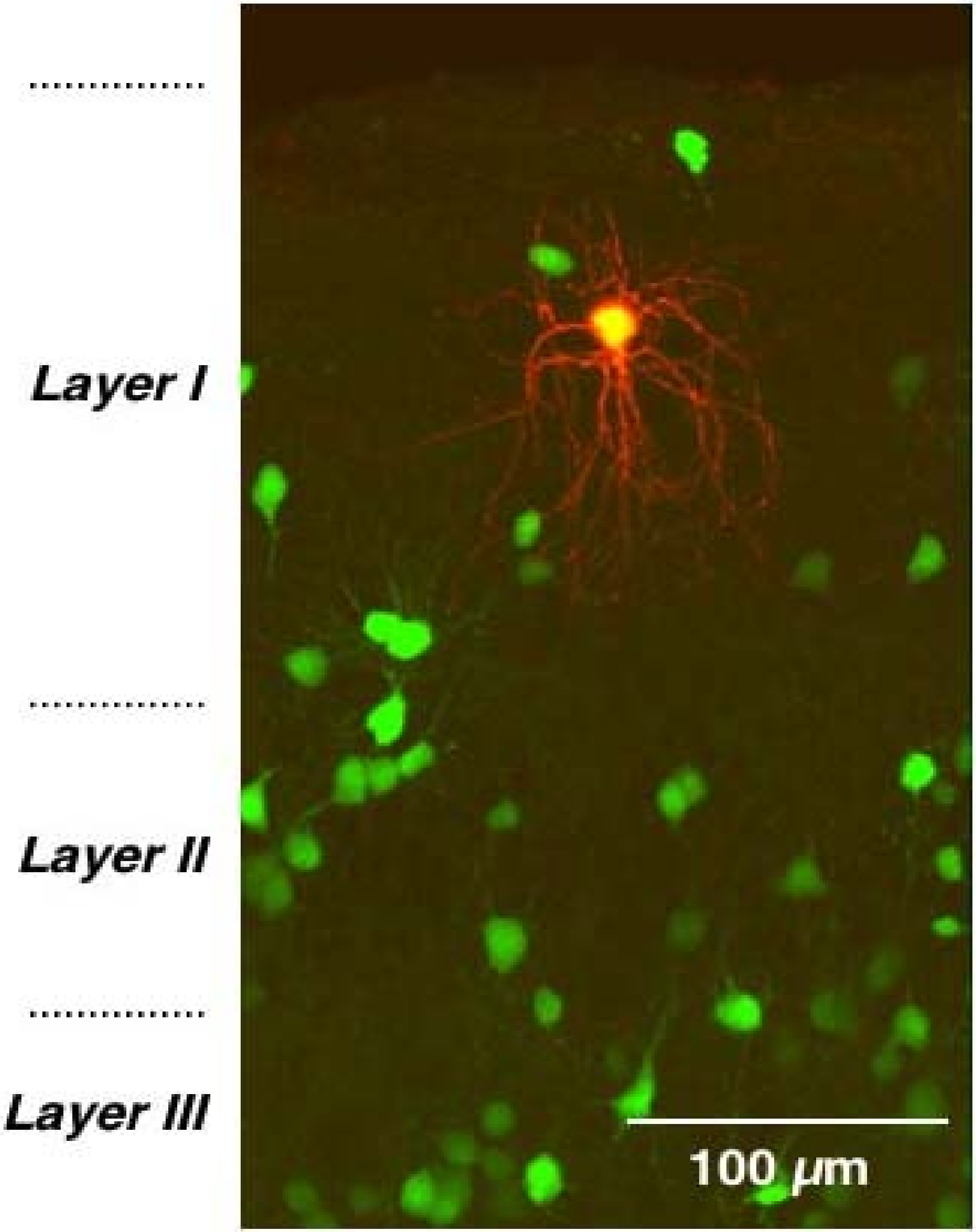
Interneuron or Association Neuron

- These neurons lie between the motor and sensory neurons
- These neurons are found in pathways where integration occurs
- Confined to CNS
- Make up 99% of the neurons of the body and are the principle neuron of the CNS



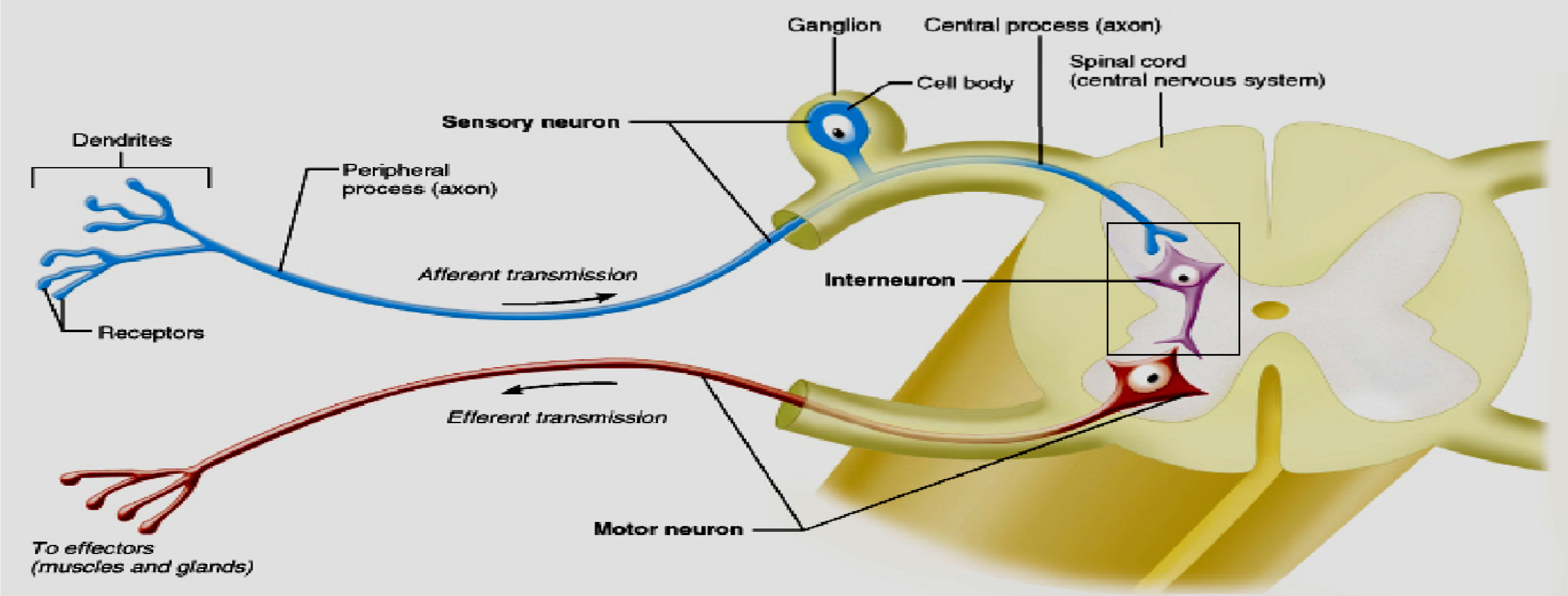






- *Neurogliaform cell (red), which is a class of inhibitory interneuron in the piriform cortex of a mouse. It is surrounded by green cells, all of which are different classes of inhibitory interneurons.*

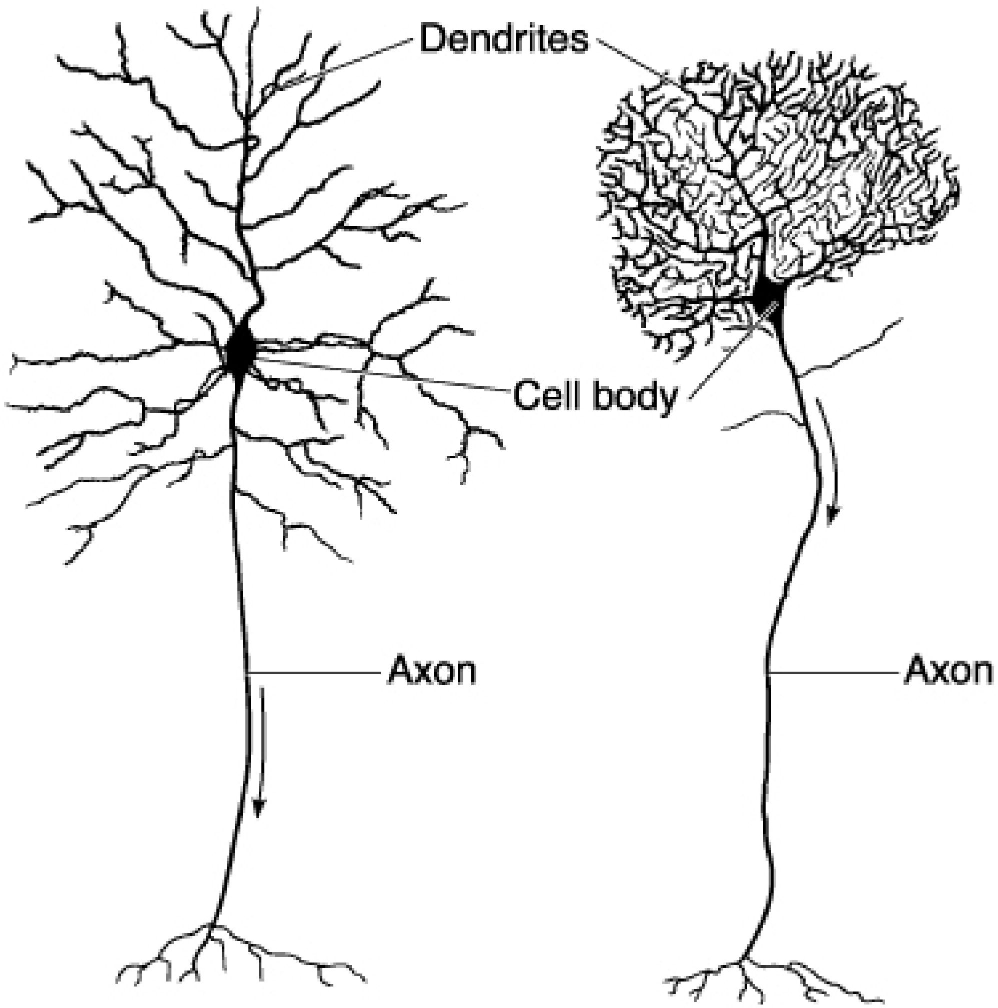
Interneuron Neurons



- Almost all interneurons are multipolar
- Interneurons show great diversity in the size and branching patterns of their processes

Interneurons

- The Pyramidal cell is the large neuron found in the primary motor cortex of the cerebrum
- The Purkinje cell from the cerebellum



(a) Pyramidal cell (b) Purkinje cell

- CNS interneurons are typically inhibitory, and use the neurotransmitter GABA or glycine.

- However, excitatory interneurons using glutamate also exist, as do interneurons releasing neuromodulators like acetylcholine.

Cerebellar interneurons

- Molecular layer interneurons (basket cells, stellate cells)
- Golgi cells
- Granule cells

Sensory neurons

These run from the various types of stimulus receptors, e.g.,

- **touch**
- **odor**
- **taste**
- **sound**
- **vision**

to the central nervous system (CNS), the brain and spinal cord.

The cell bodies of the sensory neurons leading to the spinal cord are located in clusters, called **ganglia**, next to the spinal cord.

The axons usually terminate at interneurons.

Human sensory system

The Human sensory system consists of the following sub-systems:

- **Visual system** consists of the photoreceptor cells, optic nerve, and V1.
- **Auditory system**
- **Somatosensory system** consists of the receptors, transmitters (pathways) leading to S1, and S1 that experiences the sensations labelled
  - **as touch or pressure,**
  - **temperature (warm or cold),**
  - **pain (including itchand tickle),**
  - **and the sensations of muscle movement and joint position including posture, movement, and facial expression (collectively also called proprioception).**
- **Gustatory system**
- **Olfactory system**
- **Human sensory receptors are:**
- **Chemosensor**
- **Mechanoreceptor**
- **Nociceptor**
- **Photoreceptor**
- **Thermoreceptor**

Somatic sensory system

The somatic sensory system includes

- **the sensations of touch,**
- **pressure,**
- **vibration,**
- **limb position,**
- **heat,**
- **cold,**
- **pain.**

The cell bodies of somatic sensory afferent fibers **lie in ganglia throughout the spine.**

These neurons are responsible for relaying information about the body to the central nervous system.

Neurons residing in ganglia of the head and body supply the central nervous system with information about the aforementioned external stimuli occurring to the body.

Pseudounipolar neurons are located in the dorsal root ganglia (the head)

Mechanoreceptors

Specialized receptor cells often encapsulate afferent fibers to help tune the afferent fibers to the different types of somatic stimulation.

Mechanoreceptors also help lower thresholds for action potential generation in afferent fibers and thus make them more likely to fire in the presence of sensory stimulation.

Proprioceptors are another type of mechanoreceptors which literally means "receptors for self." These receptors provide spatial information about limbs and other body parts.

Nociceptors are responsible for processing pain and temperature changes. The burning pain and irritation experienced after eating a chili pepper (due to its main ingredient, capsaicin), the cold sensation experienced after ingesting a chemical such as menthol or icillin, as well as the common sensation of pain are all a result of neurons with these receptors.

Problems with mechanoreceptors lead to disorders such as:

Neuropathic pain - a severe pain condition resulting from a damaged sensory nerve

Hyperalgesia - an increased sensitivity to pain caused by sensory ion channel, TRPM8, which is typically responds to temperatures between 23 and 26 degrees, and provides the cooling sensation associated with menthol and icillin

Phantom limb syndrome - a sensory system disorder where pain or movement is experienced in a limb that does not exist

Vision

Vision is one of the most complex sensory systems.
The eye has to first "see" via refraction of light. Then, light energy has to be converted to electrical signals by photoreceptor cells and finally these signals have to be refined and controlled by the synaptic interactions within the neurons of the retina.

The five basic classes of neurons within the retina are

- **photoreceptor cells,**
- **bipolar cells,**
- **ganglion cells,**
- **horizontal cells,**
- **amacrine cells.**

The basic circuitry of the retina incorporates a three-neuron chain consisting of

- the photoreceptor (either a rod or cone),
- bipolar cell, and the ganglion cell.

- As the picture shows, the first action potential occurs in the retinal ganglion cell. This pathway is the most direct way for transmitting visual information to the brain.

Problems and decay of sensory neurons associated with vision lead to disorders such as:

Macular degeneration – degeneration of the central visual field due to either cellular debris or blood vessels accumulating between the retina and the choroid, thereby disturbing and/or destroying the complex interplay of neurons that are present there.

Glaucoma – loss of retinal ganglion cells which causes some loss of vision to blindness.

Diabetic retinopathy – poor blood sugar control due to diabetes damages the tiny blood vessels in the retina

Auditory

The auditory system is responsible for converting pressure waves generated by vibrating air molecules or sound into signals that can be interpreted by the brain.

This mechanoelectrical transduction is mediated with hair cells within the ear.
, depending on the movement, the hair cell can either hyperpolarize or depolarize.
When the movement is towards the tallest stereocilia, the K^+ cation channels open allowing K^+ to flow into cell and the resulting depolarization causes the Ca^{2+} channels to open, thus releasing its neurotransmitter into the afferent auditory nerve.

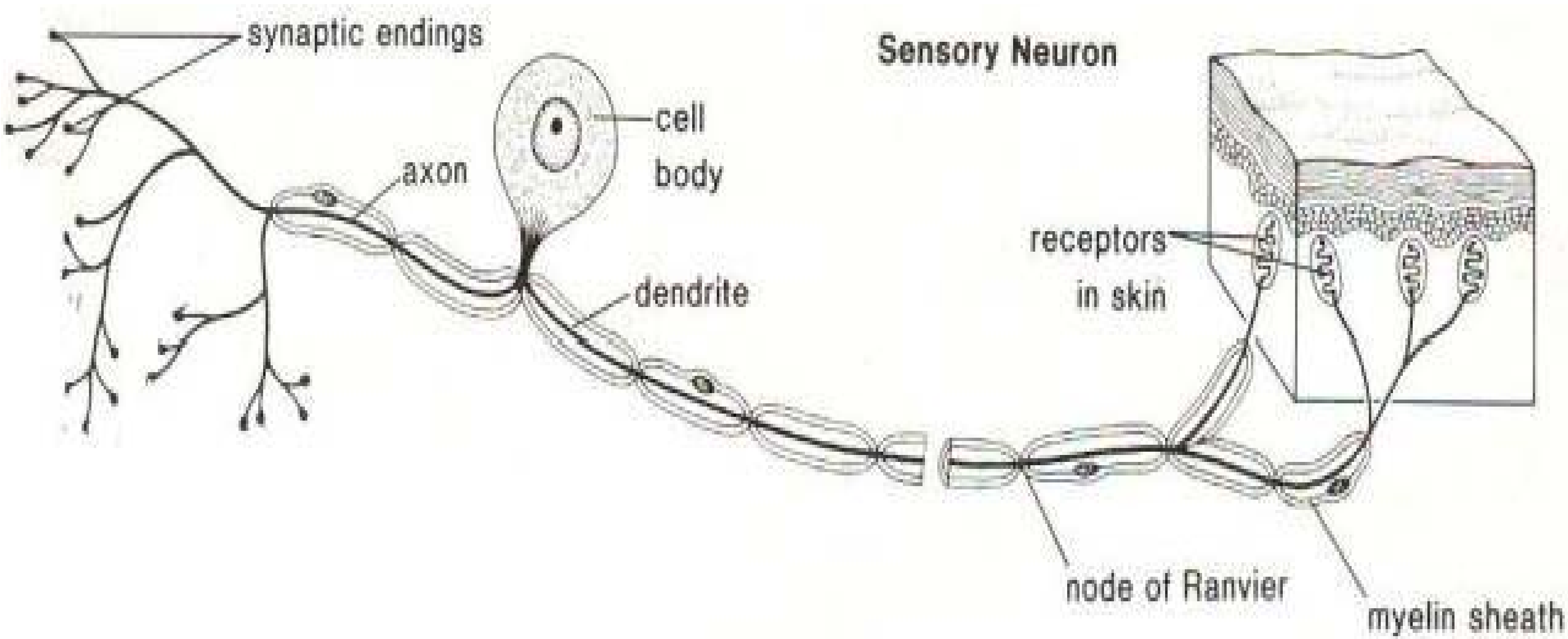
There are two types of hair cells: inner and outer.
The inner hair cells are the sensory receptors while the outer hair cells are usually from efferent axons originating from cells in the superior olivary complex

Problems with sensory neurons associated with the auditory system leads to disorders such as:

Auditory Processing Disorder – auditory information in the brain is processed in an abnormal way. Patients with auditory processing disorder can usually gain the information Normally, but their brain cannot process it properly, leading to hearing disability.

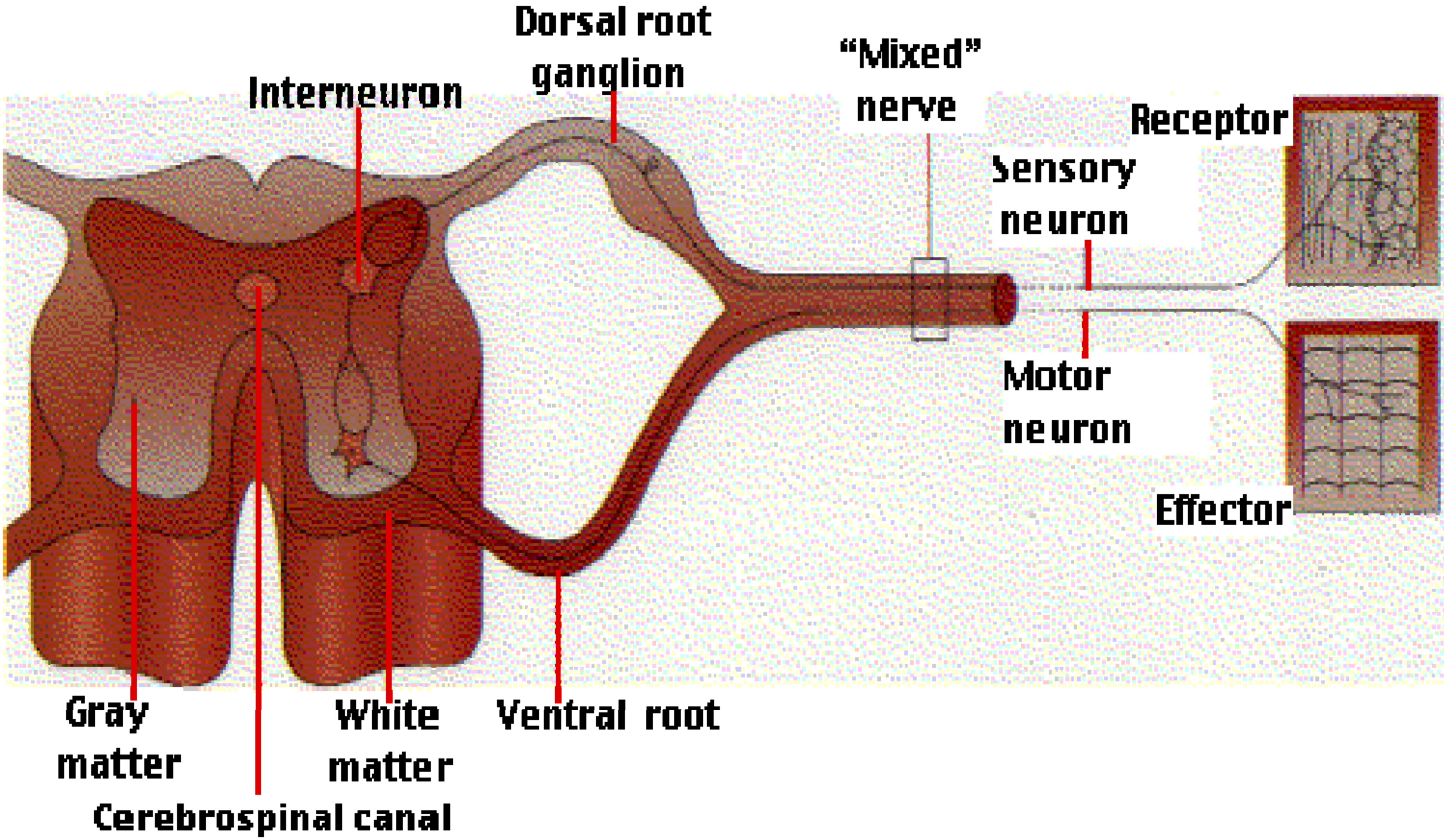
Auditory verbal agnosia – comprehension of speech is lost but hearing, speaking, reading, and writing ability is retained. This is caused by damage to the posterior superior temporal lobes, again not allowing the brain to process auditory input correctly

