The Nervous System

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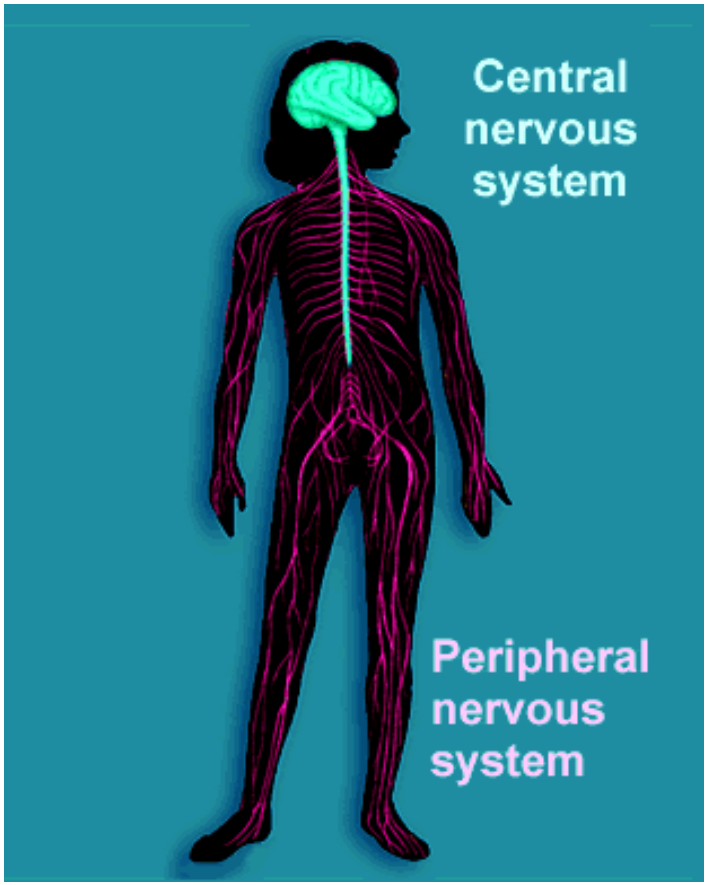
Http://10.10.10.151

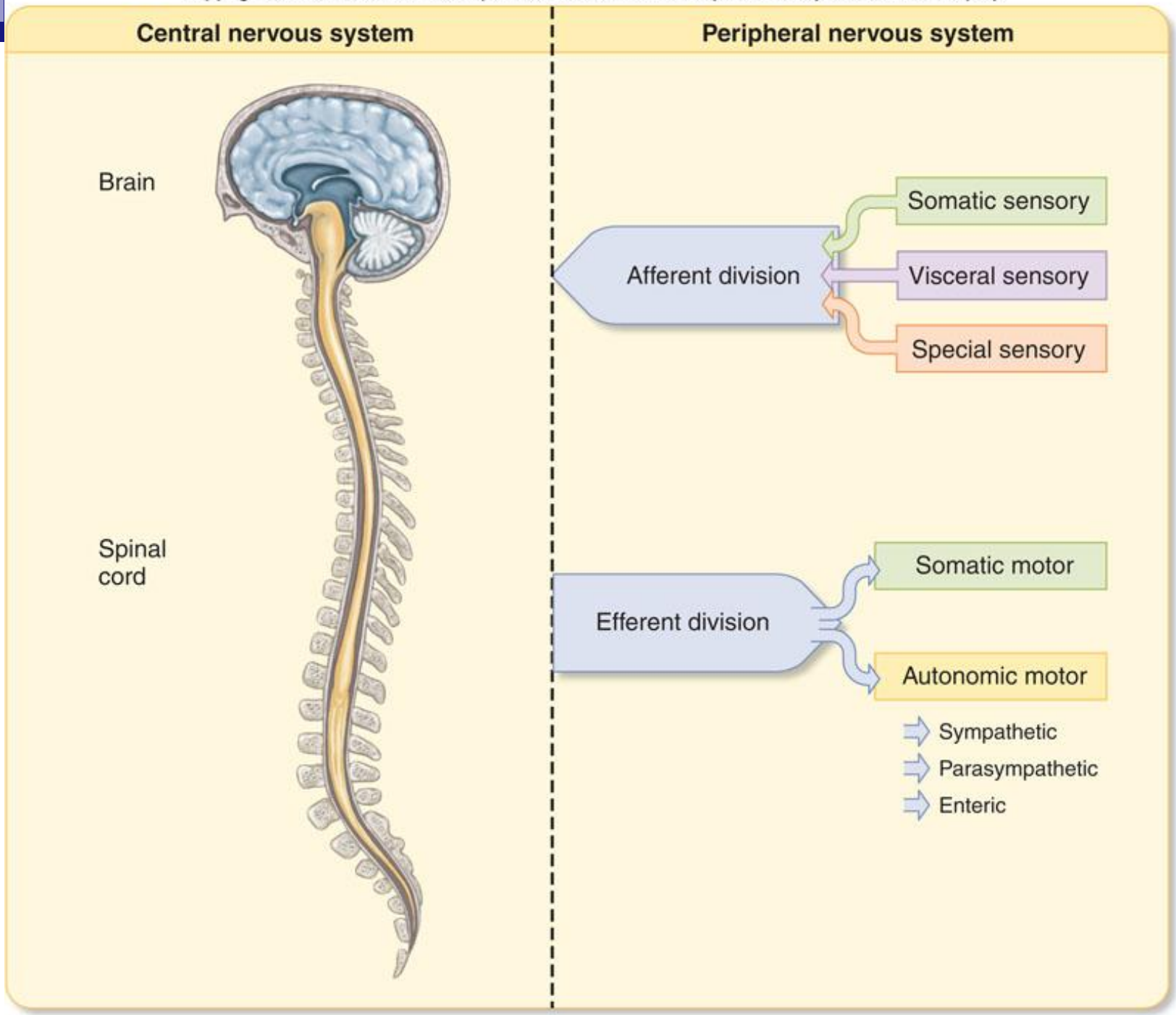
Part 1.