	Sensory neuron	Interneuron	Motor Neuron
Length of Fibers	Long dendrites and short axon	Short dendrites and short or long anxon	Short dendrites and long axons
Location	Cell body and dendrite are outside of the spinal cord; the cell body is located in a dorsal root ganglion	Entirely within the spinal cord or CNS	Dendrites and the cell body are located in the spinal cord; the axon is outside of the spinal cord
Function	Conduct impulse to the spinal cord	Interconnect the sensory neuron with appropriate motor neuron	Conduct impulse to an effector (muscle or gland)



Sensory Neurone:

- **Afferent Neuron – Moving away from a central organ or point**
- **Relays messages from receptors to the brain or spinal cord**

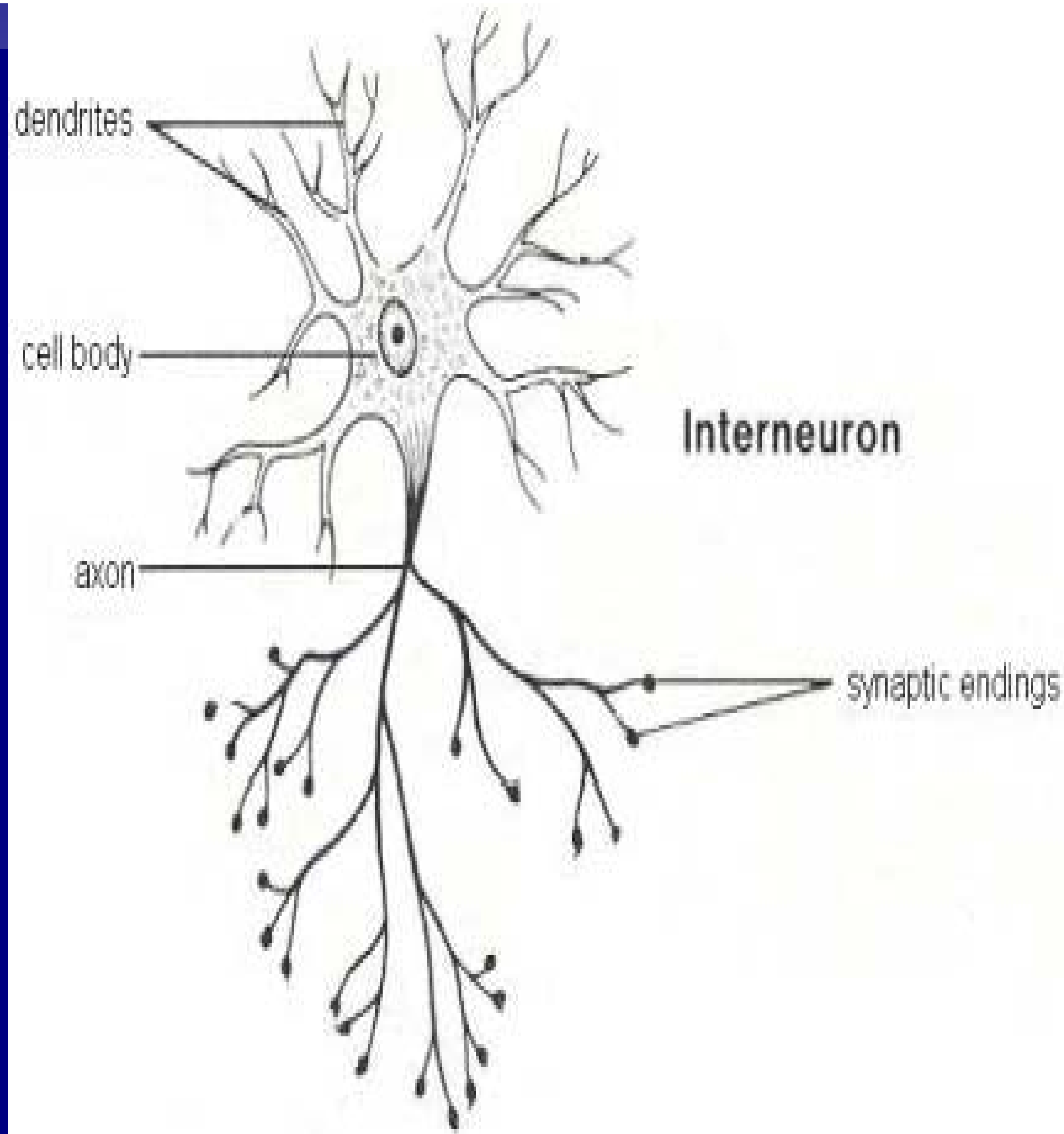

Dorsal root ganglion
Interneuron
"Mixed" nerve
Receptor
Sensory neuron
Motor neuron
Effector
Gray matter
Cerebrospinal canal
White matter
Ventral root

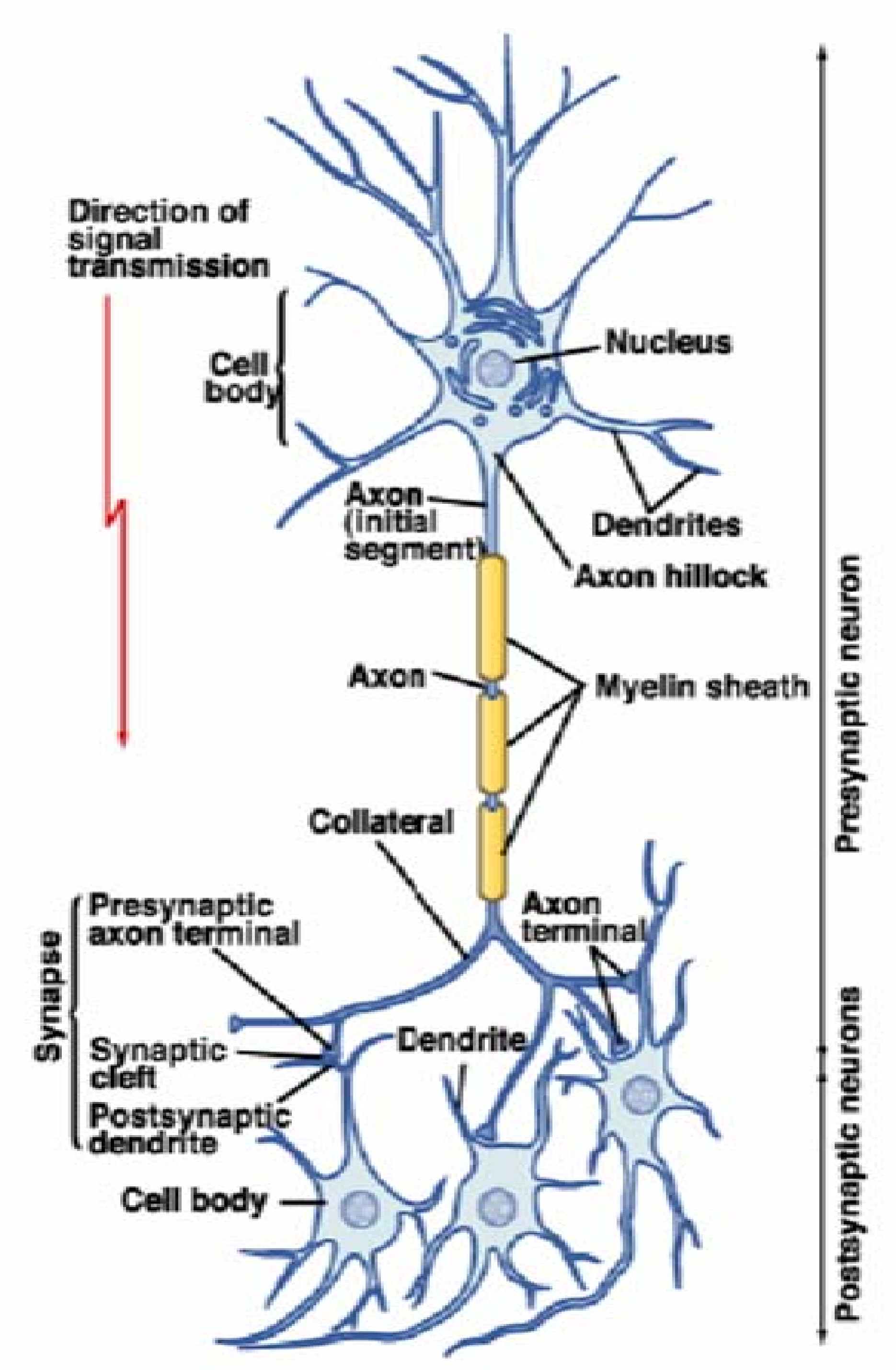
Interneurons

These are found exclusively within the spinal cord and brain.

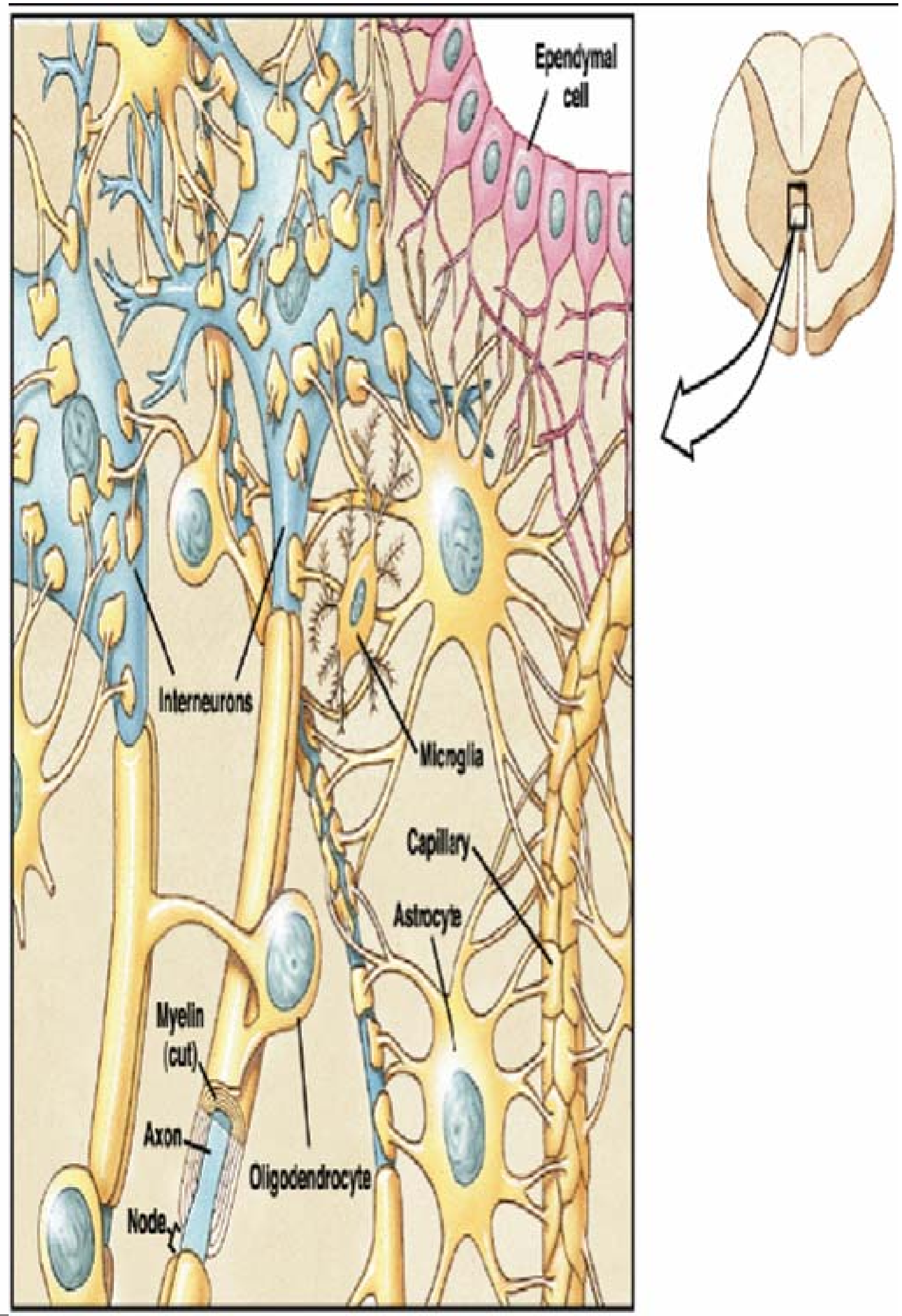
They are stimulated by signals reaching them from
- sensory neurons
- other interneurons or
- both.

Interneurons are also called **association neurons**.





Direction of signal transmission
Cell body
Nucleus
Axon (initial segment)
Dendrites
Axon hillock
Axon
Myelin sheath
Collateral
Presynaptic axon terminal
Axon terminal
Synapse
Synaptic cleft
Dendrite
Postsynaptic dendrite
Cell body
Presynaptic neuron
Postsynaptic neurons



Ependymal cell
Interneurons
Microglia
Capillary
Astrocyte
Myelin (cut)
Axon
Oligodendrocyte
Node

NEUROGLIA OR GLIA

- **Glial cells**, commonly called **neuroglia** or simply **glia**, are non-neuronal cells that provide
  - support and nutrition,
  - maintain homeostasis,
  - form myelin,
  - participate in signal transmission in the nervous system.

TYPE OF NEUROGLIA

- **Microglia** **[Microglia are specialized macrophages capable of phagocytosis that protect neurons of the CNS.]**
- **Macroglia FOR CNS**
  - » **Astrocytes: The most abundant type of glial cell, astrocytes (also called *astroglia*)**
  - » **Oligodendrocytes**
  - » **Ependymal cells**
  - » **Radial glia**
- **FOR PNS [PERIPHERIC NERVOUS SYSTEM**
  - » **Schwann cells**
  - » **Satellite cells**

The central nervous system has 4 types of neuroglia:

1. ependymal cells
2. astrocytes
3. oligodendrocytes
4. microglia

The cell bodies of neurons in the PNS are clustered in masses called ganglia, which are surrounded and protected by support cells called neuroglia.

Neuroglia of the Peripheral Nervous System,

- **There are 2 types of neuroglia in the PNS: satellite cells and Schwann cells.**

1. Satellite cells (*amphicytes*) surround ganglia and regulate the environment around the neuron.

2. Schwann cells (*neurilemmacytes*) form a myelin sheath called the neurilemma around peripheral axons.

One Schwann cell encloses only one segment of an axon, so it takes many Schwann cells to sheath an entire axon.

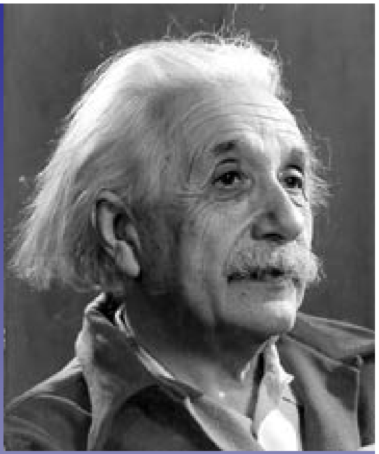
- Neurons perform all communication, information processing, and control functions of the nervous system.

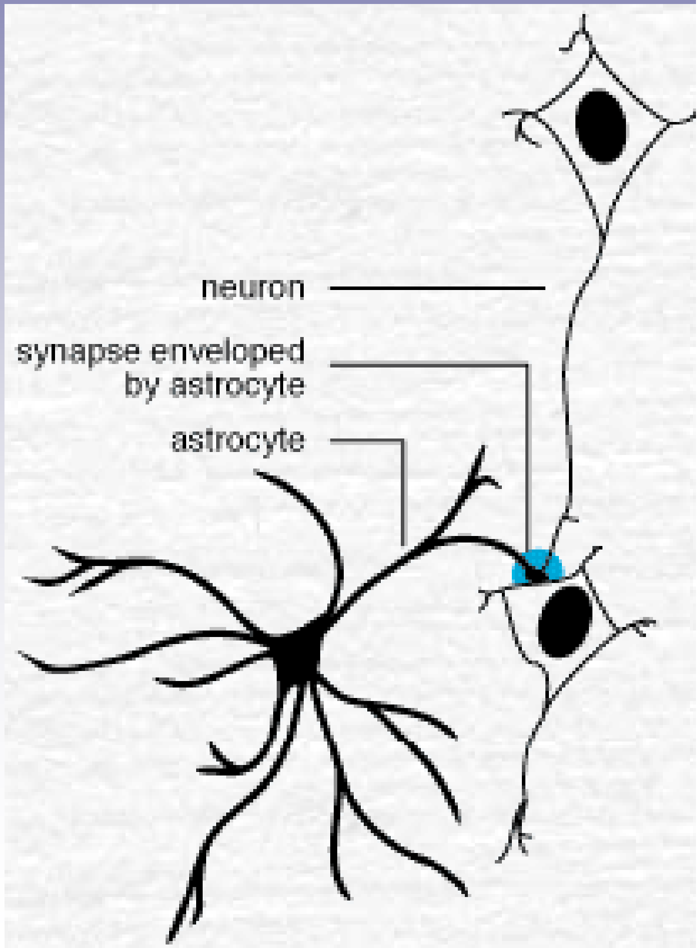
- Neuroglia preserve the physical and biochemical structure of neural tissue, and are essential to the survival and function of neurons.

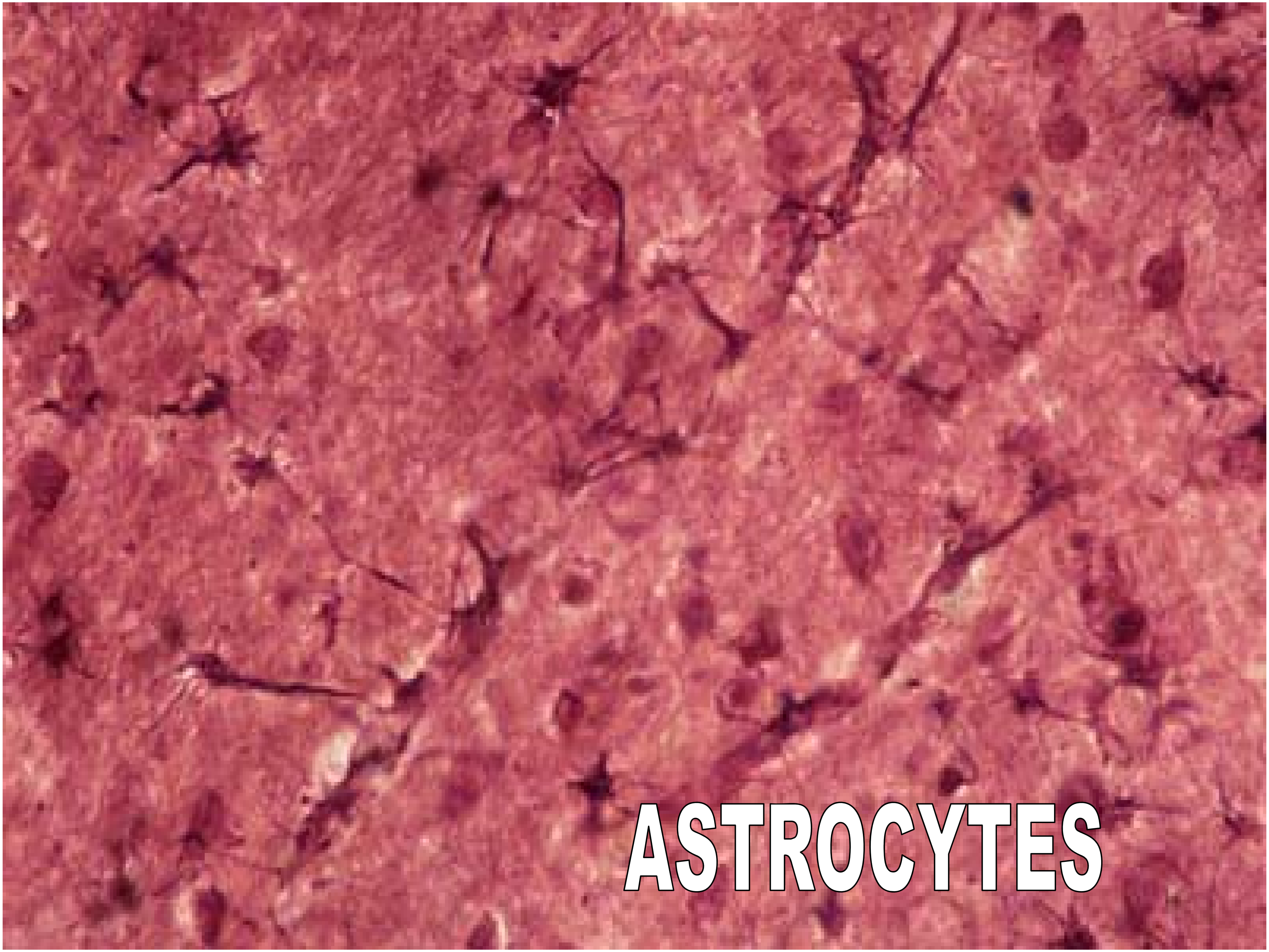
Neuroglia

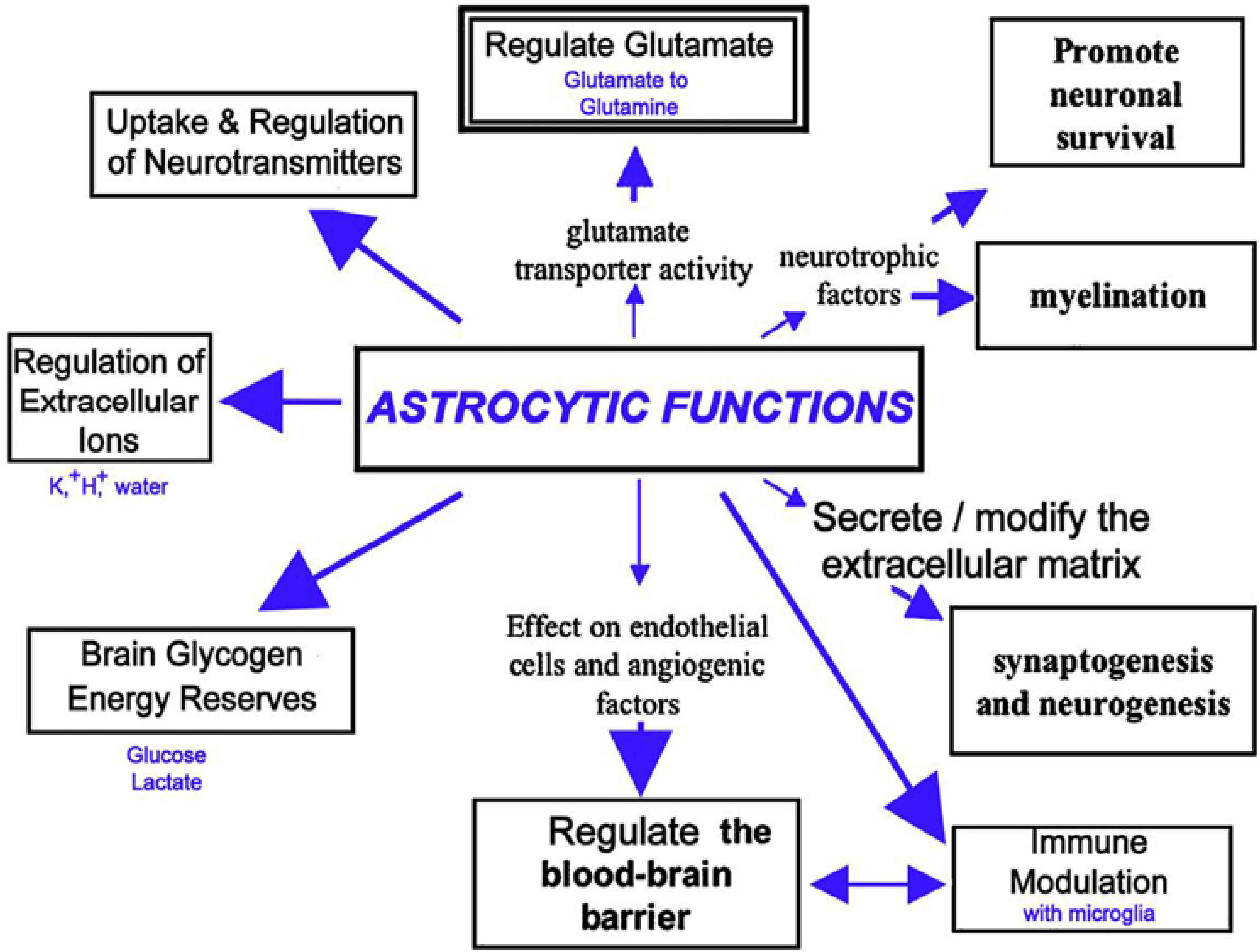
- Outnumber neurons by about 10 to 1 (the guy on the right had an inordinate amount of them).
- 6 types of supporting cells
  - 4 are found in the CNS:

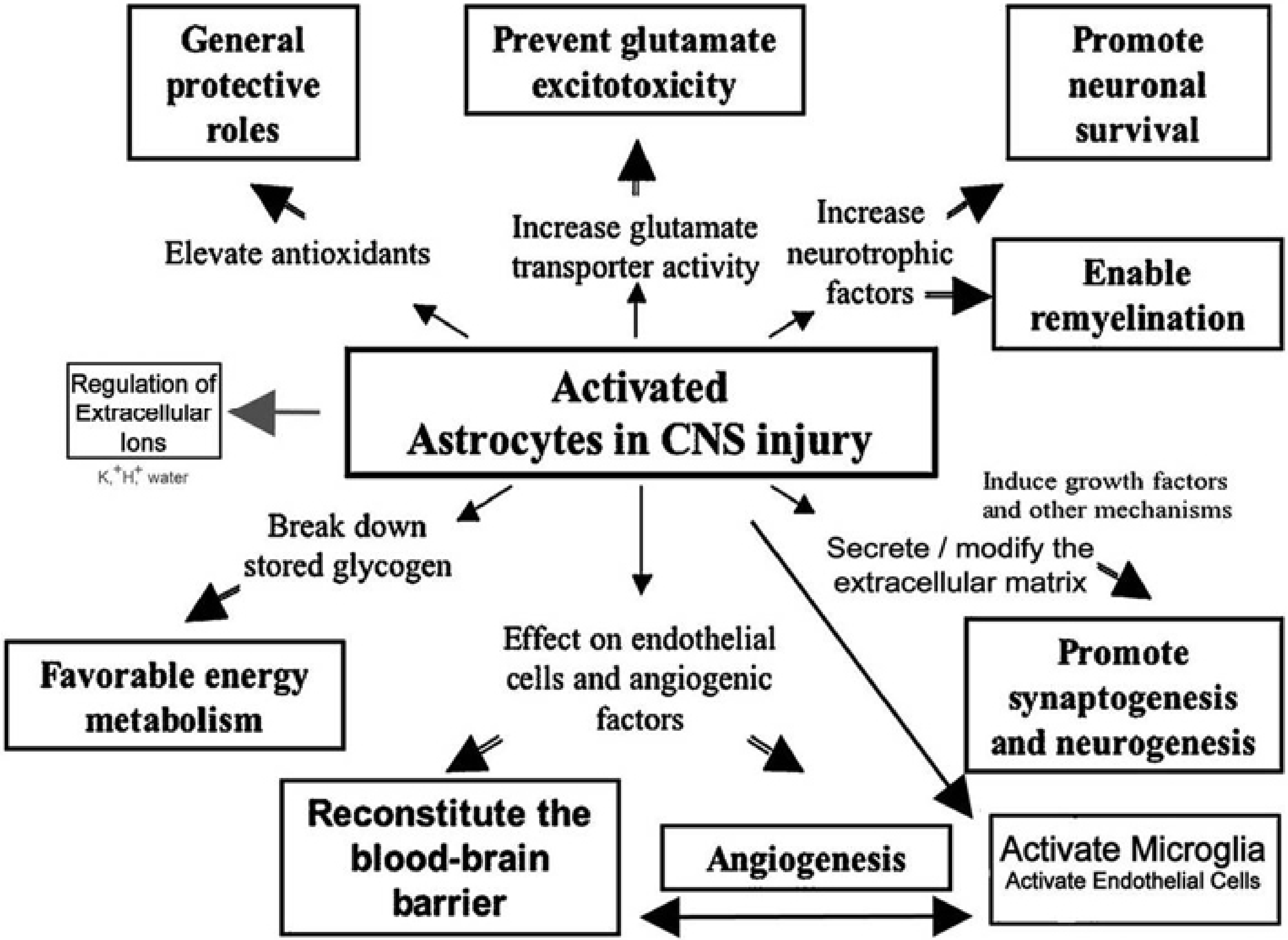
1. **Astrocytes**
   - Star-shaped, abundant, and versatile
   - Guide the migration of developing neurons
   - **Act as K+ and NT buffers**
   - Involved in the formation of the blood brain barrier
   - Function in nutrient transfer






ASTROCYTES


Regulate Glutamate
Glutamate to Glutamine
Uptake & Regulation of Neurotransmitters
Promote neuronal survival
glutamate transporter activity
neurotrophic factors
myelination
Regulation of Extracellular Ions
K^+, H^+, water
ASTROCYTIC FUNCTIONS
Secrete / modify the extracellular matrix
synaptogenesis and neurogenesis
Brain Glycogen Energy Reserves
Glucose
Lactate
Effect on endothelial cells and angiogenic factors
Regulate the blood-brain barrier
Immune Modulation
with microglia


General protective roles
Prevent glutamate excitotoxicity
Promote neuronal survival
Elevate antioxidants
Increase glutamate transporter activity
Increase neurotrophic factors
Enable remyelination
Regulation of Extracellular Ions
K^+, H^+, water
Activated Astrocytes in CNS injury
Induce growth factors and other mechanisms
Break down stored glycogen
Secrete / modify the extracellular matrix
Favorable energy metabolism
Effect on endothelial cells and angiogenic factors
Promote synaptogenesis and neurogenesis
Reconstitute the blood-brain barrier
Angiogenesis
Activate Microglia
Activate Endothelial Cells

Astrocytes

-**Astrocytes are large and have many functions, including:**

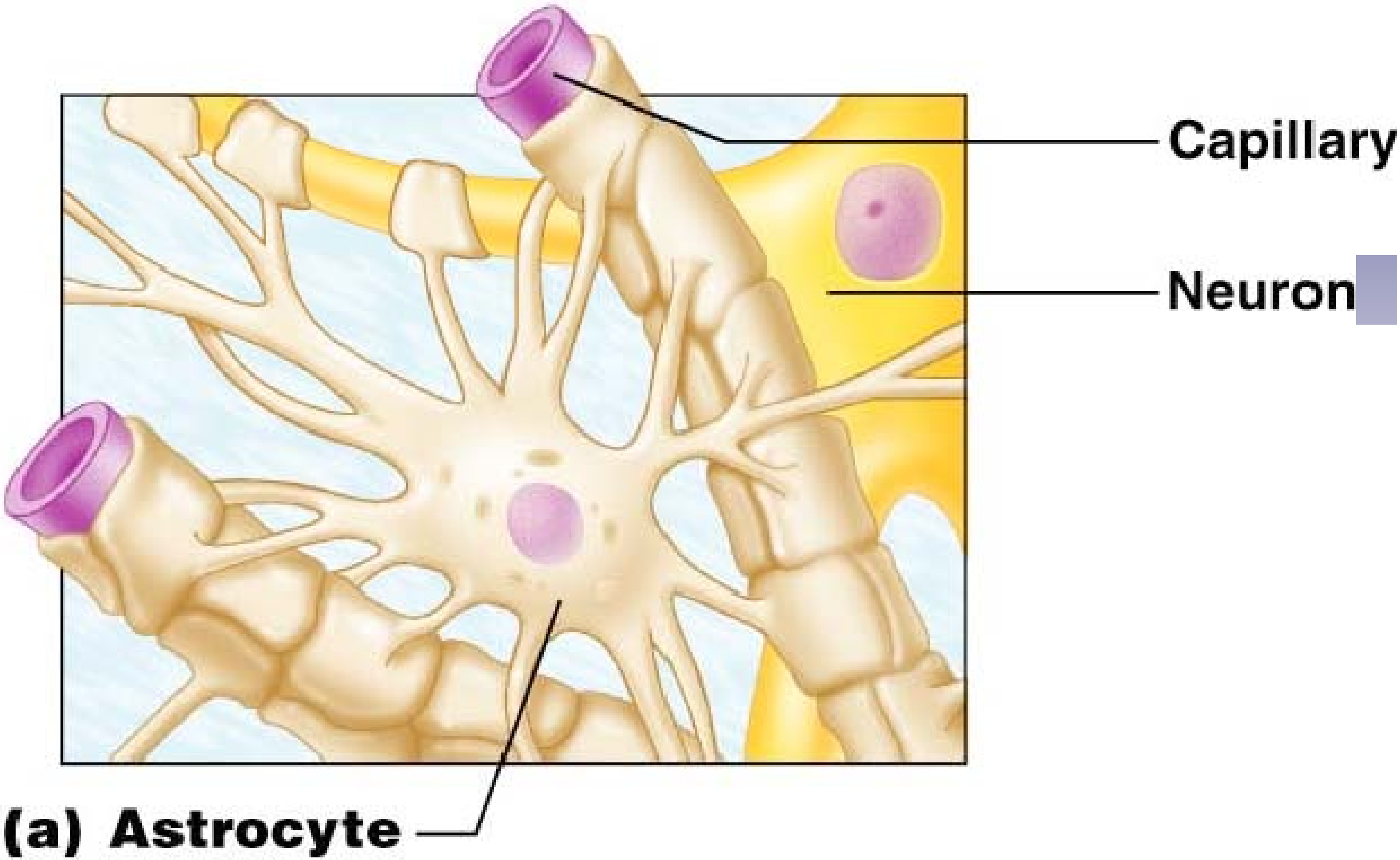
- **maintaining the blood-brain barrier that isolates the CNS**

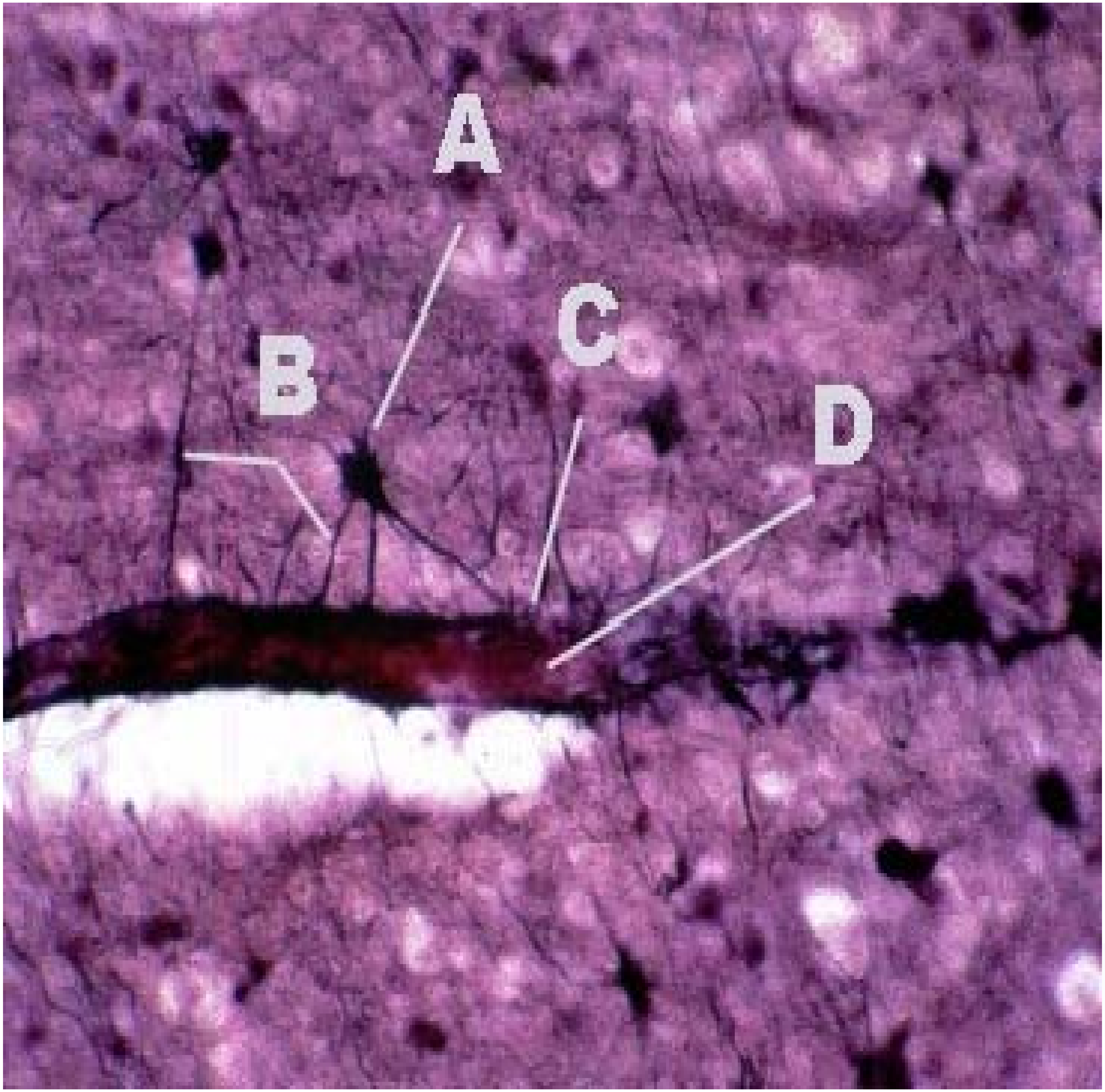
- **creating a 3-dimensional framework for the CNS**
- **repairing damaged neural tissue**