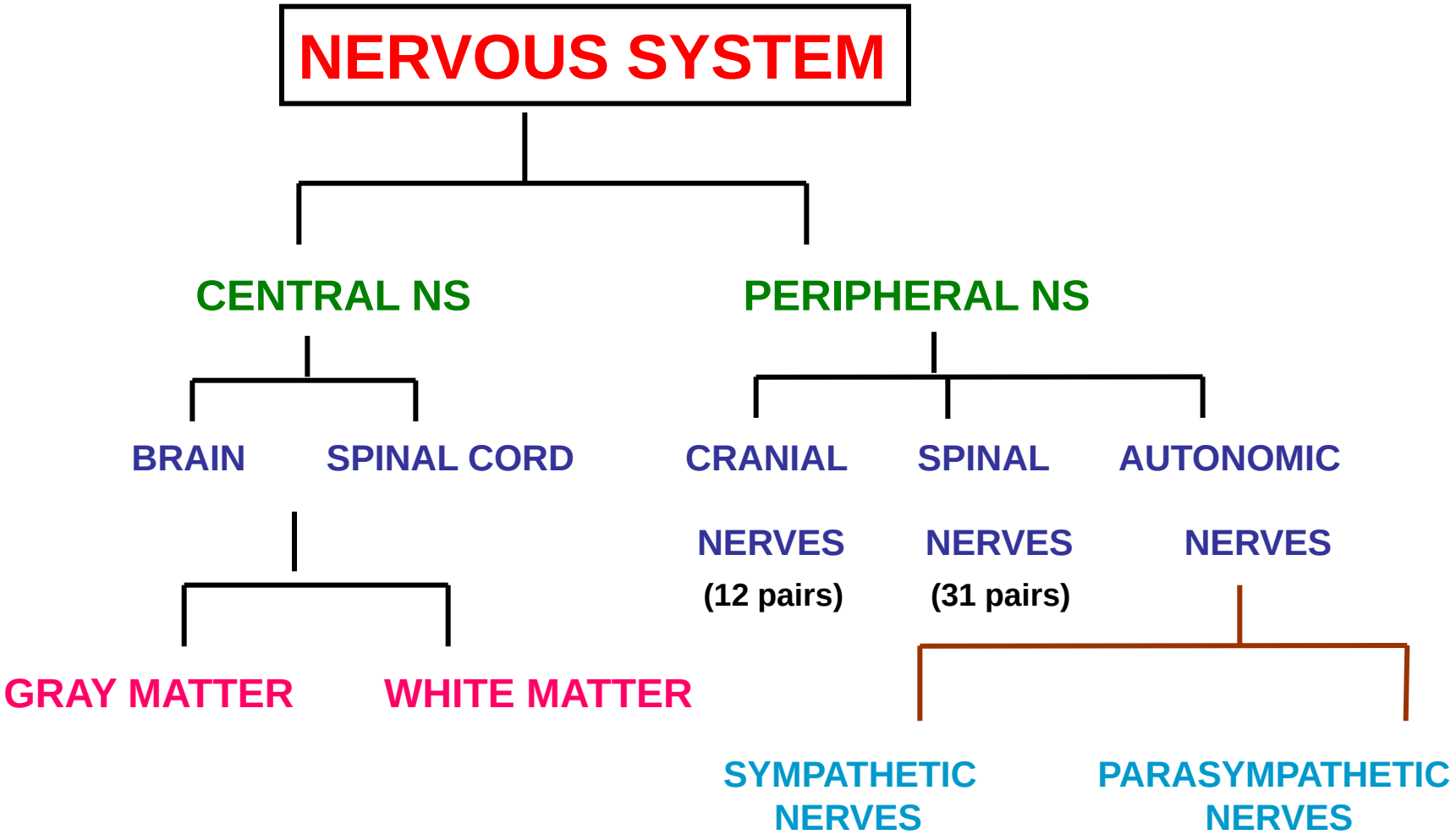
Summary of the nervous system

The Nervous System

- **Central Nervous System**
  - Brain + Spinal Cord
- **Peripheral Nervous System**
  - Nerves to the rest of body