- **guiding neuron development**

- **controlling the interstitial environment**

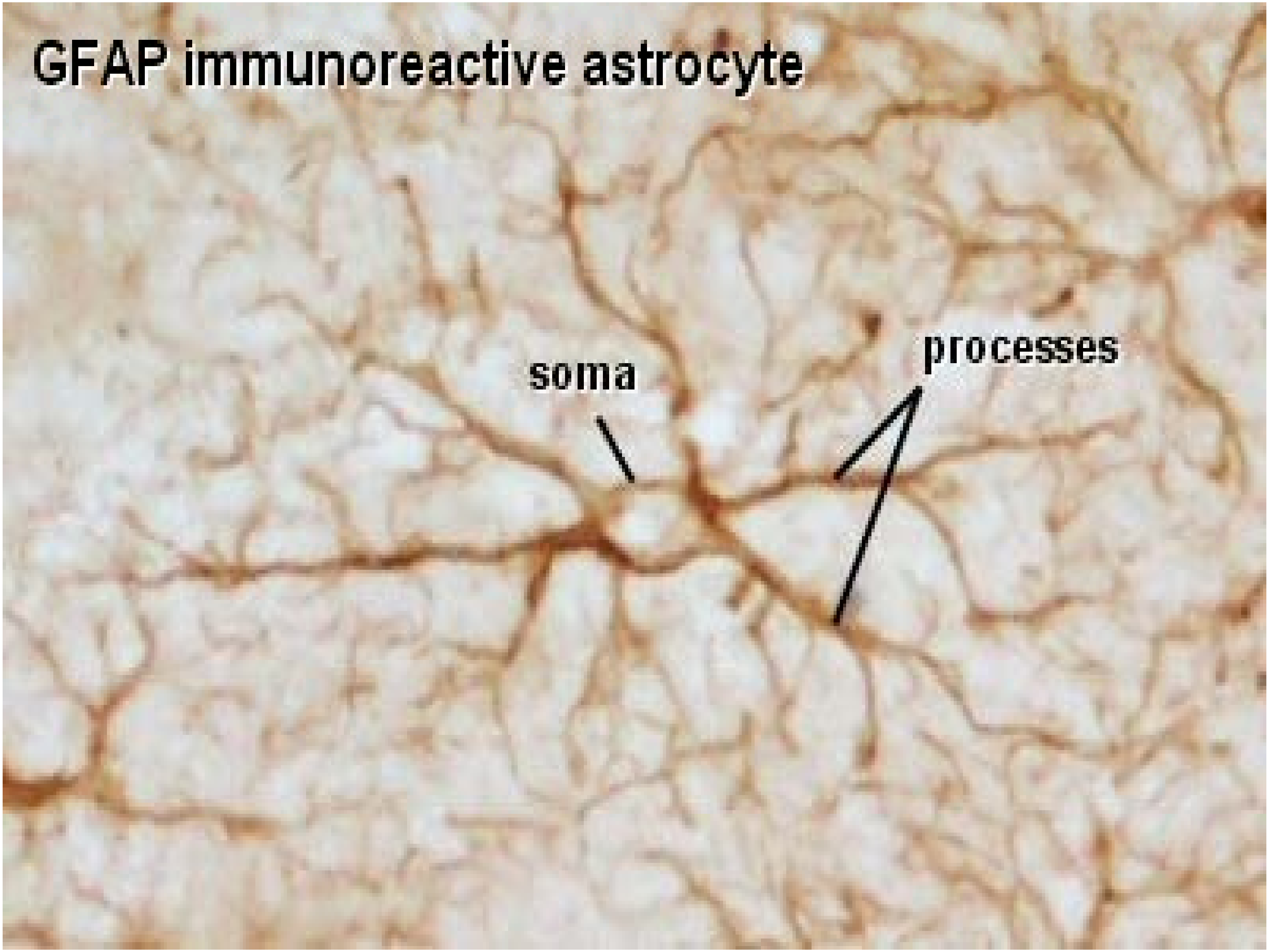
Astrocytes

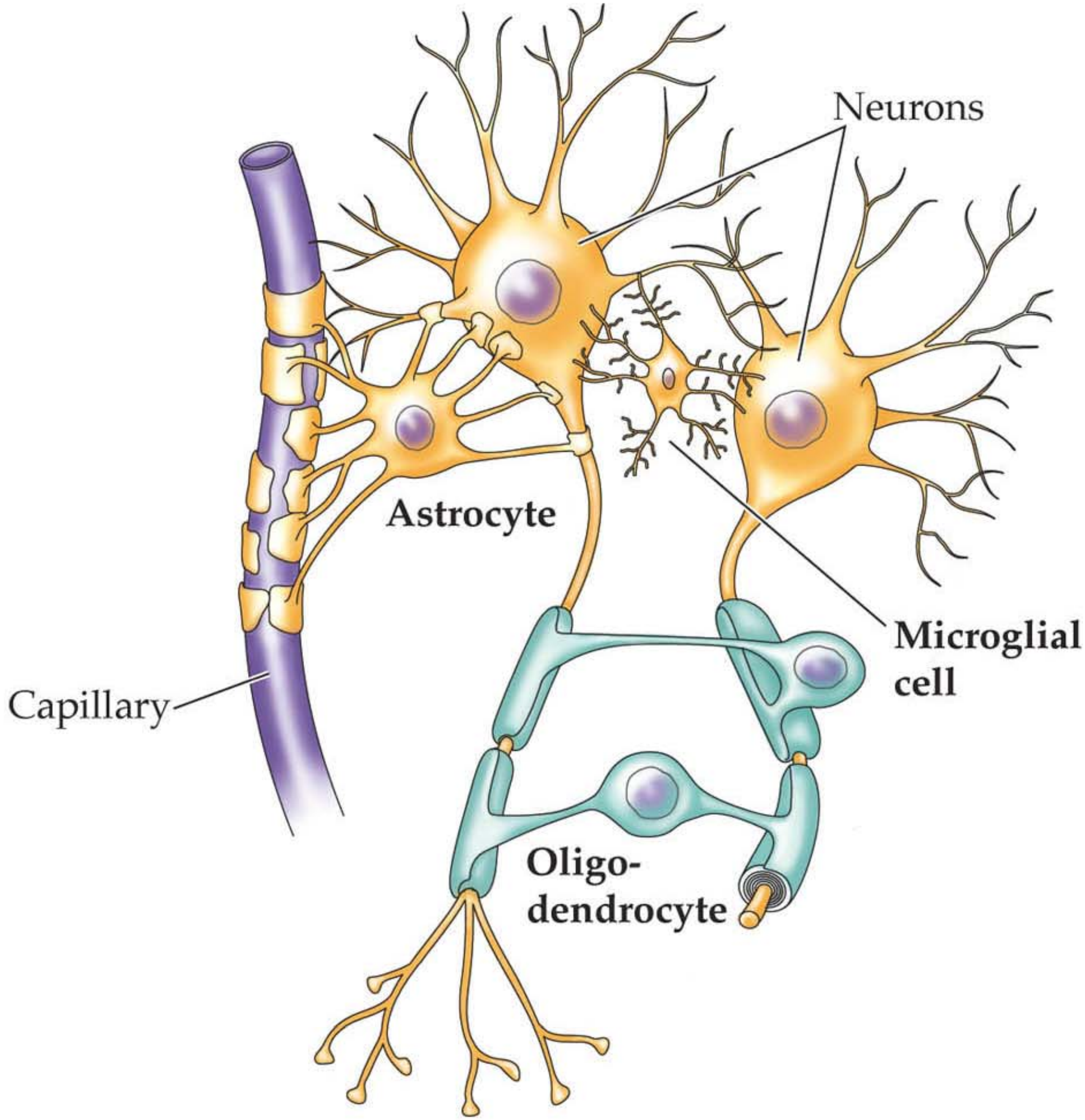




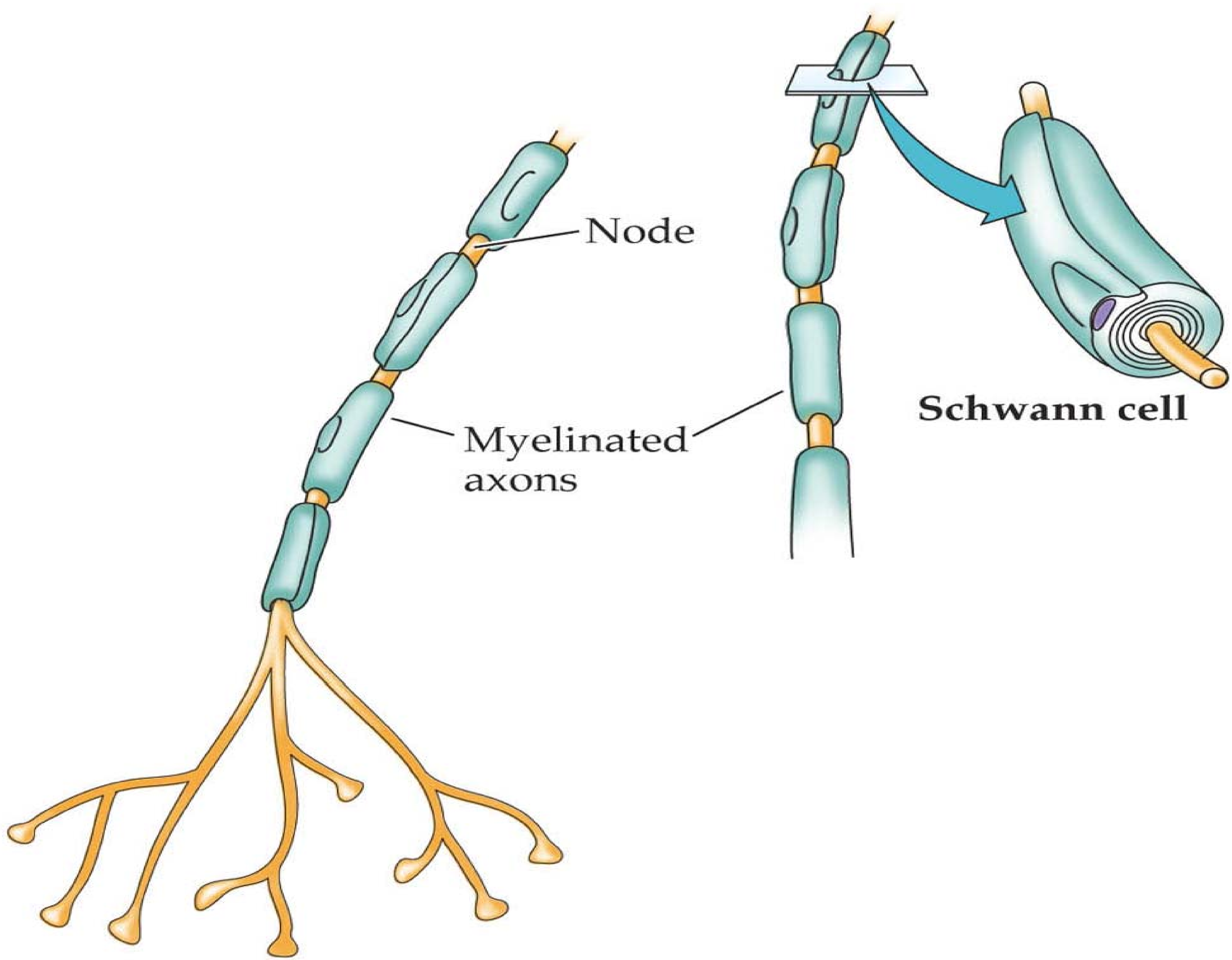
A:ASTROCYTES numerous processes (B), some astrocytic processes are in contact with nerve fibers.

Other astrocytic processes surround capillaries (D) forming perivascular end-feet (C).


GFAP immunoreactive astrocyte
soma
processes



ANIMAL PHYSIOLOGY, Figure 11.2 (Part 1)

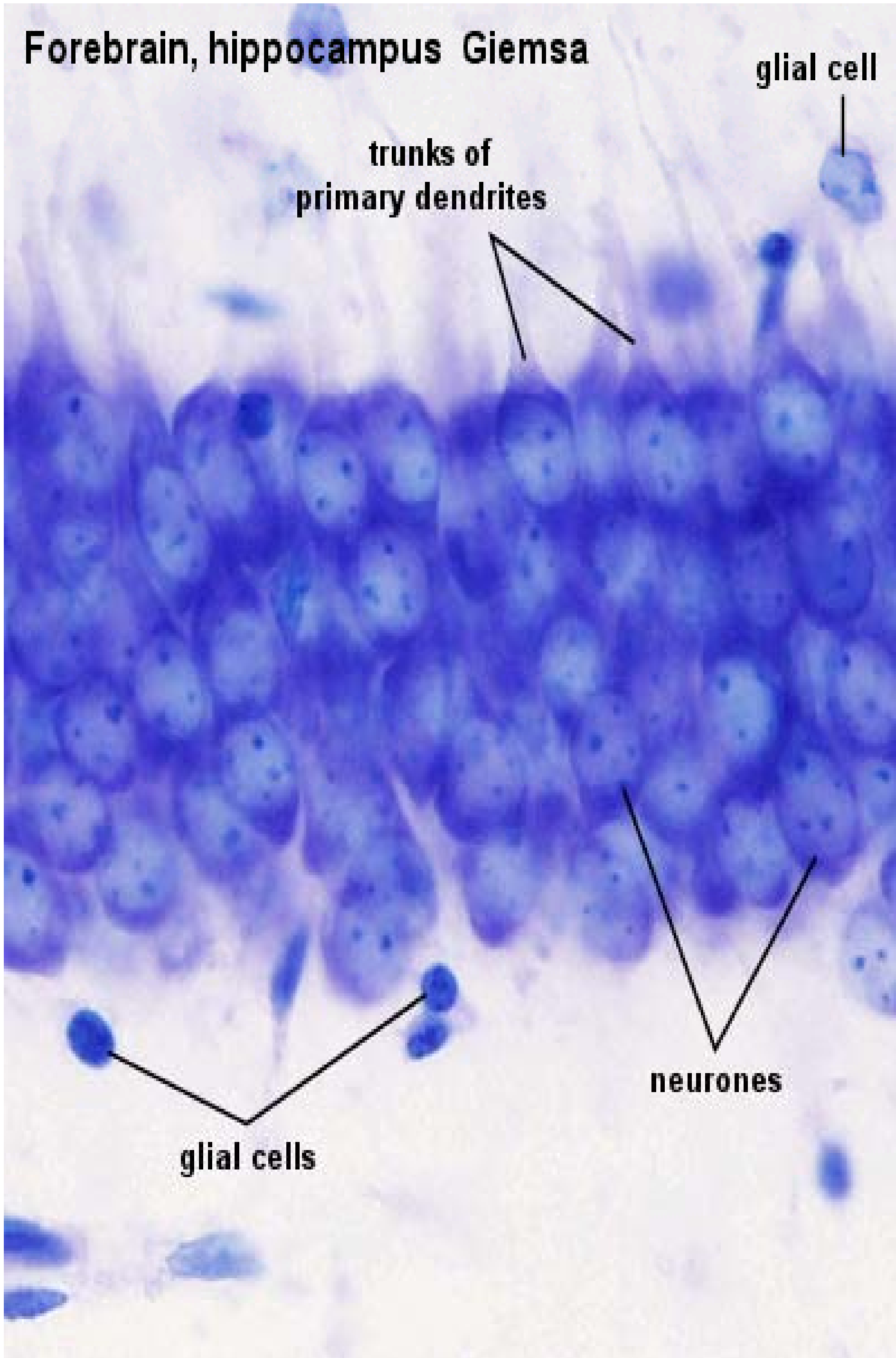


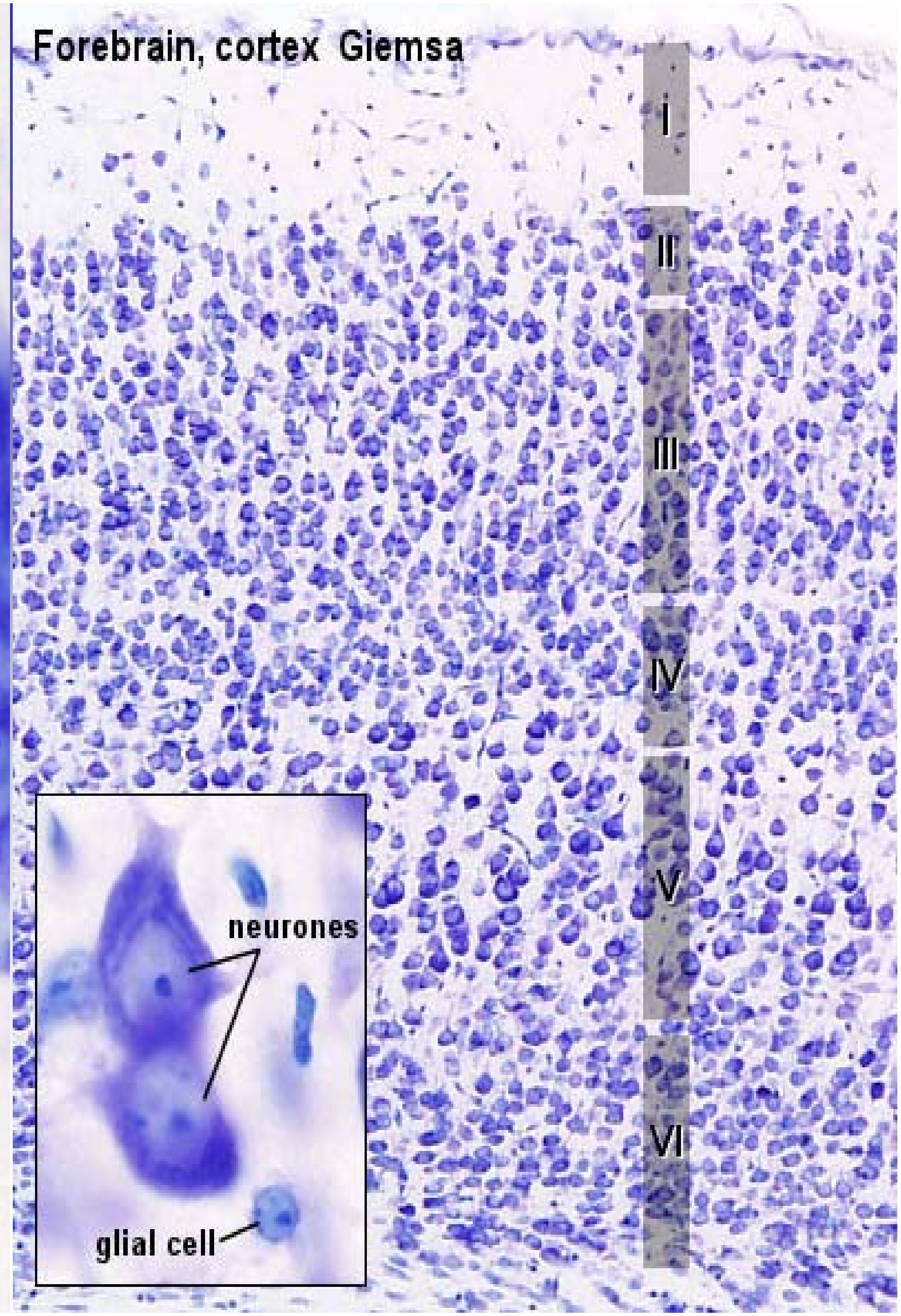
Node
Myelinated
axons
Schwann cell

- **Many glial cells do express neurotransmitter receptors, but <u>they do not form synapses with neurones</u>.**

- **Neuronal activity may regulate glial function by a spillover of transmitter from synaptic sites, which are typically surrounded by fine processes of glial cells.**

- **Glial cells may also communicate with each other via GAP junctions.**


Forebrain, hippocampus Giemsa
glial cell
trunks of
primary dendrites
neurones
glial cells


Forebrain, cortex Giemsa
I
II
III
IV
V
VI
neurones
glial cell

Neuroglia

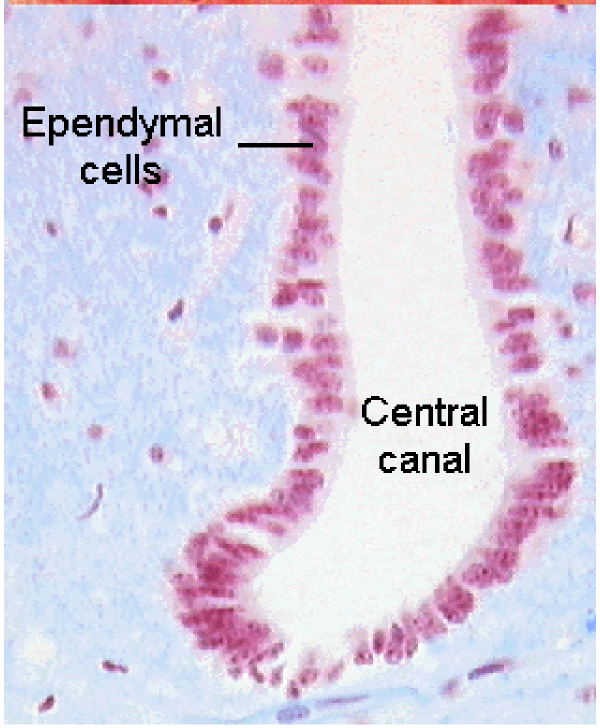
2. Microglia

- <u>**Specialized immune cells that act as the macrophages of the CNS**</u>
- **Why is it important for the CNS to have its own army of immune cells? Microglia**
- **- Microglia are small, with many fine-branched processes. They migrate**
- **through neural tissue, cleaning up cellular debris, waste products and**
- **pathogens.**

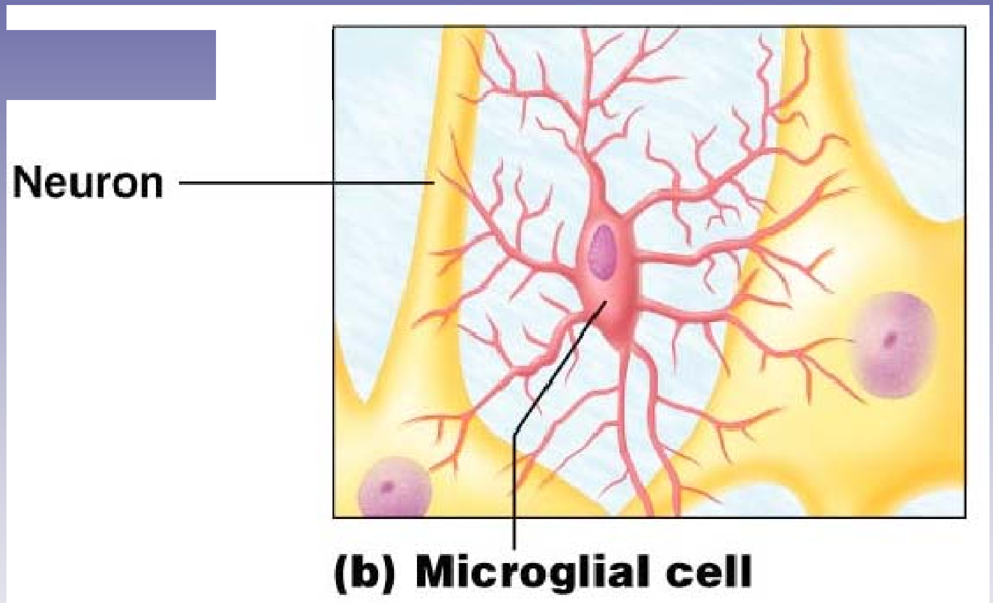
3. Ependymal Cells

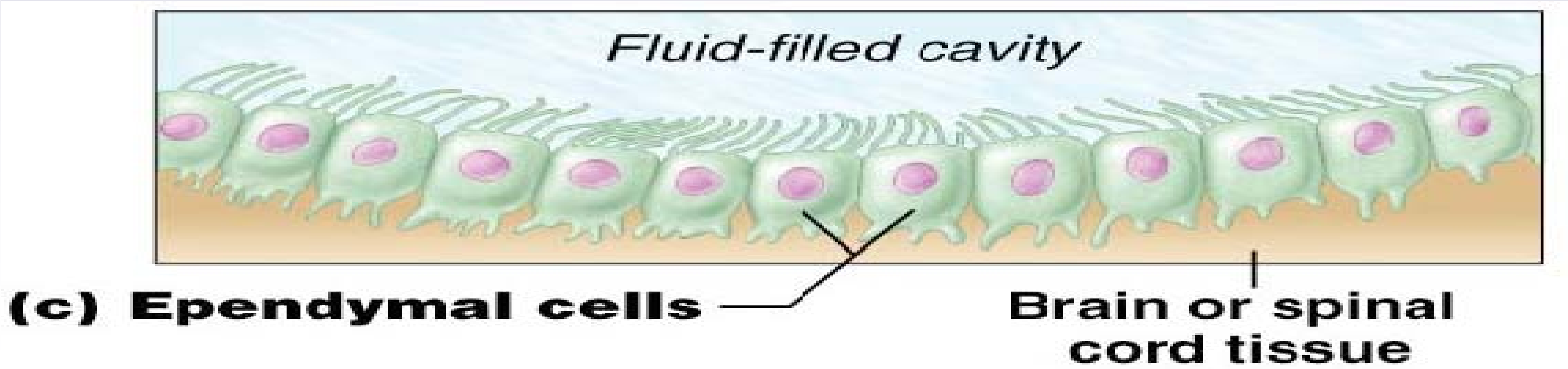
- **Low columnar epithelial-esque cells that line the ventricles of the brain and the central canal of the spinal cord**
- **Some are ciliated which facilitates the movement of cerebrospinal fluid**

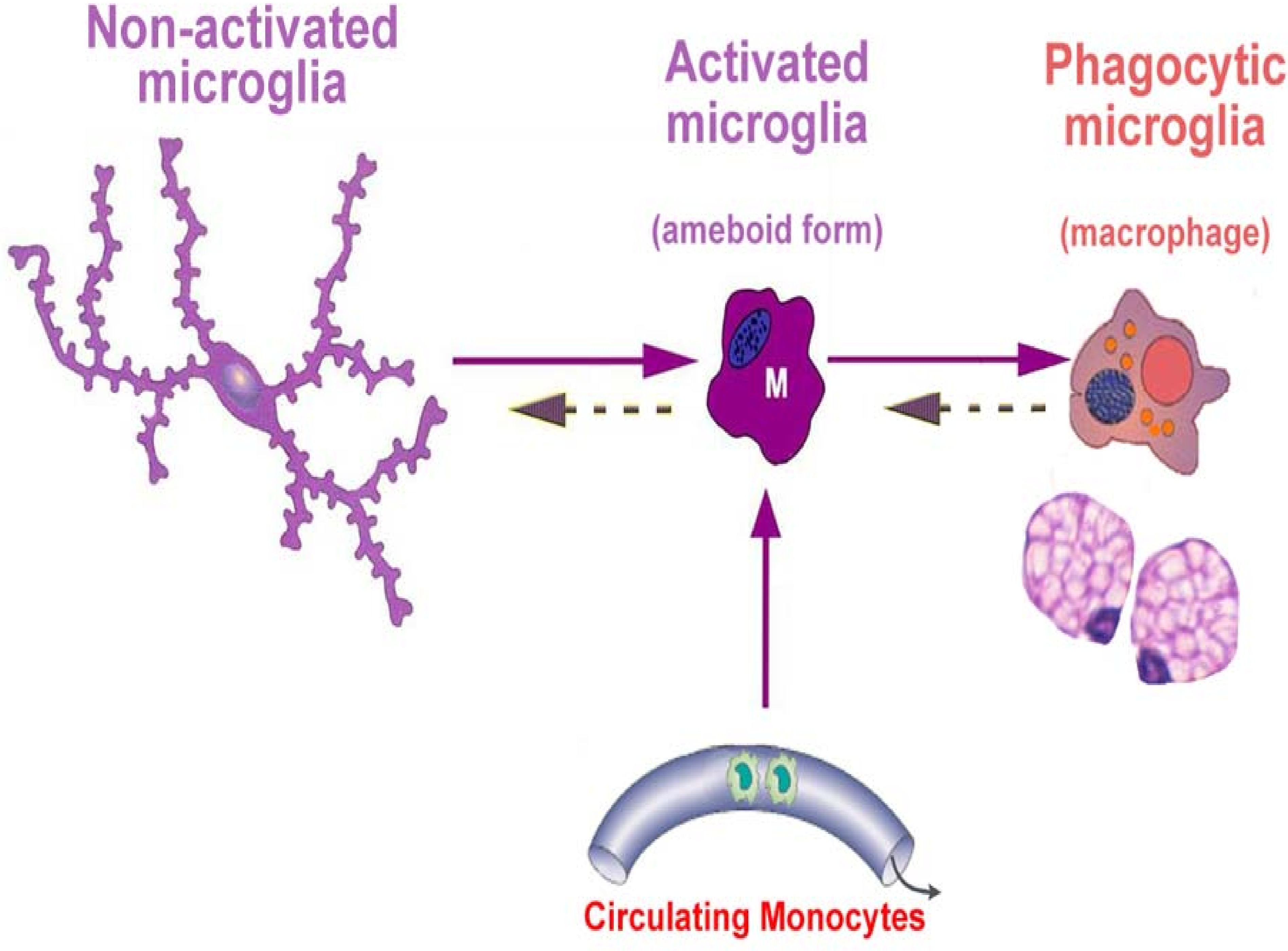
MICROGLIA CELL - GOLGI STAIN



Microglia and Ependymal Cells

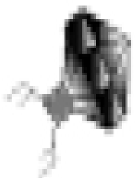




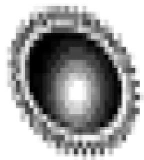

Non-activated microglia
Activated microglia
(ameboid form)
M
Phagocytic microglia
(macrophage)
Circulating Monocytes