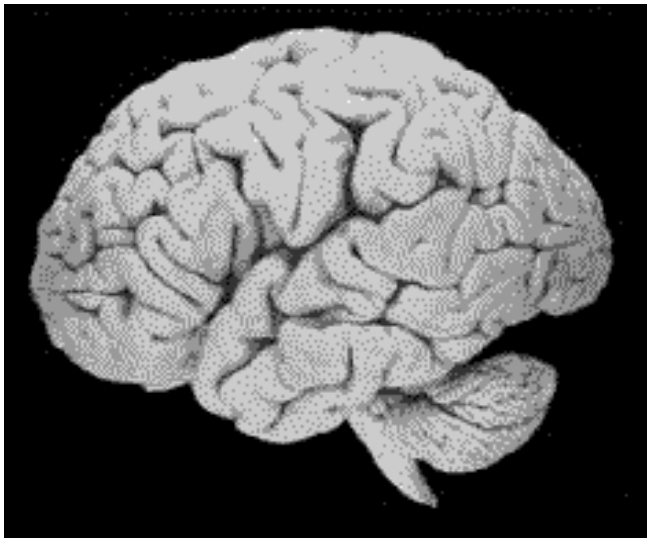




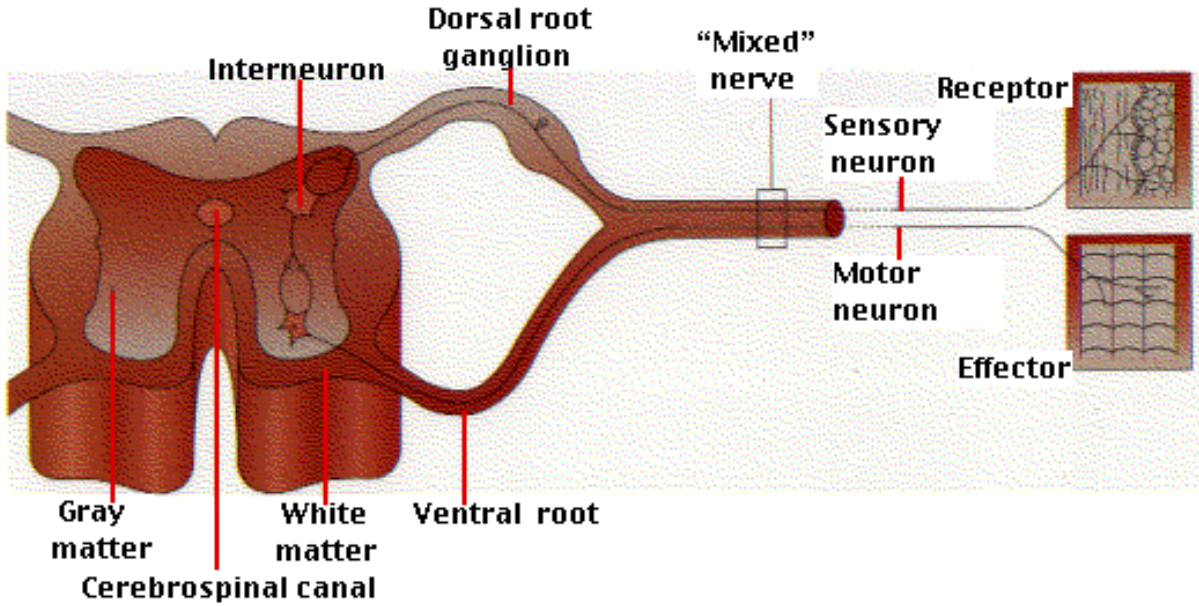

NERVOUS SYSTEM
CENTRAL NS
PERIPHERAL NS
BRAIN
SPINAL CORD
CRANIAL NERVES (12 pairs)
SPINAL NERVES (31 pairs)
AUTONOMIC NERVES
GRAY MATTER
WHITE MATTER
SYMPATHETIC NERVES
PARASYMPATHETIC NERVES

Central Nervous System

Brain

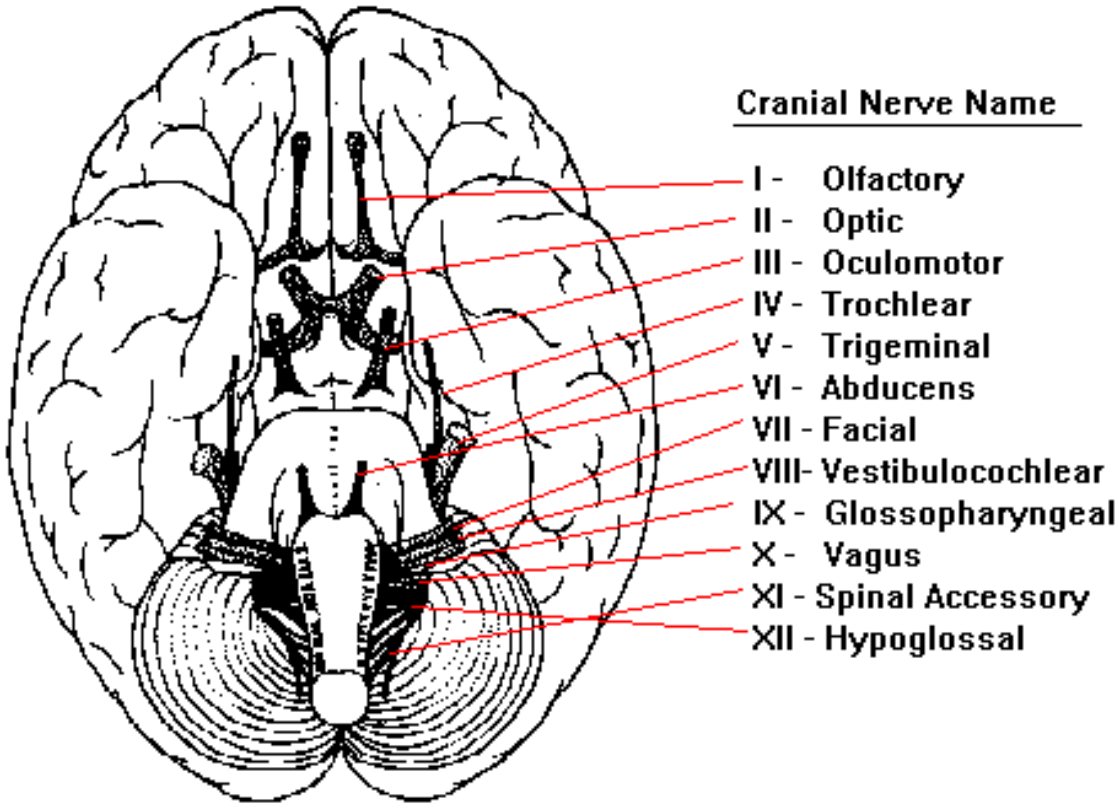


Spinal cord

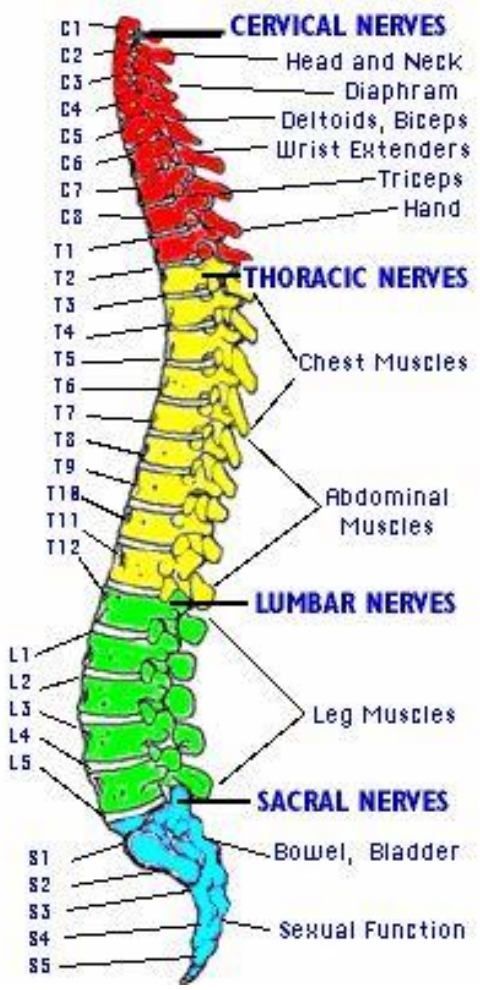


Peripheral Nervous System

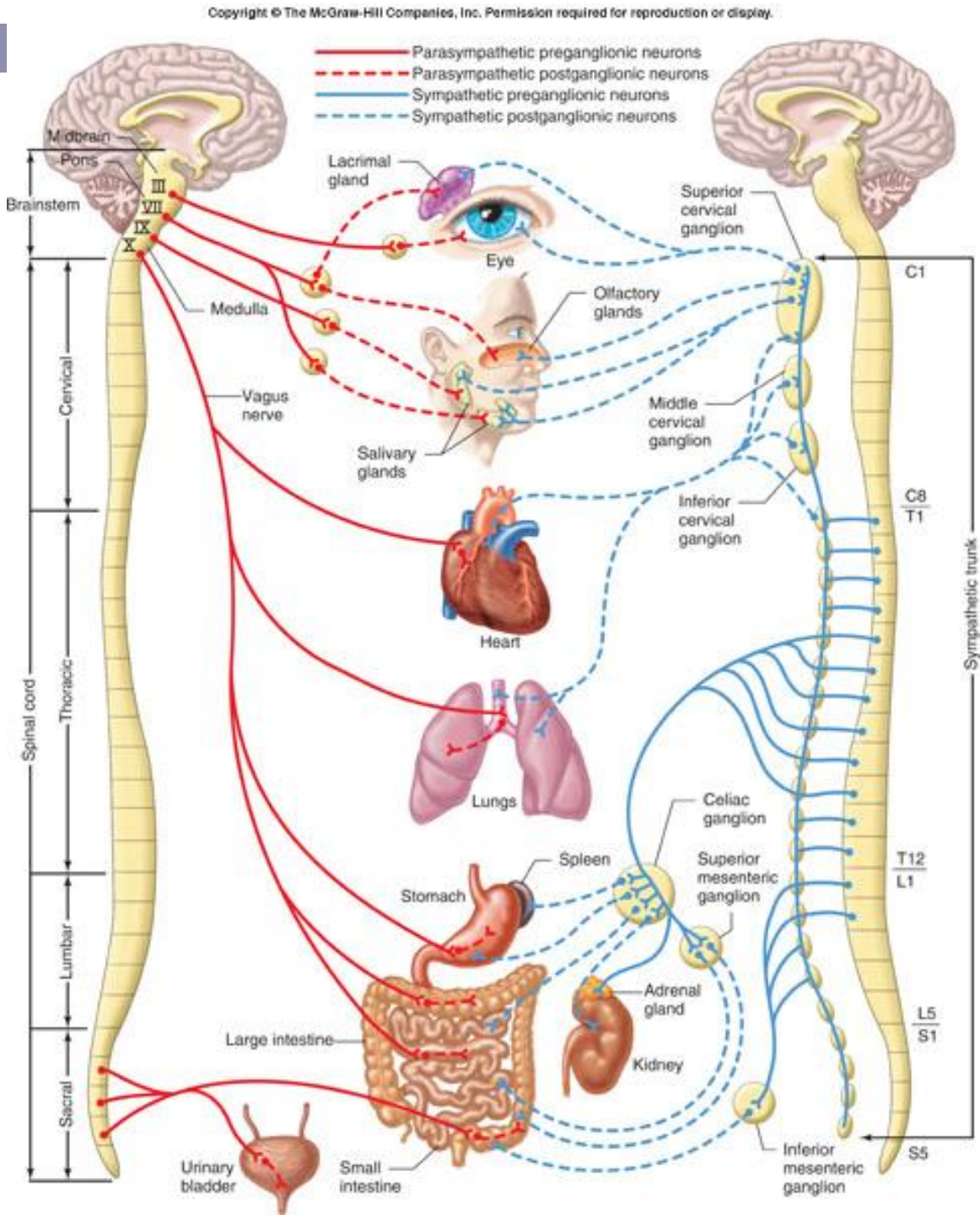
Cranial nerves (12 pair)



Spinal nerves (31 pair)