MICROGLIA STIMULATORS

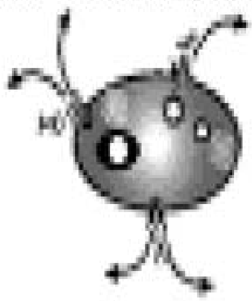
viruses



bacteria



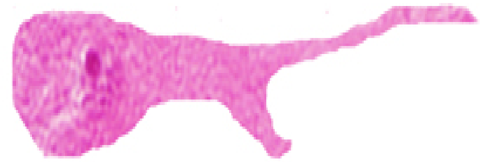
dead cells/debris



CNS toxins

ABeta40/42

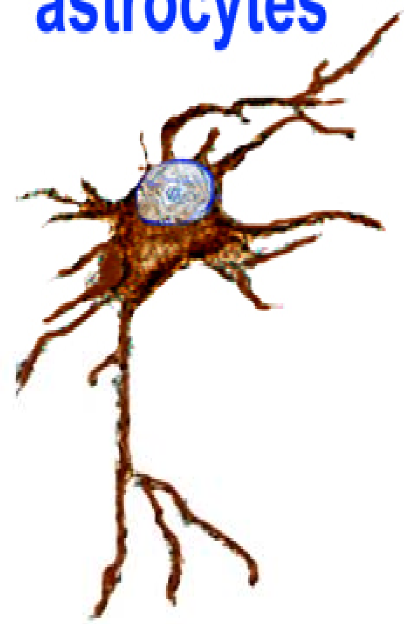
damaged neurons

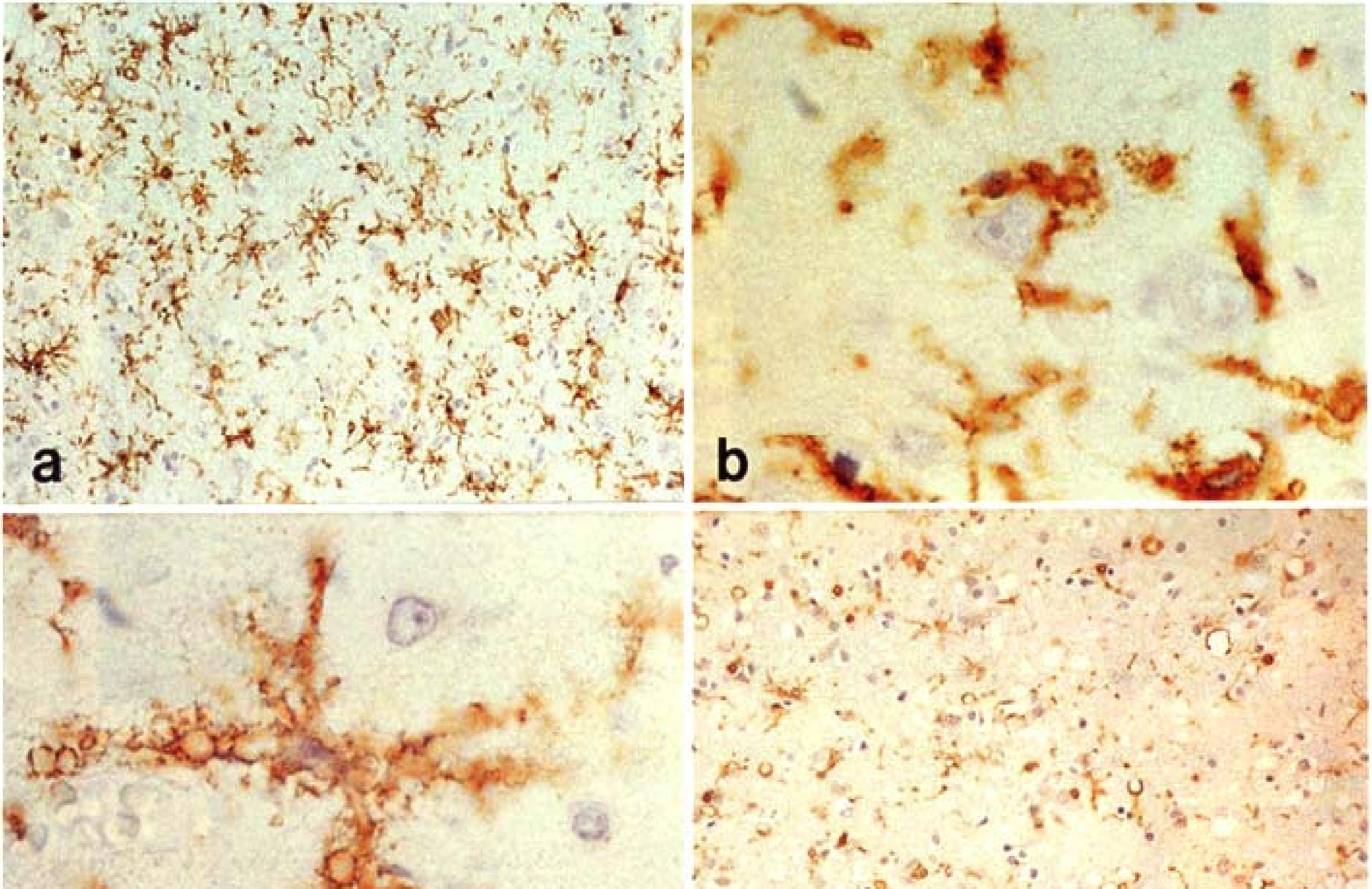


ischemia

neuronal
degeneration

activated
astrocytes





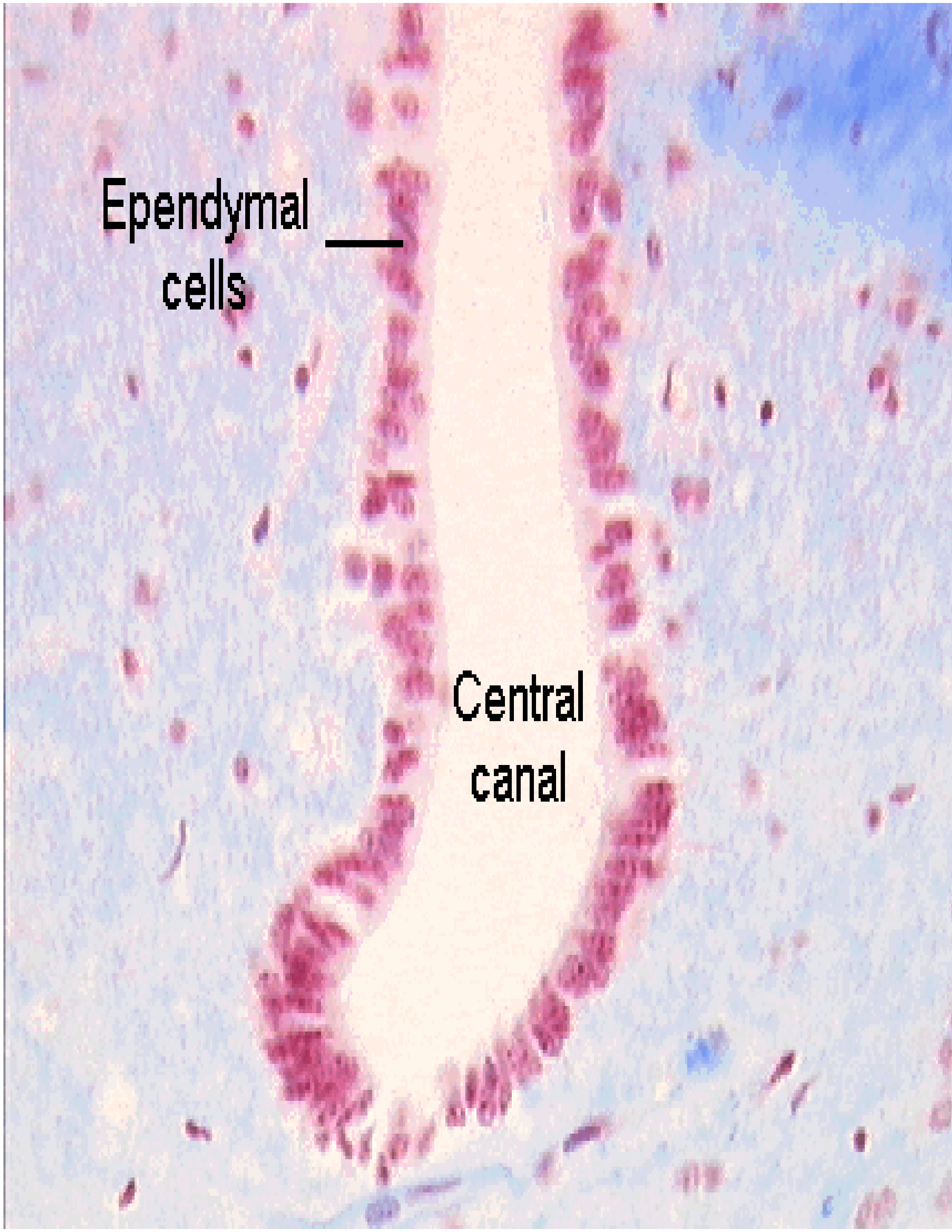
a
b
c
d

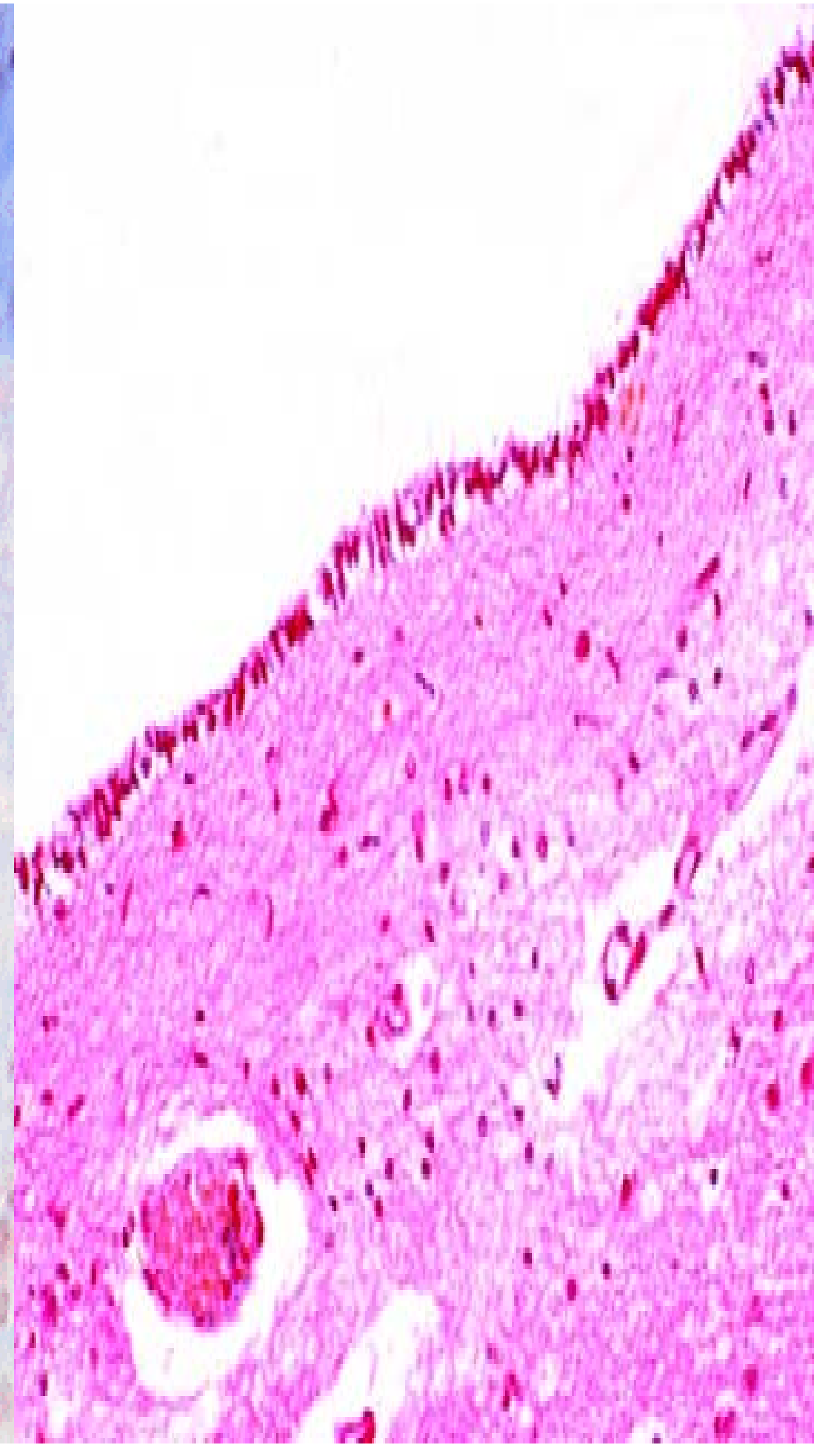
1. Ependymal Cells

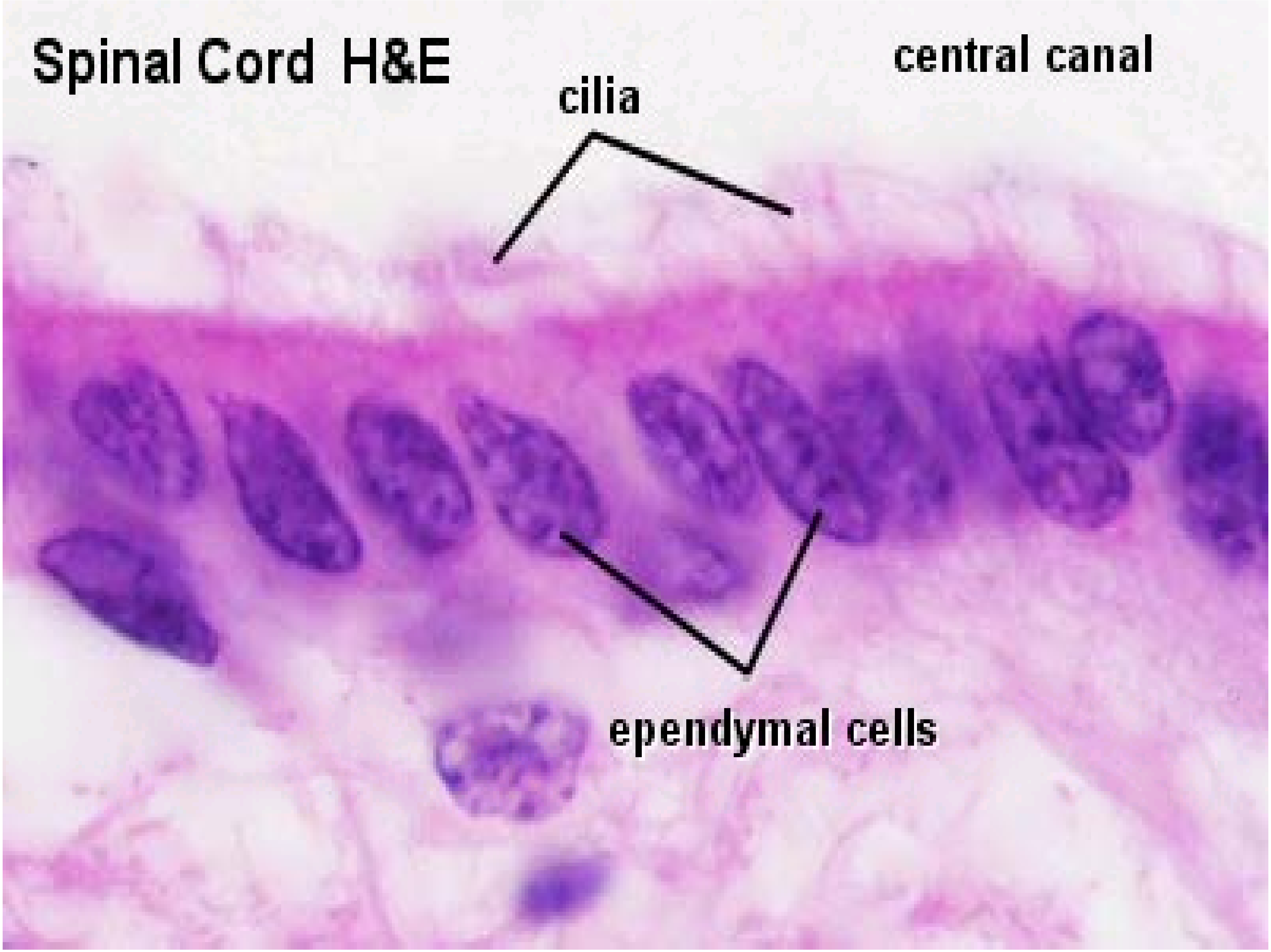
-The central canal of the spinal cord and ventricles of the brain, filled with circulating cerebrospinal fluid (CSF), are lined with ependymal cells which form an epithelium called the ependyma.

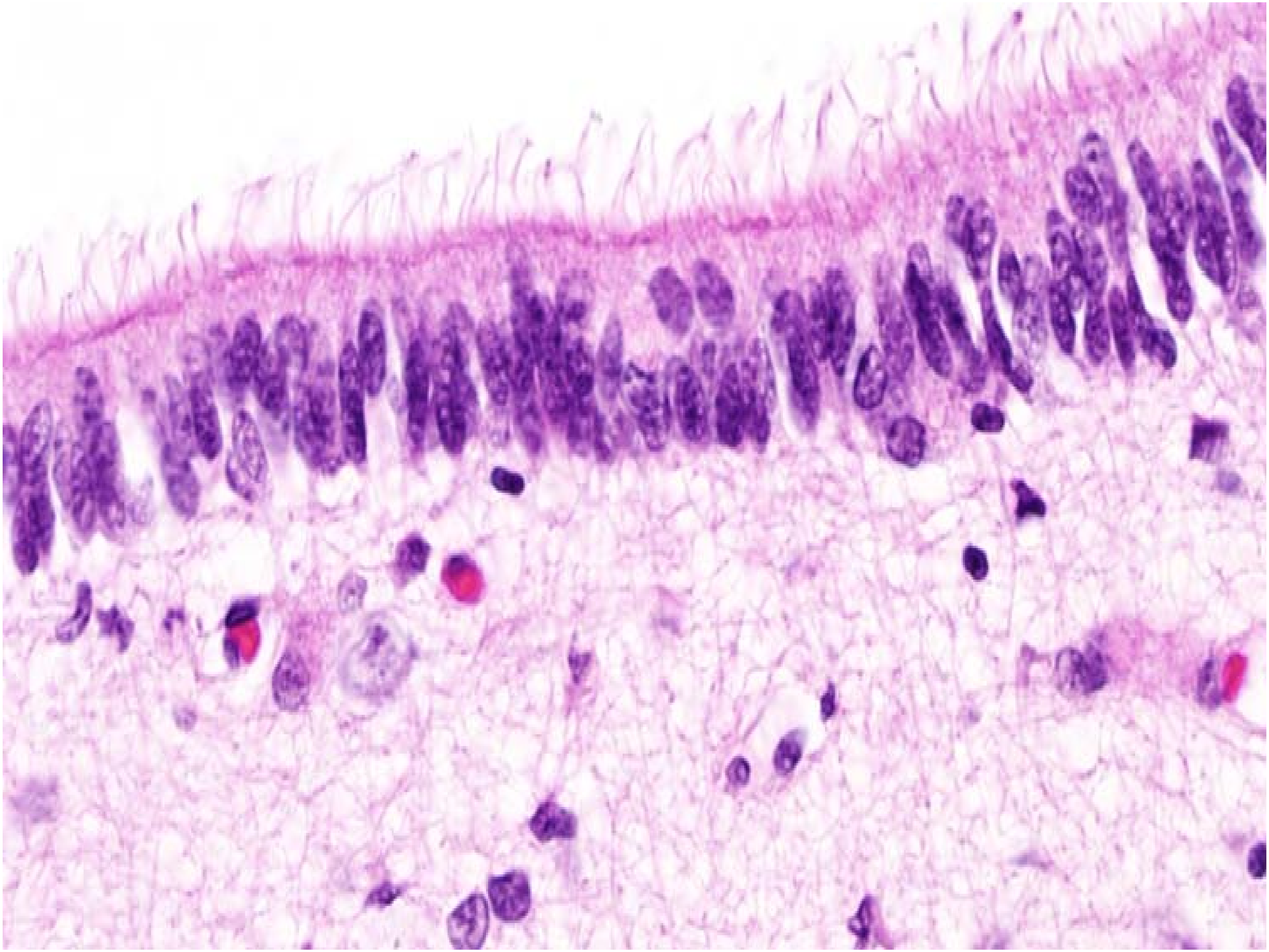
-Some ependymal cells secrete cerebrospinal fluid, and some have cilia or microvilli that help circulate CSF.

-Others monitor the CSF or contain stem cells for repair. Processes of ependymal cells are highly branched and contact neuroglia directly.


Ependymal
cells
Central
canal




Spinal Cord H&E
central canal
cilia
ependymal cells



•**The ventricles of the brain and the central canal of the spinal cord are lined with ependymal cells.**

•**The cells are often cilated and form a simple cuboidal or low columnar epithelium.**

•**The lack of tight junctions between ependymal cells allows a free exchange between cerebrospinal fluid and nervous tissue.**

•**Tanycytes** are special ependymal cells located in the floor of the third ventricle having processes extending deep into the hypothalamus. It is possible that their function is to transfer chemical signals from CSF to CNS.