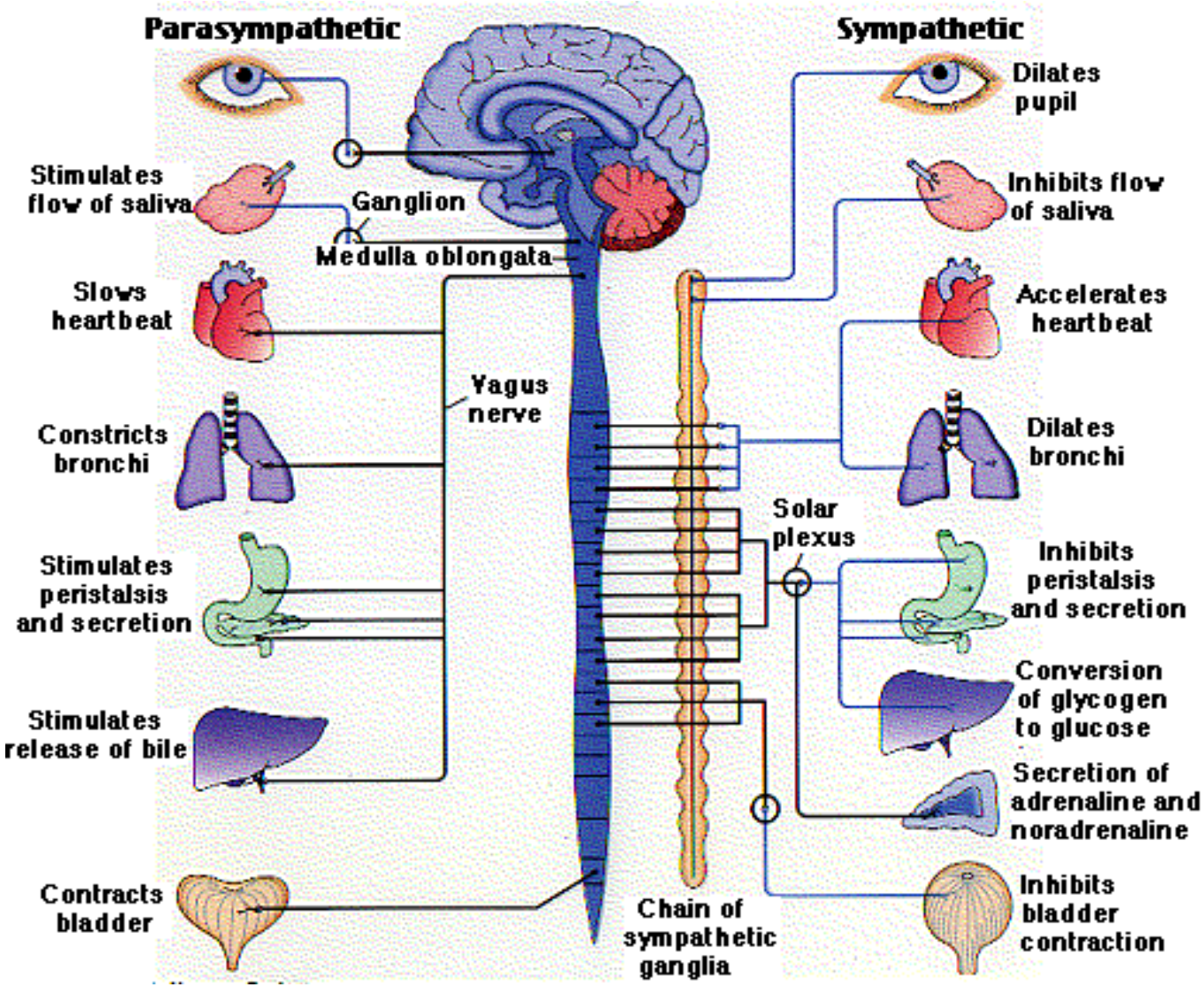


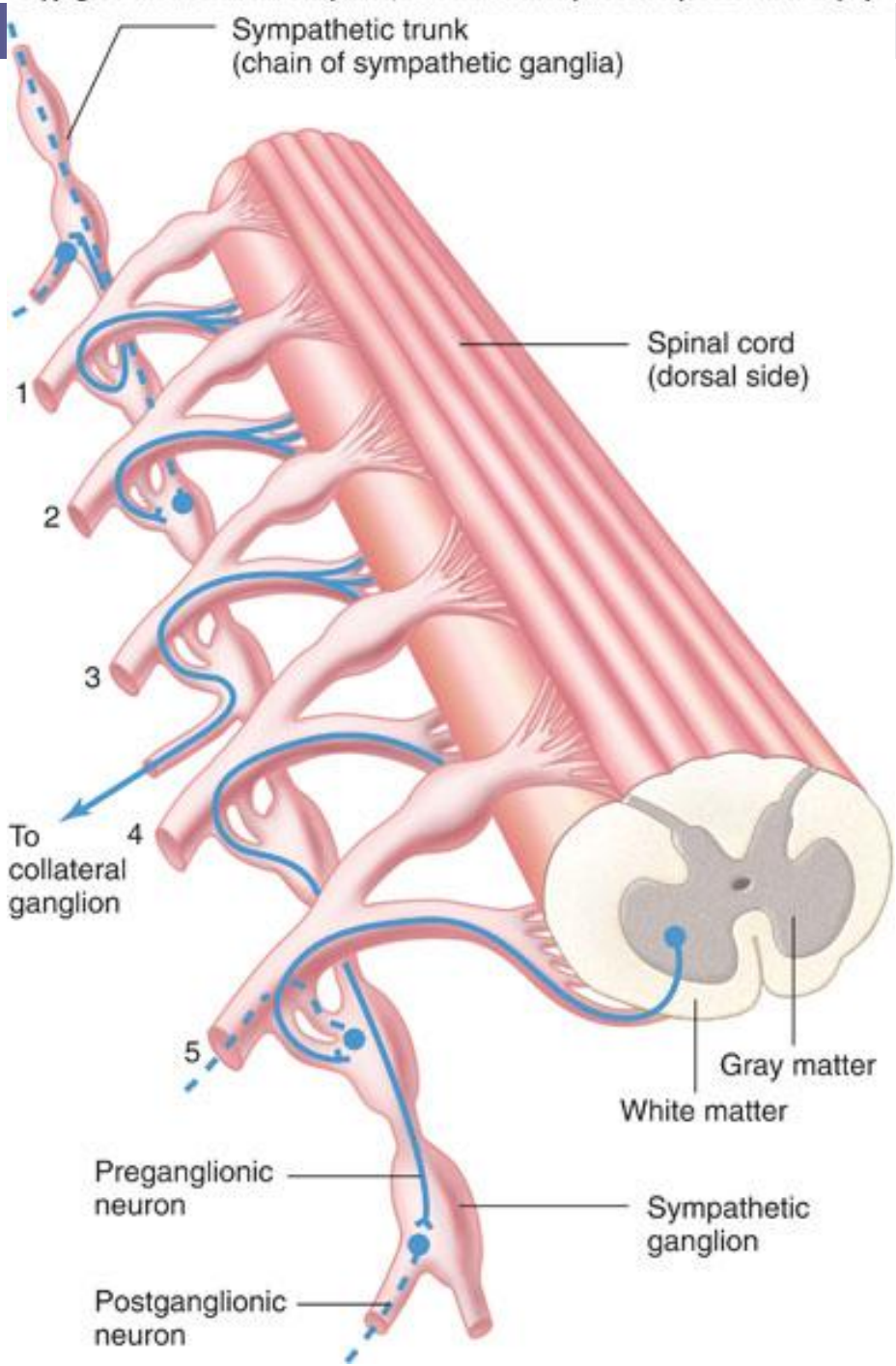
Autonomic nerves



Parasympathetic nerves

Sympathetic nerves

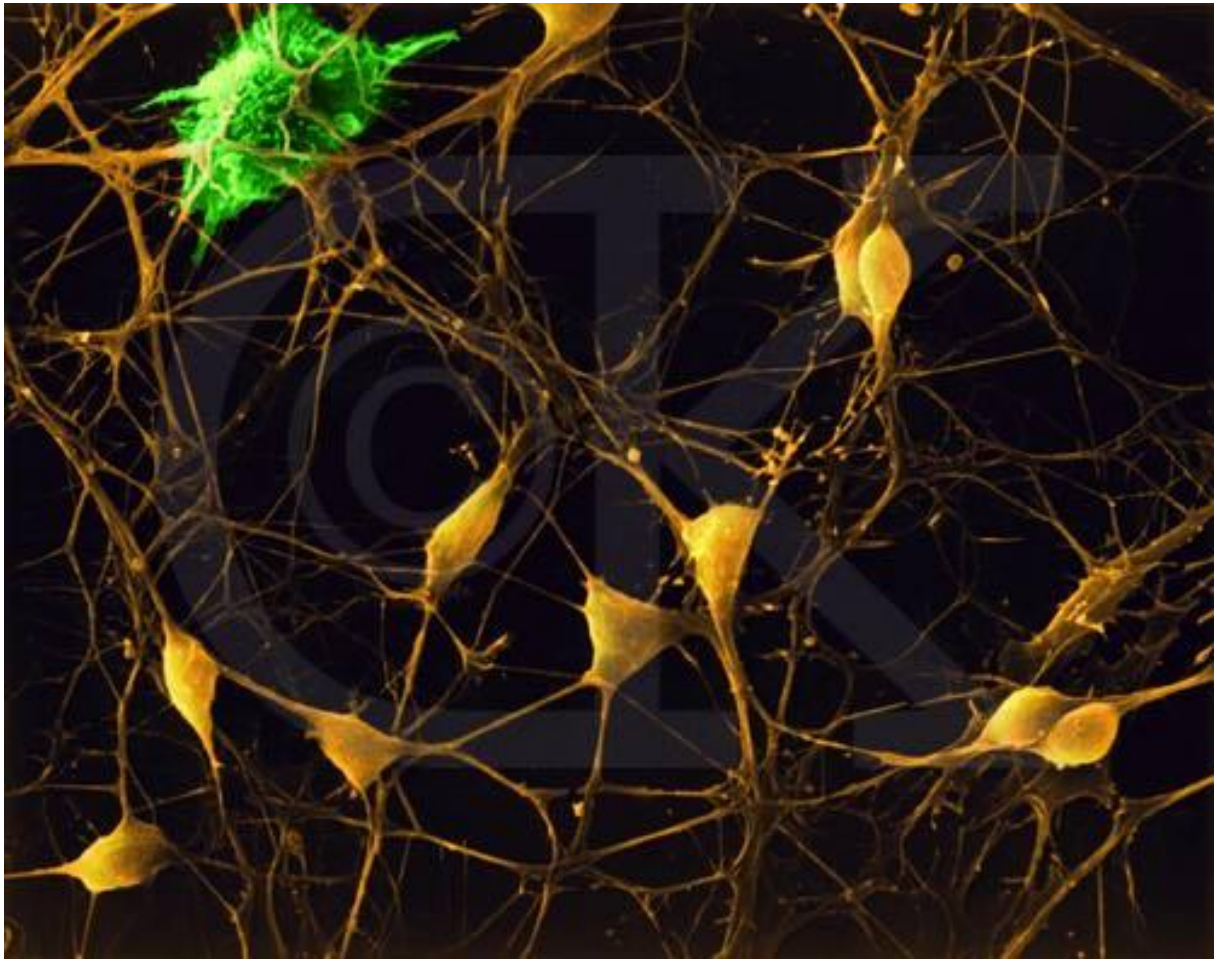




Part 2.