•**Tanycytes form the ventricular lining over the few CNS regions in which the blood-brain barrier is incomplete.**

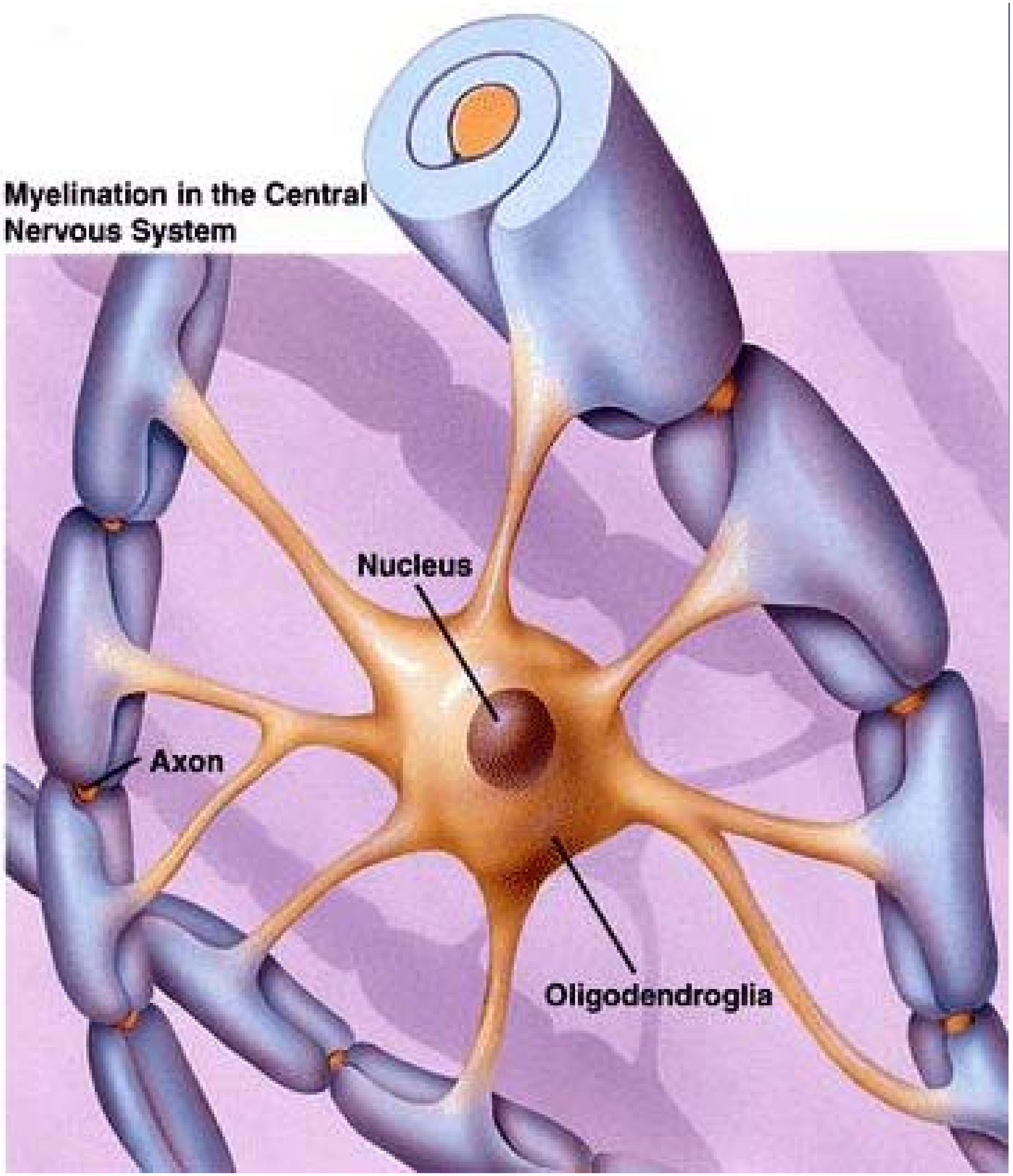
•**They do form tight junctions and control the exchange of substances between these regions and surrounding nervous tissue or cerebrospinal fluid.**

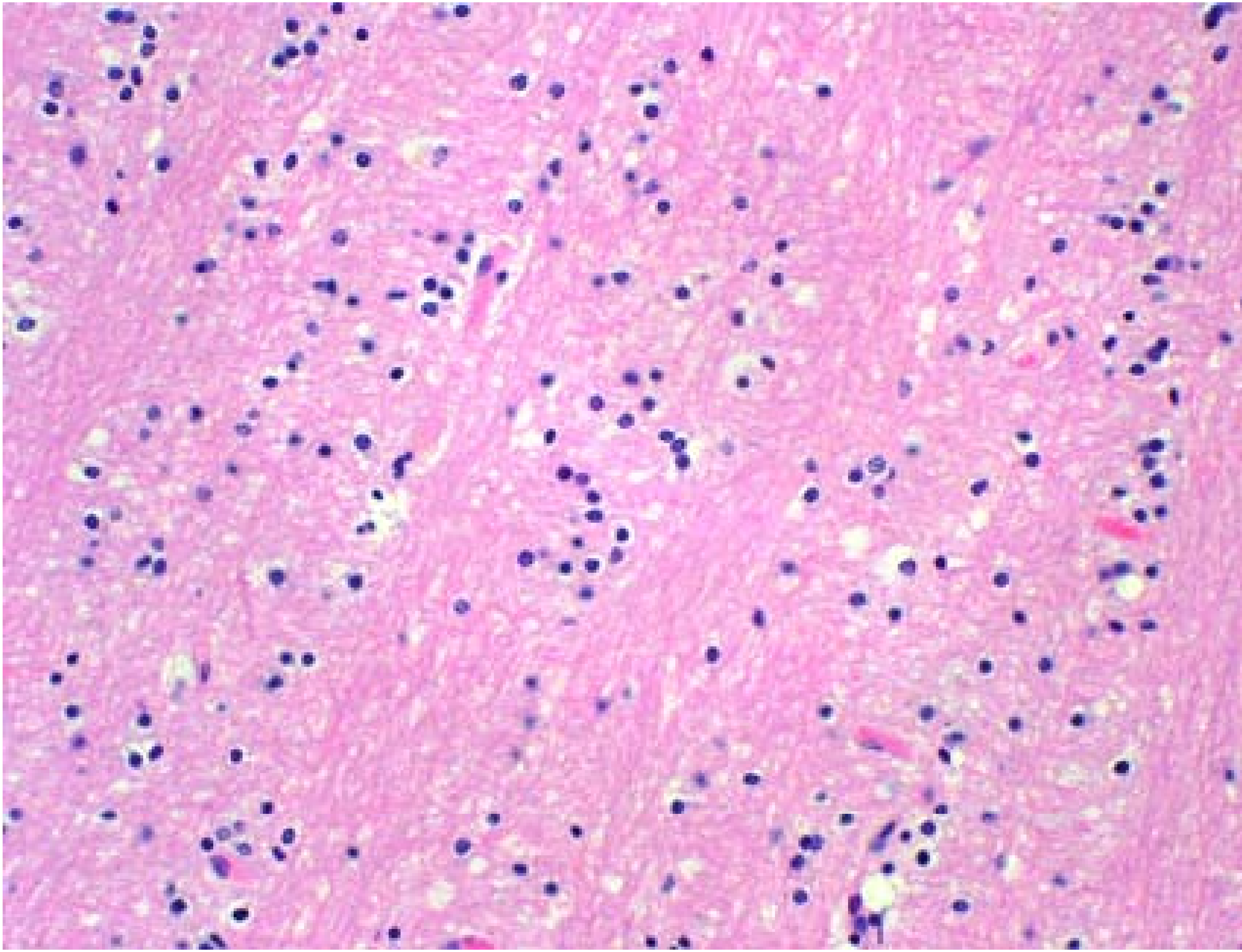
•tanycytes participate in the release of gonadotropic hormone-releasing hormone (Gn-RH).

Neuroglia

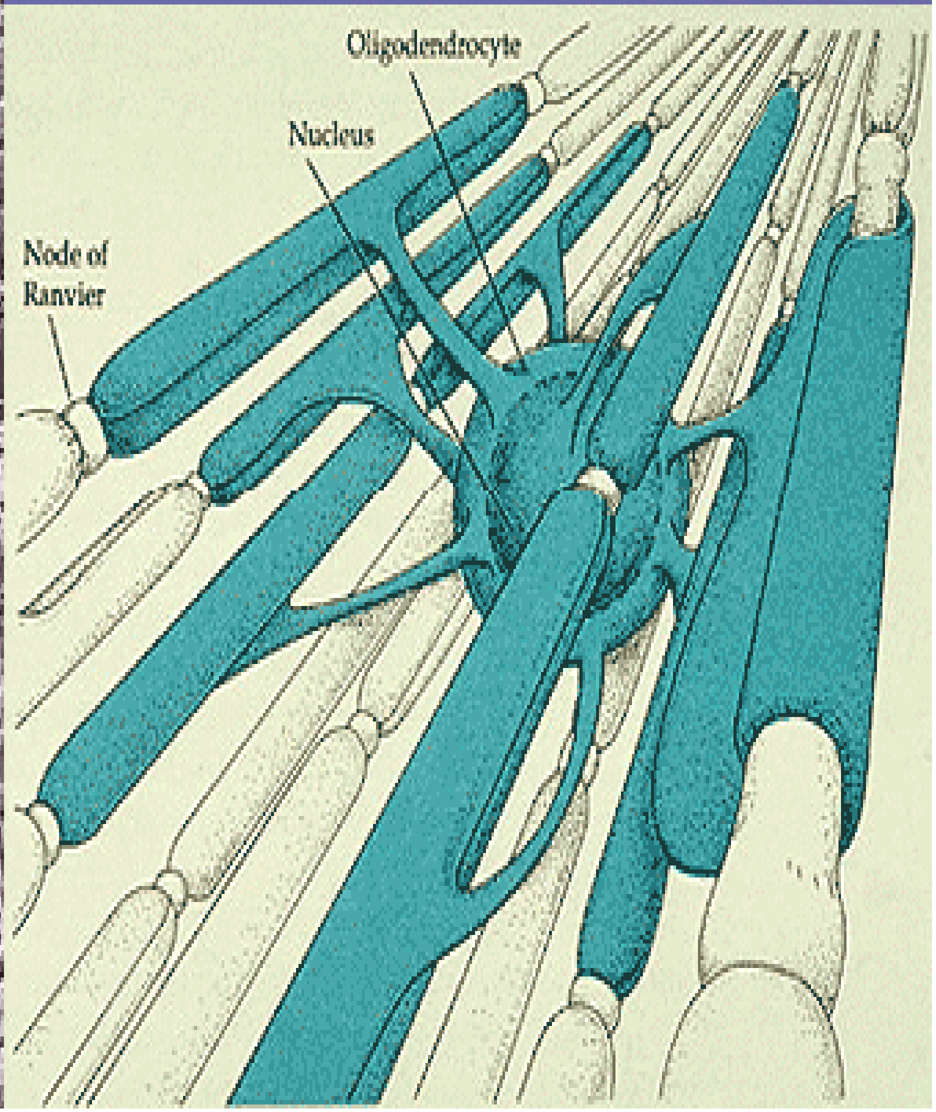
4.Oligodendrocytes

- **Produce the myelin sheath which provides the electrical insulation for certain neurons in the CNS**





Electron micrograph showing branched oligodendrocytes with processes extending to several underlying axons



Oligodendrocytes

-**Oligodendrocytes have smaller cell bodies and fewer processes than astrocytes.**

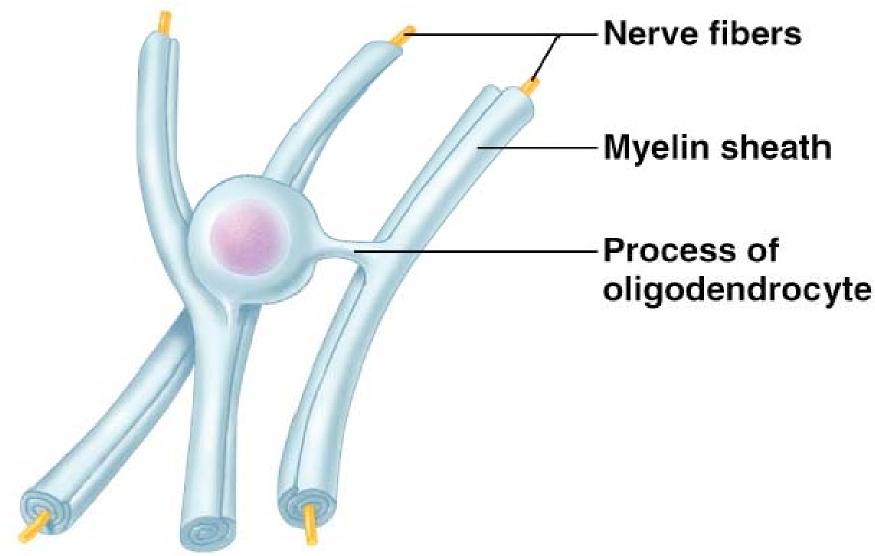
-**Processes may contact other neuron cell bodies, or wrap around axons to form insulating myelin sheaths.**

-**An axon covered with myelin (myelinated) increases the speed of action potentials.**

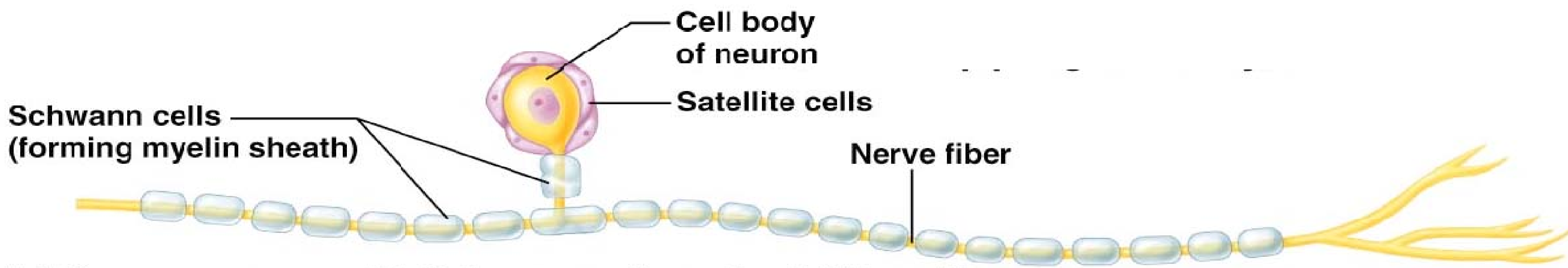
-**Myelinated segments of an axon are called internodes. The gaps between internodes, where axons may branch, are called nodes (*nodes of Ranvier*).**

- Because myelin is white, regions of the CNS that have many myelinated nerves are called white matter, while unmyelinated areas are called gray matter.

Oligodendrocytes, Schwann Cells, and Satellite Cells



(d) Oligodendrocyte



(e) Sensory neuron with Schwann cells and satellite cells

•Most glial cells are much smaller than neurones.

• Their nuclei are generally much smaller than neuronal nuclei, and they rarely contain an easily visible nucleolus.

•Other aspects of their morphology are variable.

•The glial cytoplasm is, if visible at all, very weakly stained.

• Different types of glial cells cannot be easily distinguished by their appearance in this type of preparation.

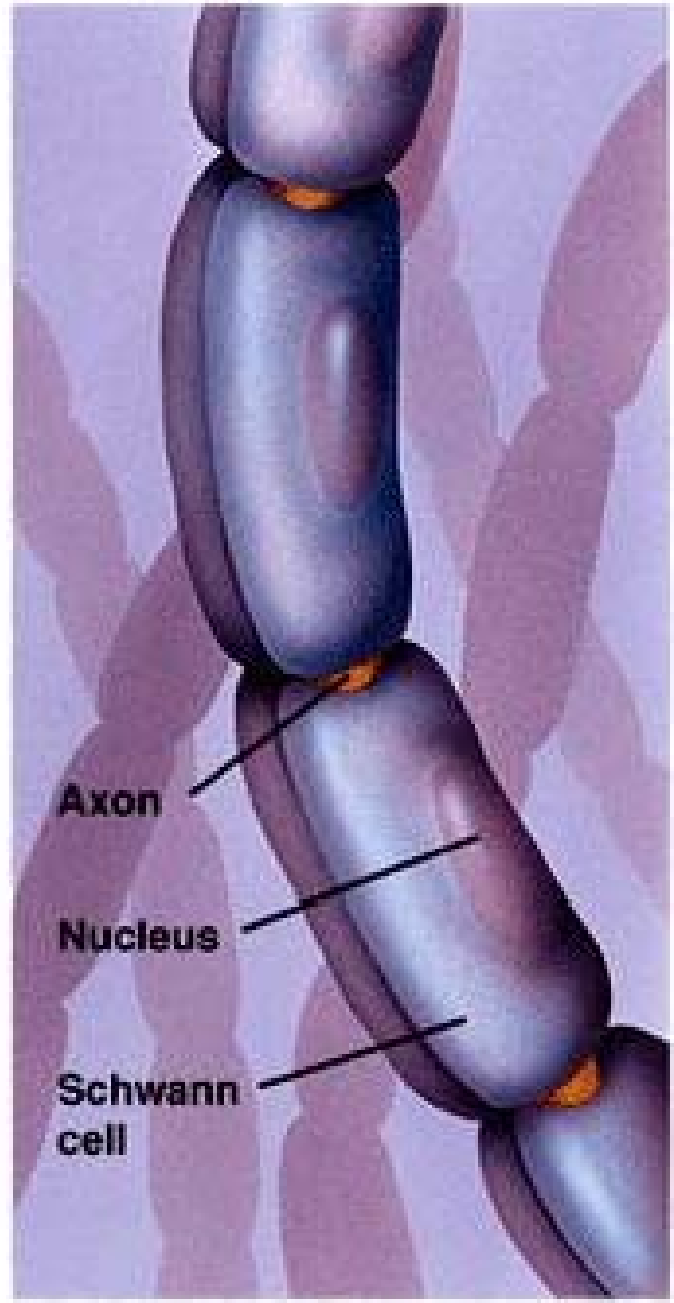
•Most of the small nuclei located in the white matter of the CNS, where they may form short rows, are likely to represent oligodendrocytes.

Neuroglia

- 2 types of glia in the PNS

1. **Satellite glial cells**
   - Surround clusters of neuronal cell bodies in the PNS
   - Unknown function
2. **Schwann cells**
   - Form myelin sheaths around the larger nerve fibers in the PNS.
   - Vital to neuronal regeneration

Myelination in the Peripheral Nervous System



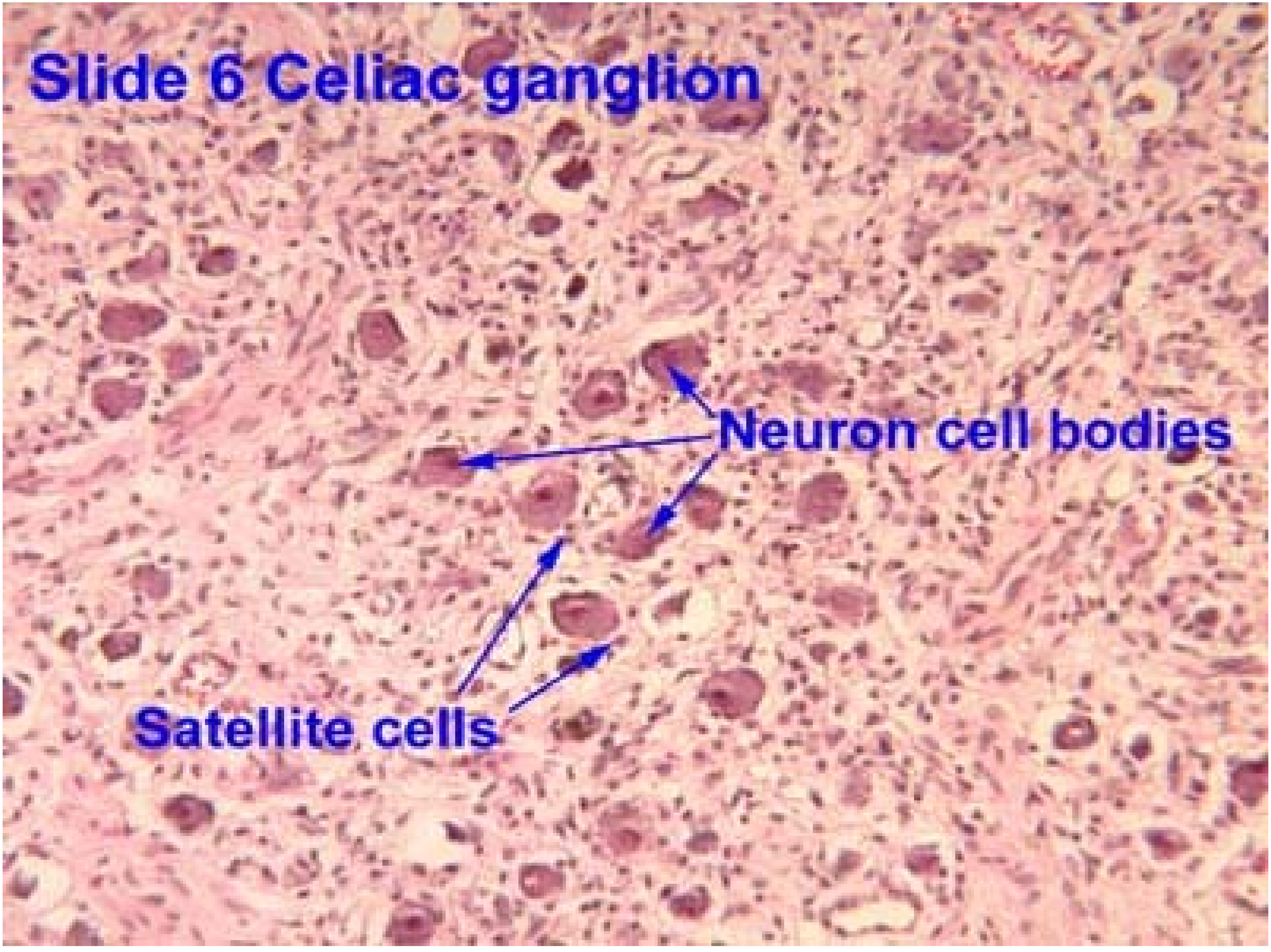
Satellite glial cells are the principle glial cells found in the peripheral nervous system,

- **specifically in sensory,**
- **sympathetic,**
- **parasympathetic ganglia**

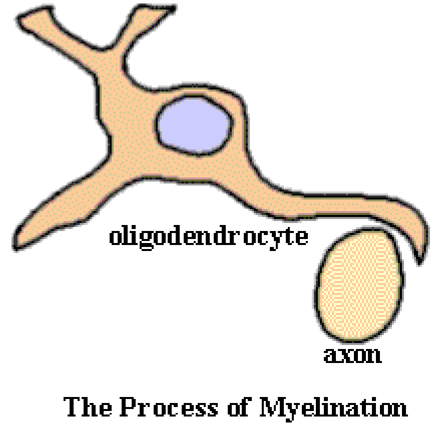
- Might have the same role as astrocytes

Do not confuse with :

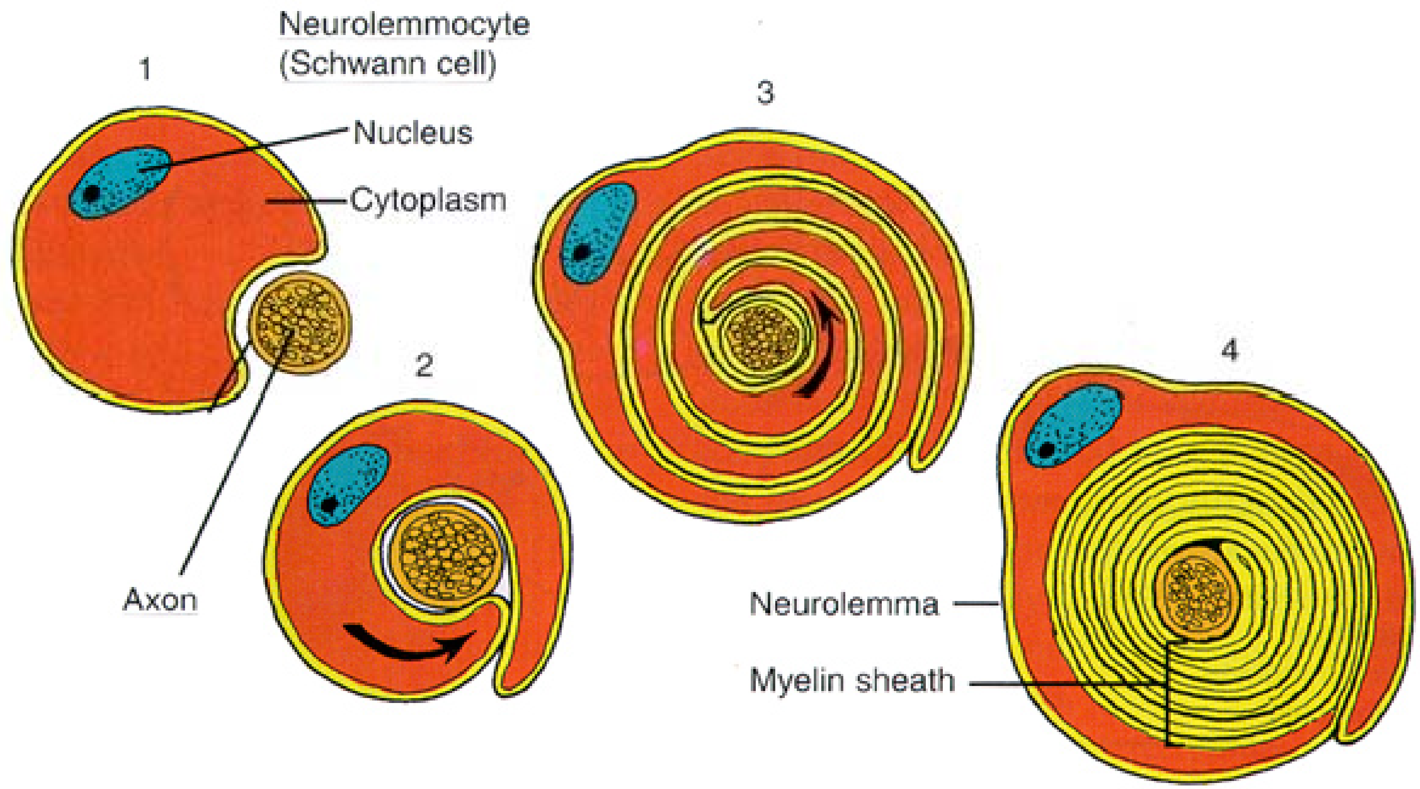
Myosatellite cells or **satellite cells** are small mononuclear progenitor cells with virtually no cytoplasm found in mature muscle. hey are found sandwiched between the basement membrane and sarcolemma (cell membrane) of individual muscle fibers. These cells represent the oldest known adult stem cell niche, and are involved in the normal growth of muscle, as well as regeneration following injury or disease.