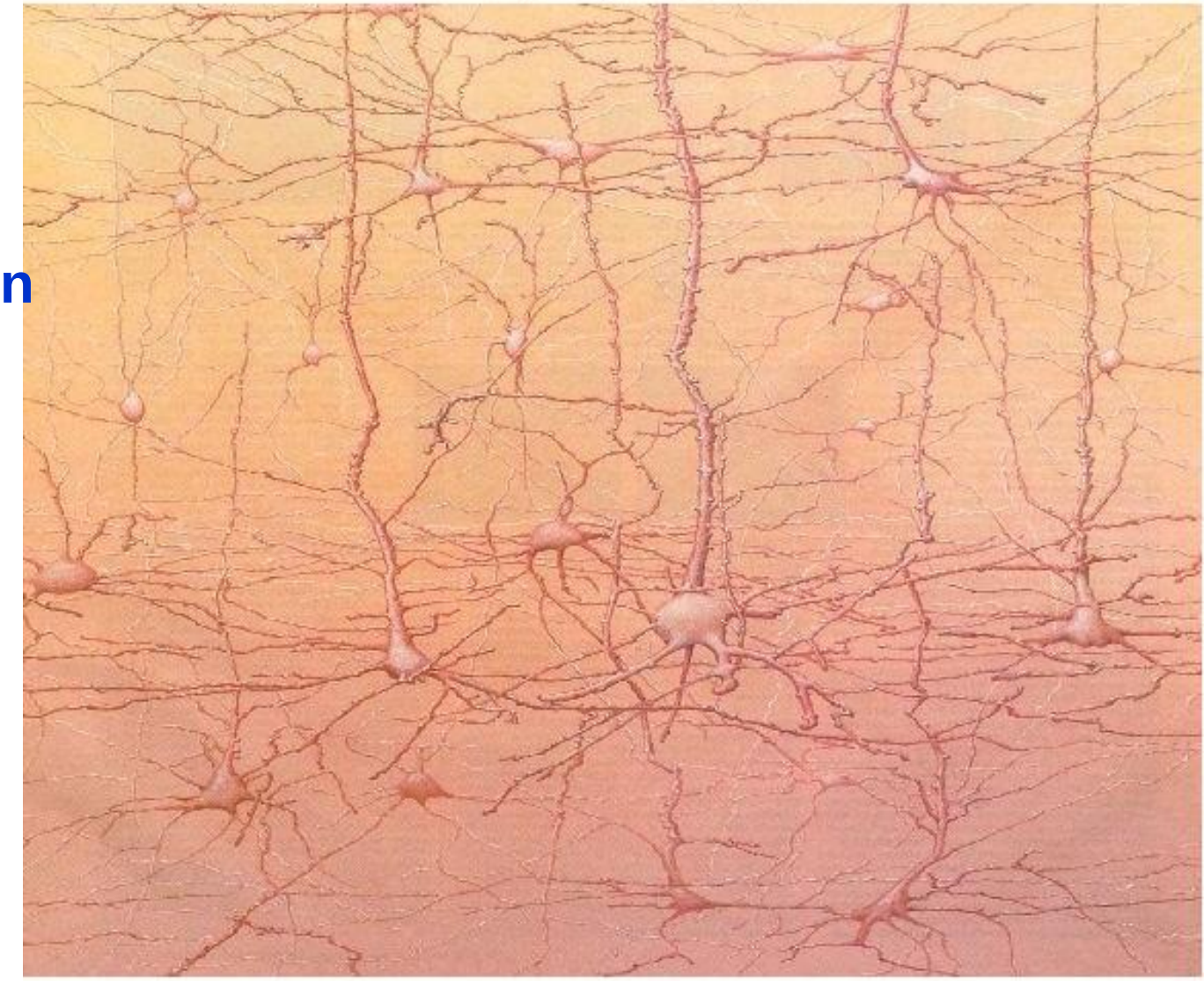
Cells in nervous system

Nervous tissue is composed of two main cell types: neurons and glial cells



Neurons and Astrocyte

Each cubic millimeter of cerebral cortex contains about 90,000 neurons, 400 meters of dendrite, 3.4 kilometers of axon, and 700,000,000 synapses



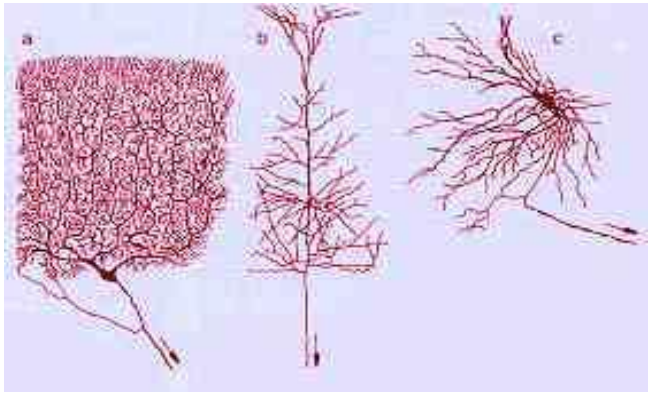
From:
Hinton GE (1992) How neural networks learn from experience. Scientific American 267(3), 104-109.