Slide 6 Celiac ganglion
Neuron cell bodies
Satellite cells

Myelination in the CNS



Myelination in the PNS

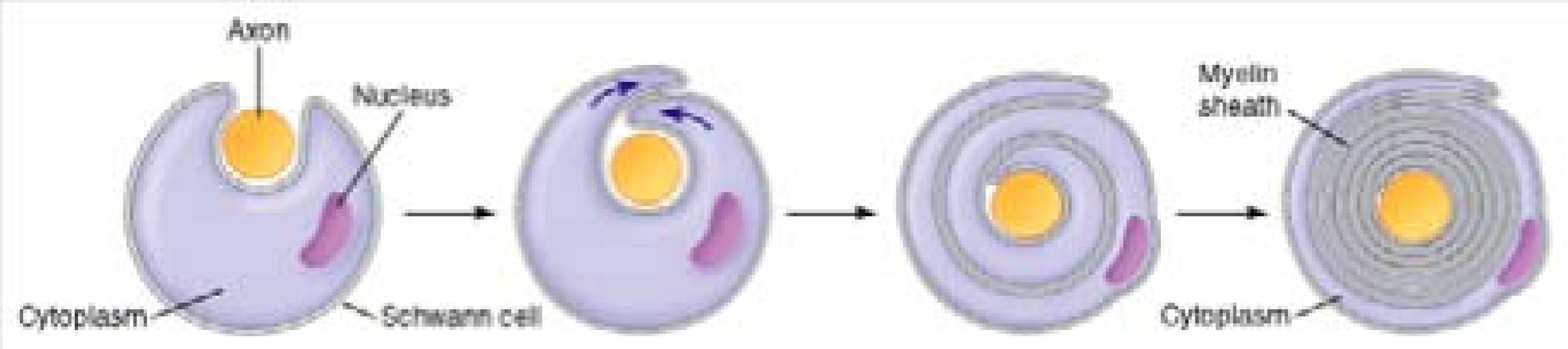


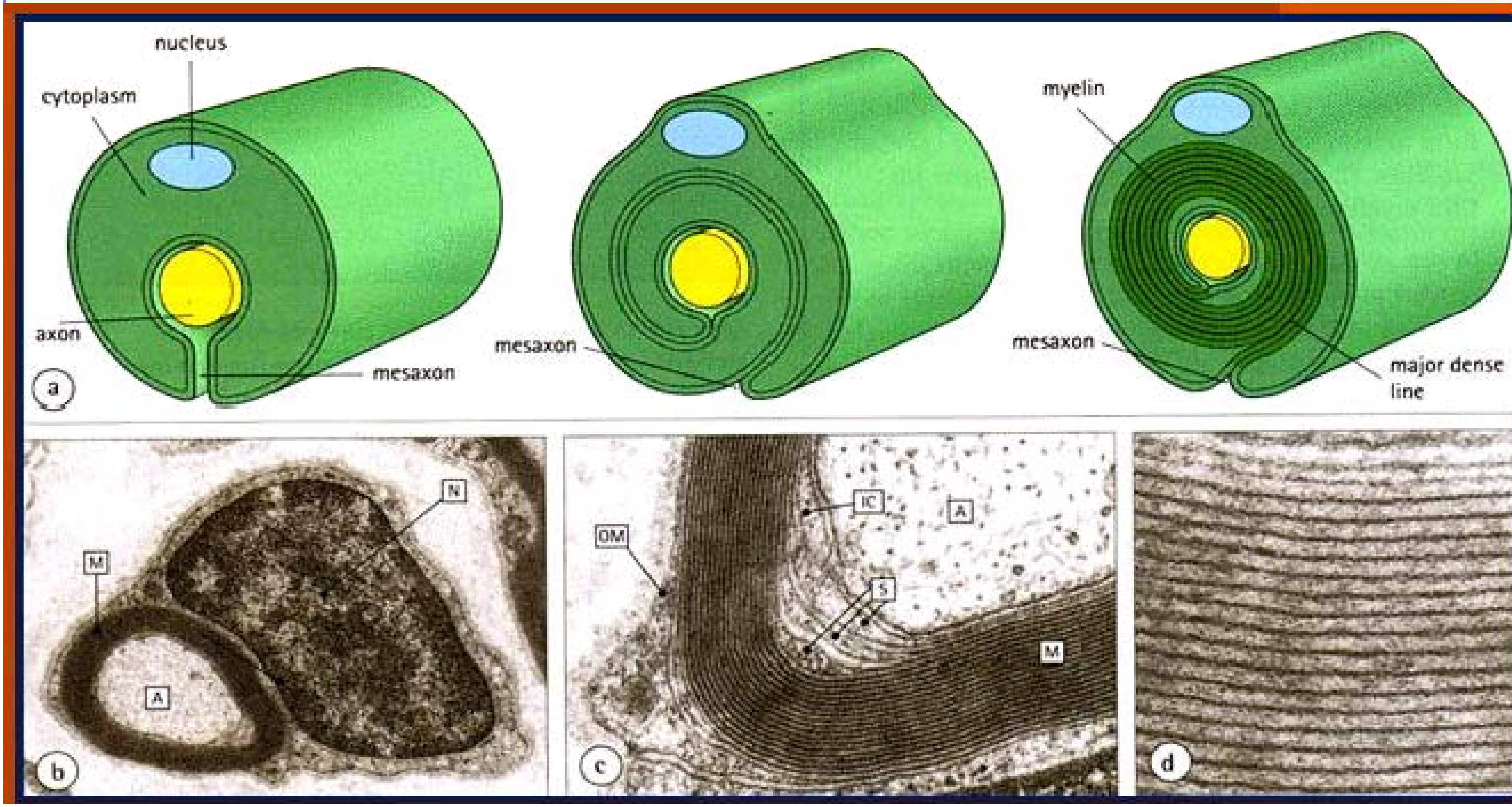
Myelin Sheath and Neurilemma: Formation

- Formed by Schwann cells in the PNS
- A Schwann cell:
  - Envelopes an axon in a trough
  - Encloses the axon with its plasma membrane
  - Has concentric layers of membrane that make up the myelin sheath
- Neurilemma – remaining nucleus and cytoplasm of a Schwann cell

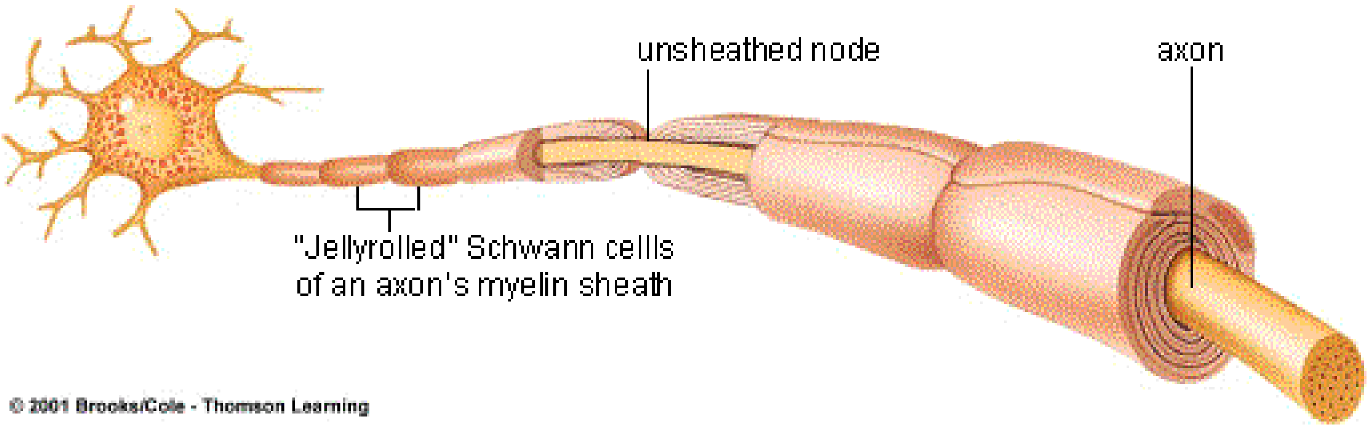
<u>MYELIN SHEATH</u>

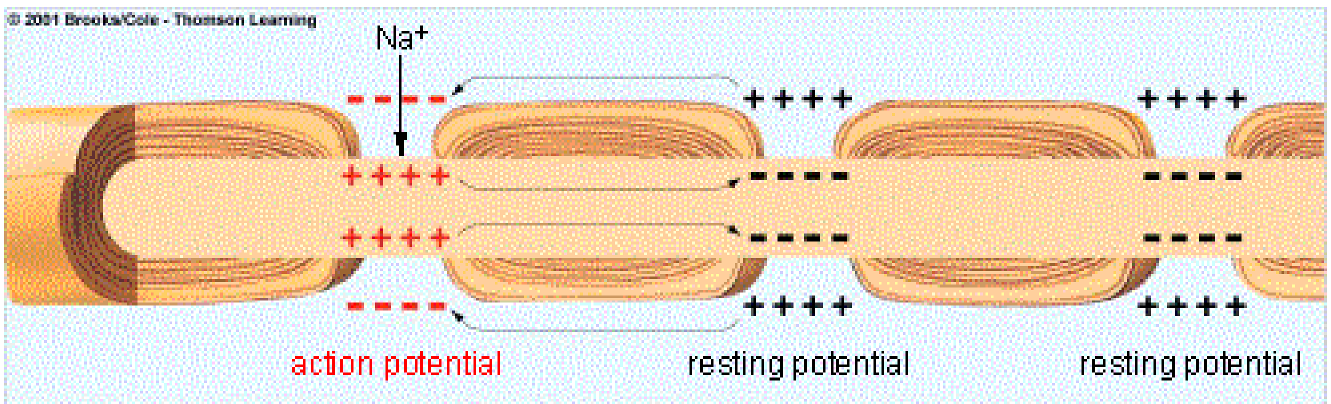
1. Myelin Sheaths greatly increase the speed of impulse along an axon.
2. Myelin is composed of 80% lipid and 20% protein.
3. Myelin is made of special cells called Schwann Cells that forms an insulated sheath, or wrapping around the axon.
4. There are **<u>SMALL NODES or GAPS</u>** called the **<u>Nodes of Ranvier</u>** between adjacent myelin sheath cells along the axon.
5. As an impulse moves down a myelinated (covered with myelin) axon, the impulse JUMPS form Node to Node instead of moving along the membrane.
6. This jumping from Node to Node greatly increase the speed of the impulse.
7. Some myelinated axons conduct impulses as rapid as 200 meters per second.
8. The formation of myelin around axons can be thought of as a crucial event in evolution of vertebrates.
9. Destruction of large patches of Myelin characterize a disease called **<u>Multiple Sclerosis</u>**. In multiple sclerosis, small, hard plaques appear throughout the myelin. Normal nerve function is impaired, causing symptoms such as double vision, muscular weakness, loss of memory, and paralysis.

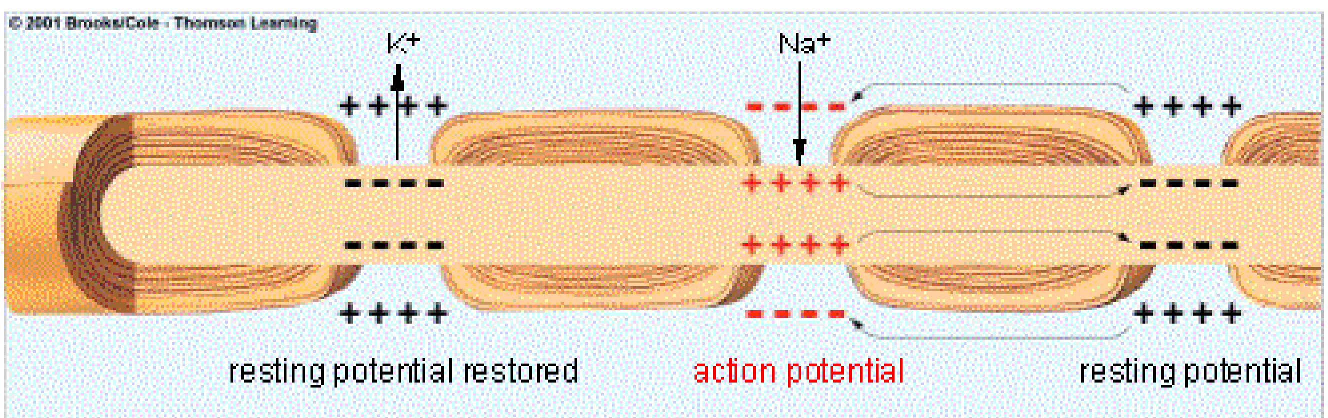

Axon
Nucleus
Myelin sheath
Cytoplasm
Schwann cell
Cytoplasm


nucleus
cytoplasm
axon
mesaxon
a
mesaxon
myelin
mesaxon
major dense line
M
N
A
b
OM
IC
A
S
M
c
d

Myelin Sheath



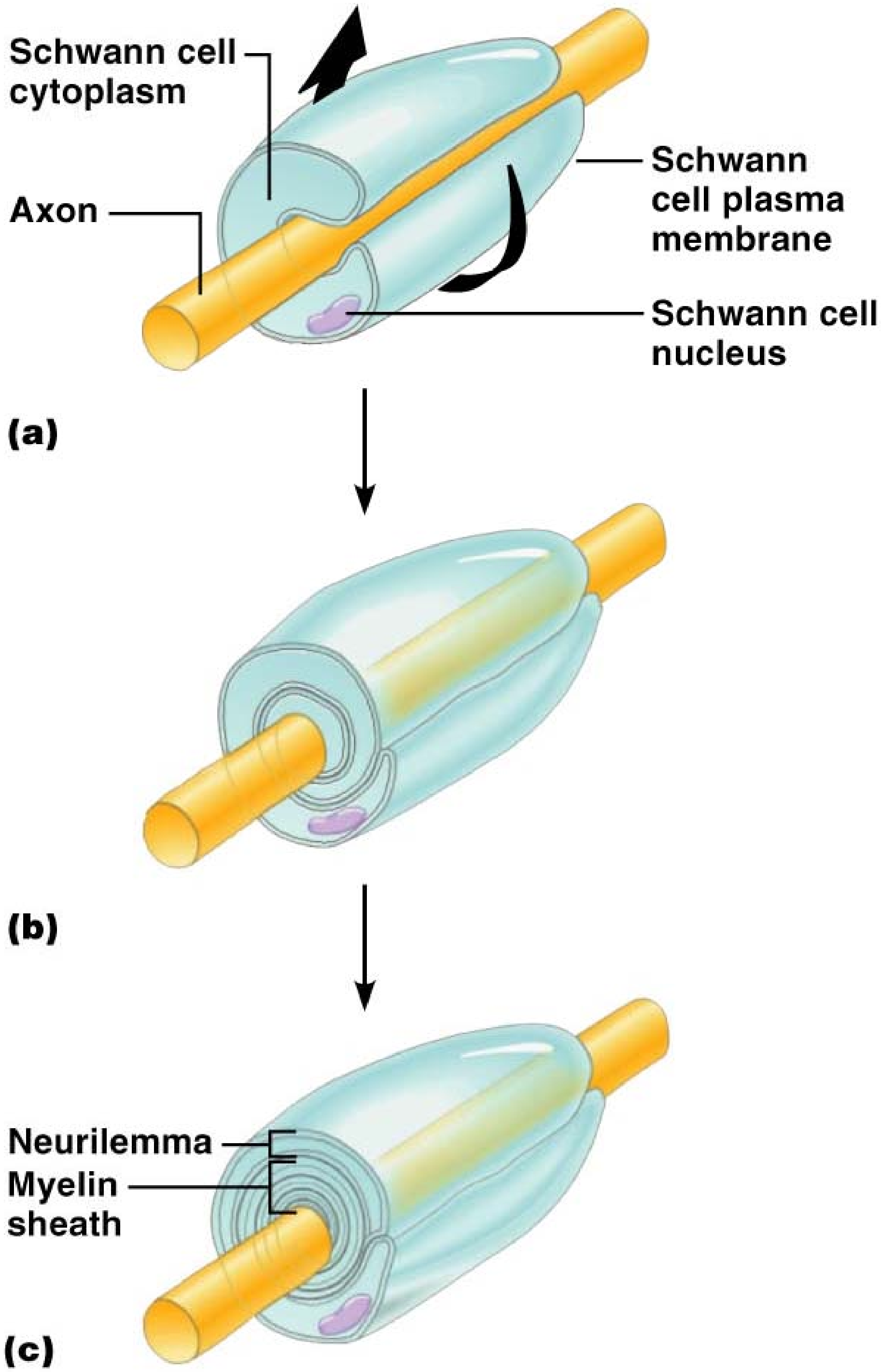




A series of Schwann cells

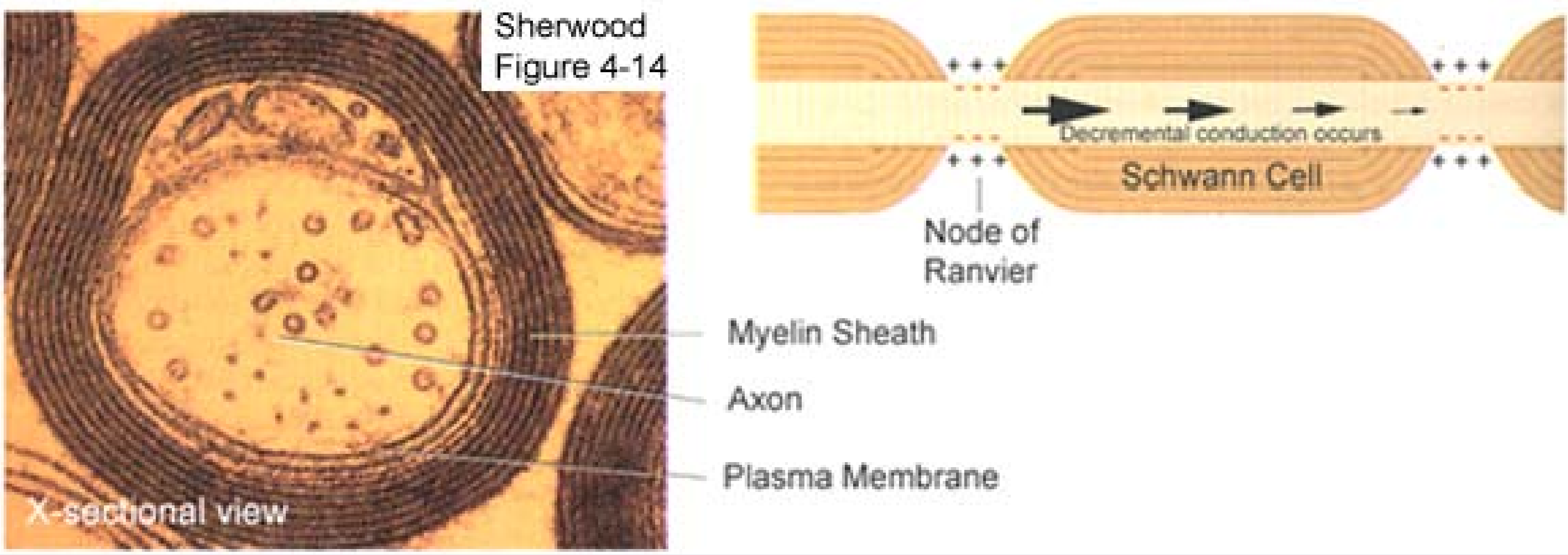
Sheath blocks ion movements

Action potential must "jump" from node to node



The outer nucleated cytoplasmic layer of the neurolemmocyte, which encloses the myelin sheath, is called the neurolemma (sheath of Schwann). A neurolemma is found only around the axons in the PNS. When an axon is injured, the neurolemma aids in the regeneration by forming a regeneration tube that guides and stimulates regrowth of the axon. At intervals along an axon, the myelin sheath has gaps called neurofibral nodes (nodes of Ranvier).

Action Potential Leaps From Node of Ranvier to Node of Ranvier



Development of the myelin sheath of a peripheral axon, as seen in transverse section.

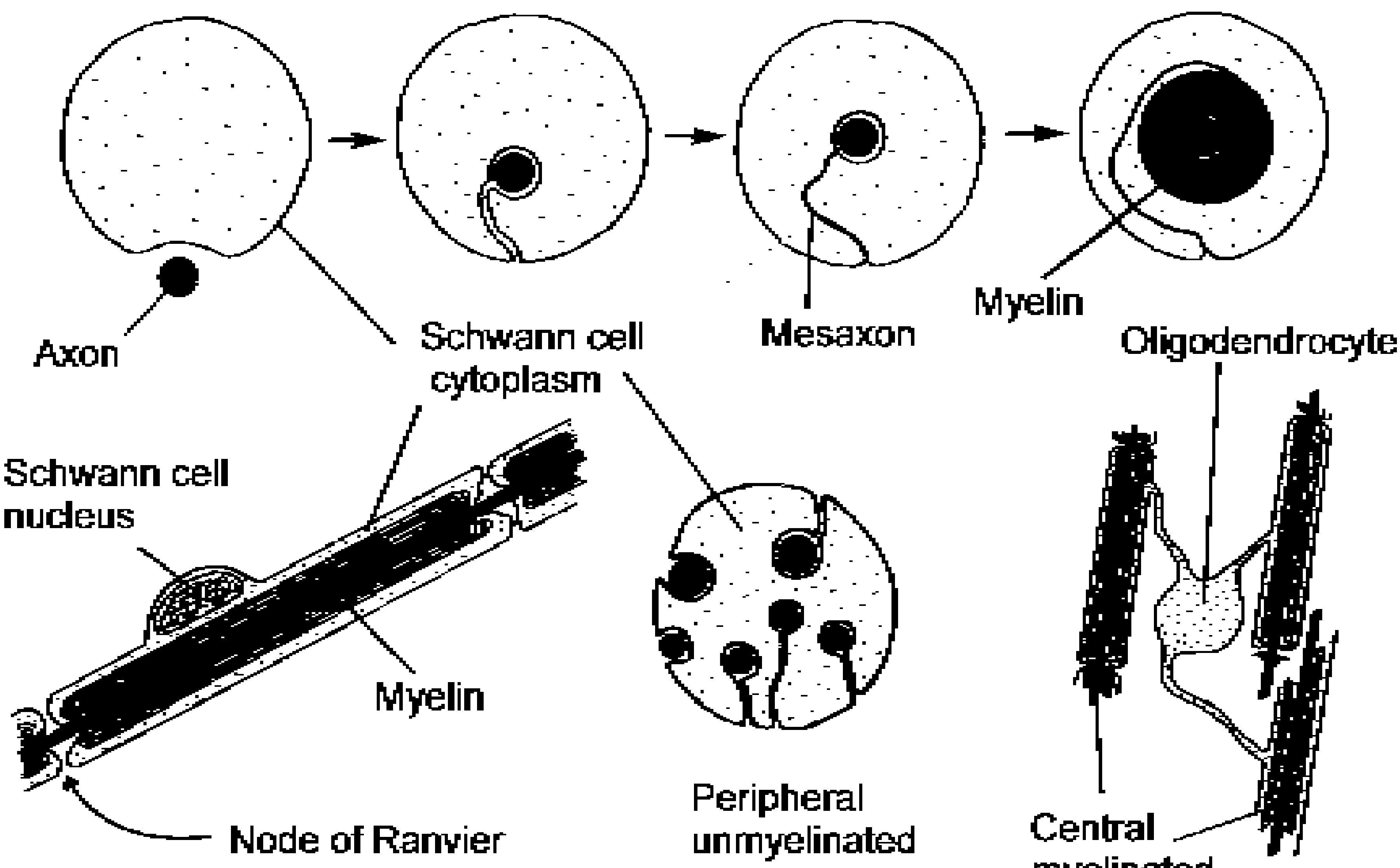
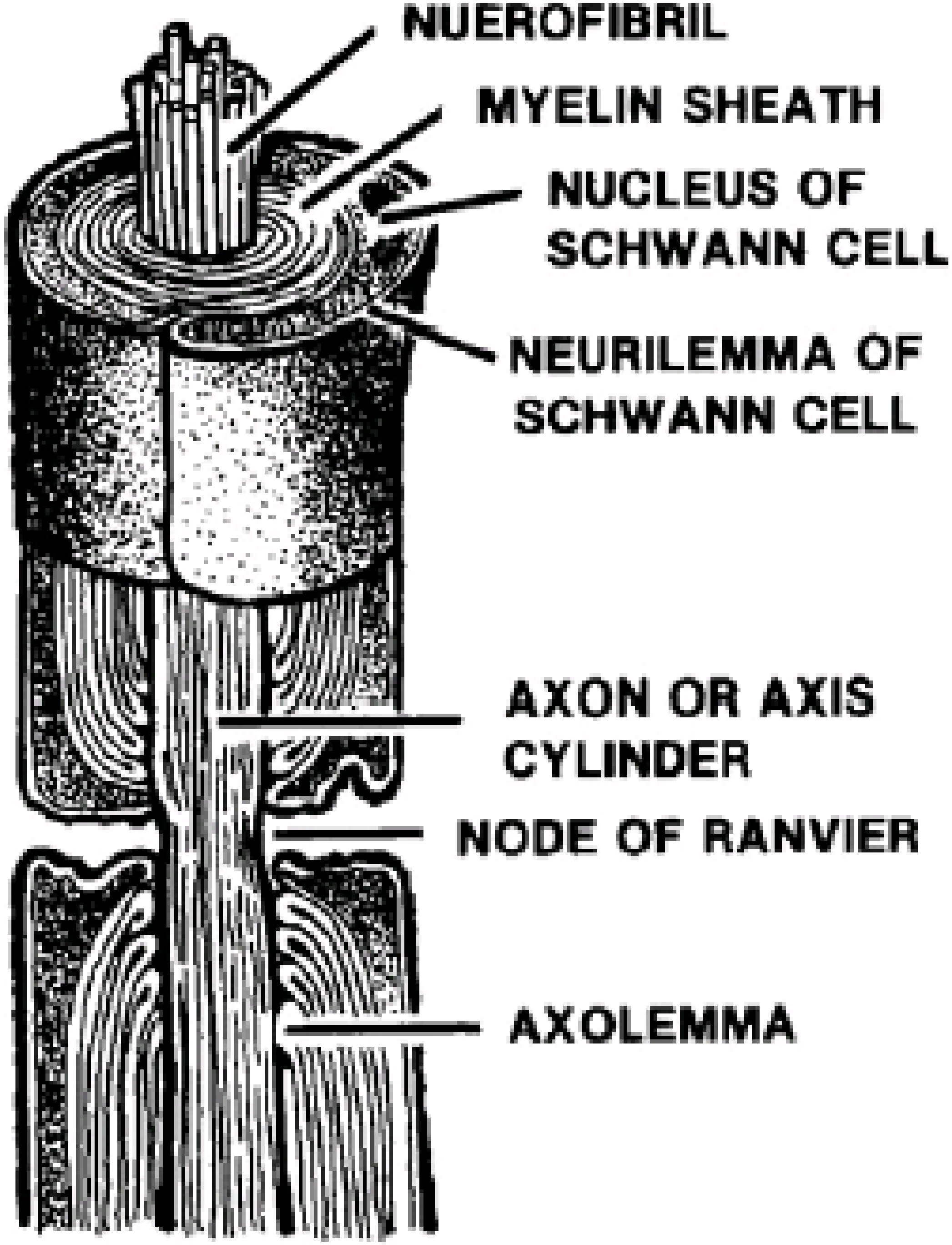


Fig. 6. Myelination. (Individual layers of mature myelin are not resolved in these diagrams.)



Neurilemma.

The *neurilemma* is the nucleated cytoplasmic layer of the Schwann cell.

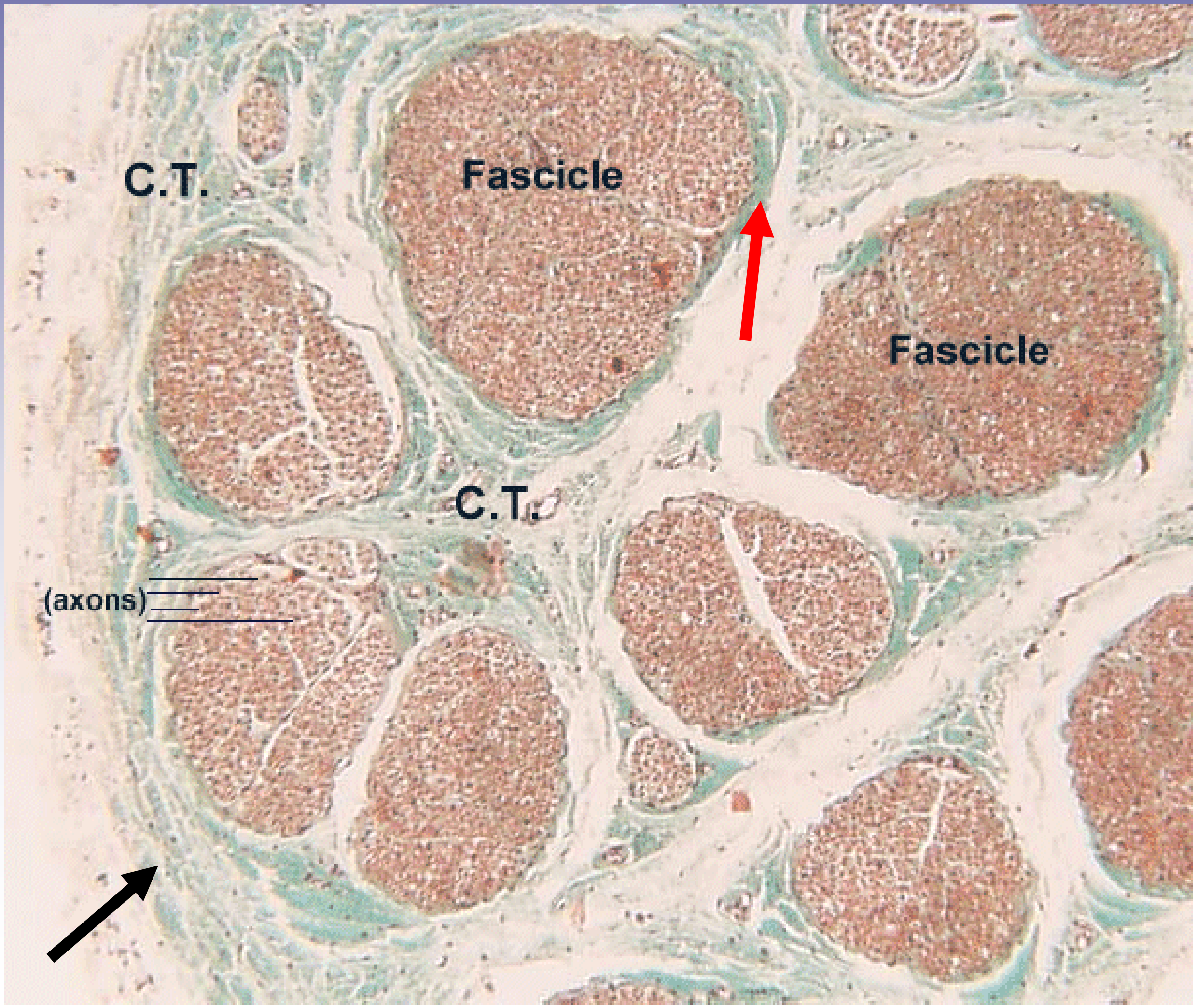
The neurilemma allows damaged nerves to regenerate. Nerves in the brain and spinal cord DO NOT have a neurilemma and, therefore, DO NOT recover when damaged.

Regions of the Brain and Spinal Cord

- White matter – dense collections of myelinated fibers
- Gray matter – mostly soma and unmyelinated fibers

- A bundle of processes in the PNS is a nerve.
- Within a nerve, each axon is surrounded by an endoneurium *(too small to see on the photomicrograph)* – a layer of loose CT.

- Groups of fibers are bound together into bundles (fascicles) by a perineurium (red arrow).
- All the fascicles of a nerve are enclosed by a epineurium (black arrow).



Comparison of Structural Classes of Neurons

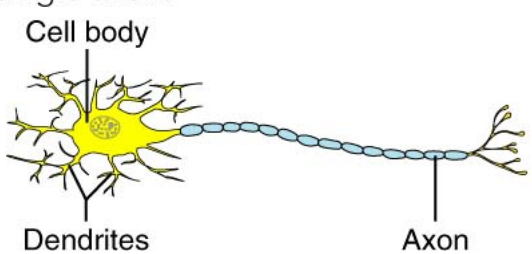
TABLE 11.1 Comparison of Structural Classes of Neurons

NEURON TYPE

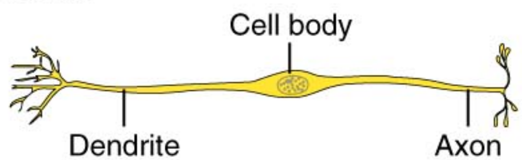
MULTIPOLAR	BIPOLAR	UNIPOLAR (PSEUDOUNIPOLAR)

STRUCTURAL CLASS: NEURON TYPE ACCORDING TO THE NUMBER OF PROCESSES EXTENDING FROM THE CELL BODY

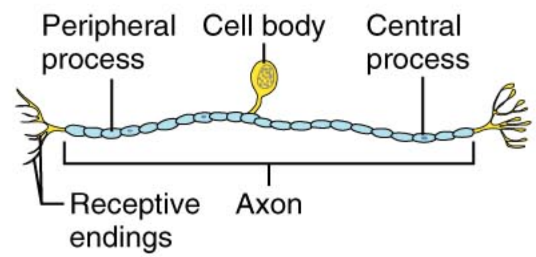
Multipolar: Many processes extend from the cell body; all are dendrites except for a single axon.



Bipolar: Two processes extend from the cell body: one is a fused dendrite, the other is an axon.



Unipolar (pseudounipolar): One process extends from the cell body and forms central and peripheral processes, which together comprise an axon.

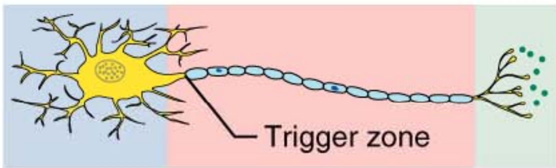


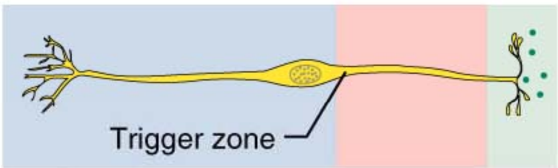
RELATIONSHIP OF ANATOMY TO THE THREE FUNCTIONAL REGIONS

= Receptive region (receives stimulus). Plasma membrane exhibits chemically gated ion channels.

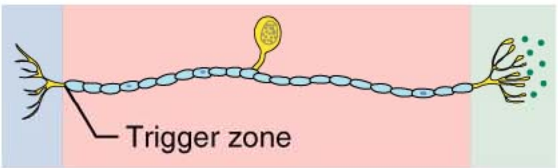
= Conducting region (generates/ transmits action potential). Plasma membrane exhibits voltage-gated Na^+ and K^+ channels.

= Secretory region (axon terminals release neurotransmitters). Plasma membrane exhibits voltage-gated Ca^+ channels.



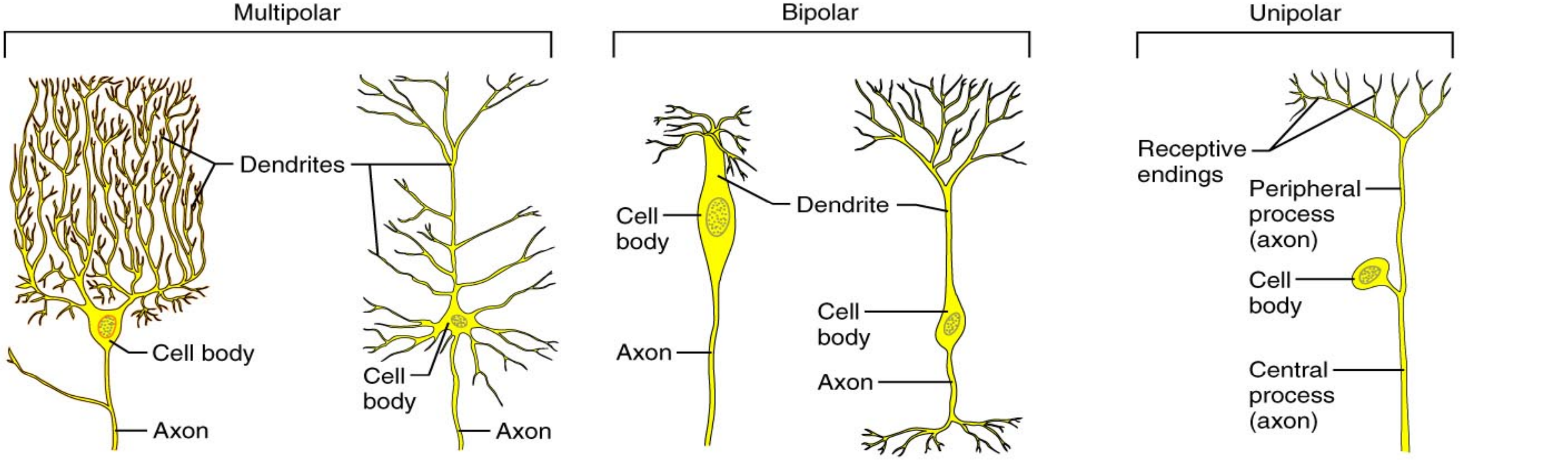


(Many bipolar neurons do not generate action potentials and, in those that do, the location of the trigger zone is not universal.)



Comparison of Structural Classes of Neurons

TABLE 11.1 Comparison of Structural Classes of Neurons (continued)		
NEURON TYPE		
MULTIPOLAR	**BIPOLAR**	**UNIPOLAR (PSEUDOUNIPOLAR)**
RELATIVE ABUNDANCE AND LOCATION IN HUMAN BODY		
Most abundant in body. Major neuron type in the CNS.	Rare. Found in some special sensory organs (olfactory mucosa, eye, ear).	Found mainly in the PNS. Common only in dorsal root ganglia of the spinal cord and sensory ganglia of cranial nerves.
STRUCTURAL VARIATIONS		



Purkinje cell of cerebellum

Pyramidal cell

Olfactory cell

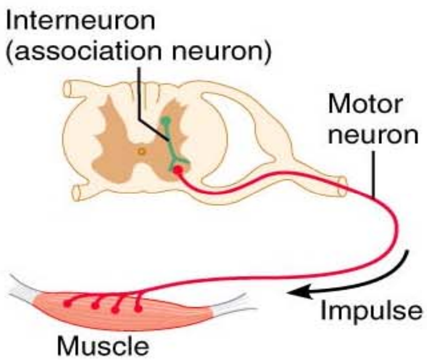
Retinal cell

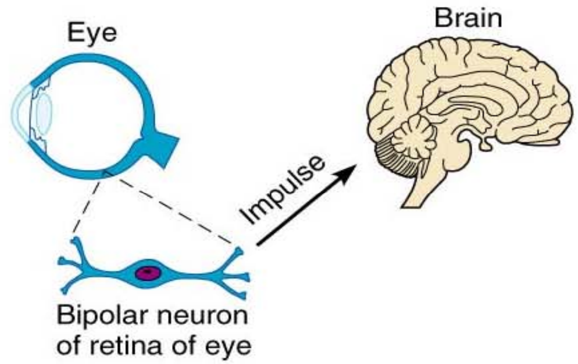
Dorsal root ganglion cell

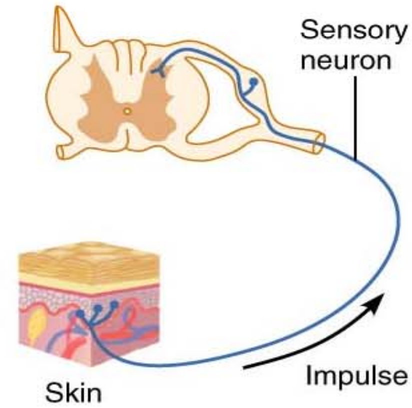
Comparison of Structural Classes of Neurons

TABLE 11.1 Comparison of Structural Classes of Neurons *(continued)*

NEURON TYPE		
MULTIPOLAR	**BIPOLAR**	**UNIPOLAR (PSEUDOUNIPOLAR)**
FUNCTIONAL CLASS: NEURON TYPE ACCORDING TO DIRECTION OF IMPULSE CONDUCTION		
1. Most multipolar neurons are **interneurons (association neurons)** that conduct impulses within the CNS, integrating sensory input or motor output; may be one of a chain of CNS neurons, or a single neuron connecting sensory and motor neurons. **2.** Some multipolar neurons are **motor neurons** that conduct impulses along the efferent pathways from the CNS to an effector (muscle/gland).	Essentially all bipolar neurons are **sensory neurons** that are located in some special sense organs. For example, bipolar cells of the retina are involved with the transmission of visual inputs from the eye to the brain (via an intermediate chain of neurons).	Most unipolar neurons are **sensory neurons** that conduct impulses along afferent pathways to the CNS for interpretation. (These sensory neurons are called primary or first-order sensory neurons.)







In the PNS, peripheral nerves can regenerate after injury. Scwann cells assist in a process called Wallerian degeneration.

As the axon distal to the injury site degenerates, Schwann cells form a line along the path of the original axon, and wrap the new axon as it grows.

- In the CNS, nerve regeneration is limited because astrocytes block growth by releasing chemicals and producing scar tissue.

Terms TO KNOW:

ganglion - a collection of cell bodies located outside the Central Nervous System. The spinal ganglia or dorsal root ganglia contain the cell bodies of sensory neurons entering the cord at that region.

nerve - a group of fibers (axons) *outside* the CNS. The spinal nerves contain the fibers of the sensory and motor neurons. A nerve does not contain cell bodies. They are located in the ganglion (sensory) or in the gray matter (motor).

tract - a group of fibers *inside* the CNS. The spinal tracts carry information up or down the spinal cord, to or from the brain. Tracts within the brain carry information from one place to another within the brain. Tracts are always part of white matter.

gray matter - an area of unmyelinated neurons where cell bodies and synapses occur. In the spinal cord the synapses between sensory and motor and interneurons occurs in the gray matter. The cell bodies of the interneurons and motor neurons also are found in the gray matter.

white matter - an area of myelinated fiber tracts. Myelination in the CNS differs from that in nerves.