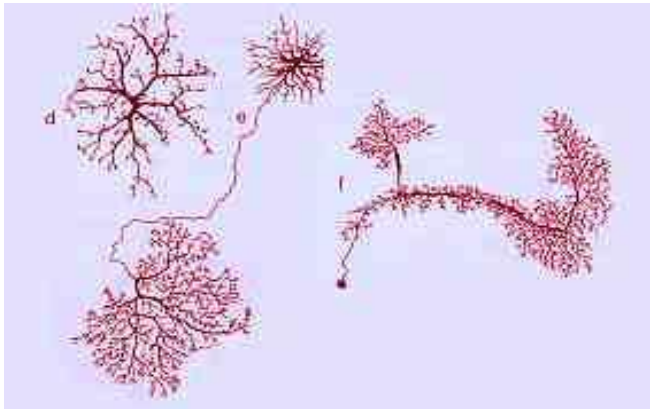
In the human brain

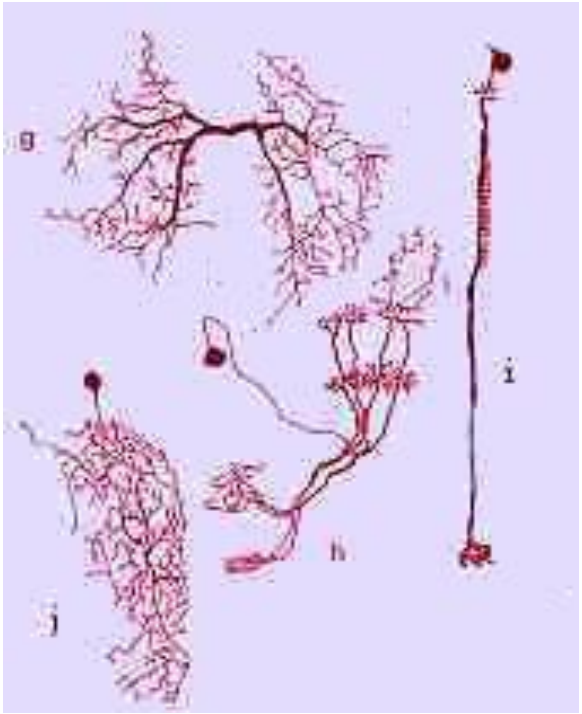
100 billion (10^{11}) neurons

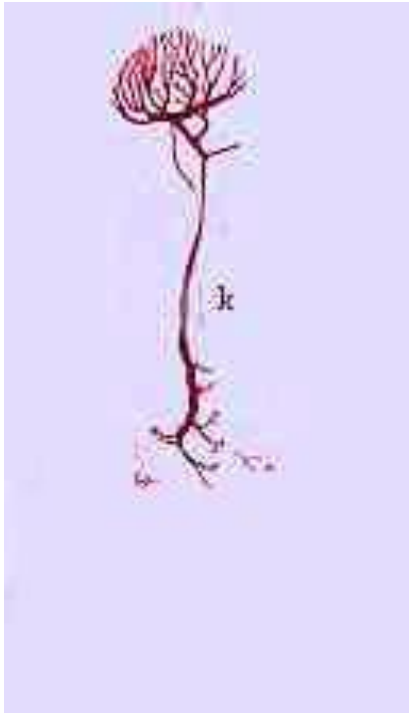
Neuron (Nerve cell)

Definition: able to respond to stimuli, conduct impulses, and communicate with other cells.



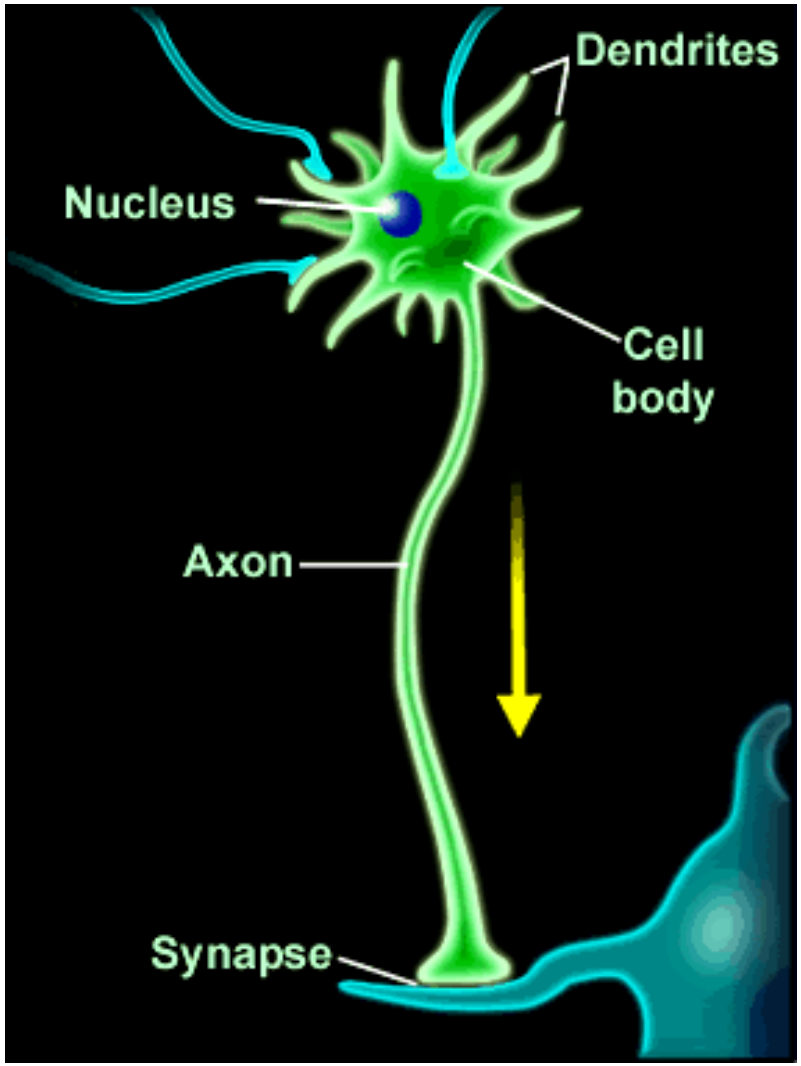


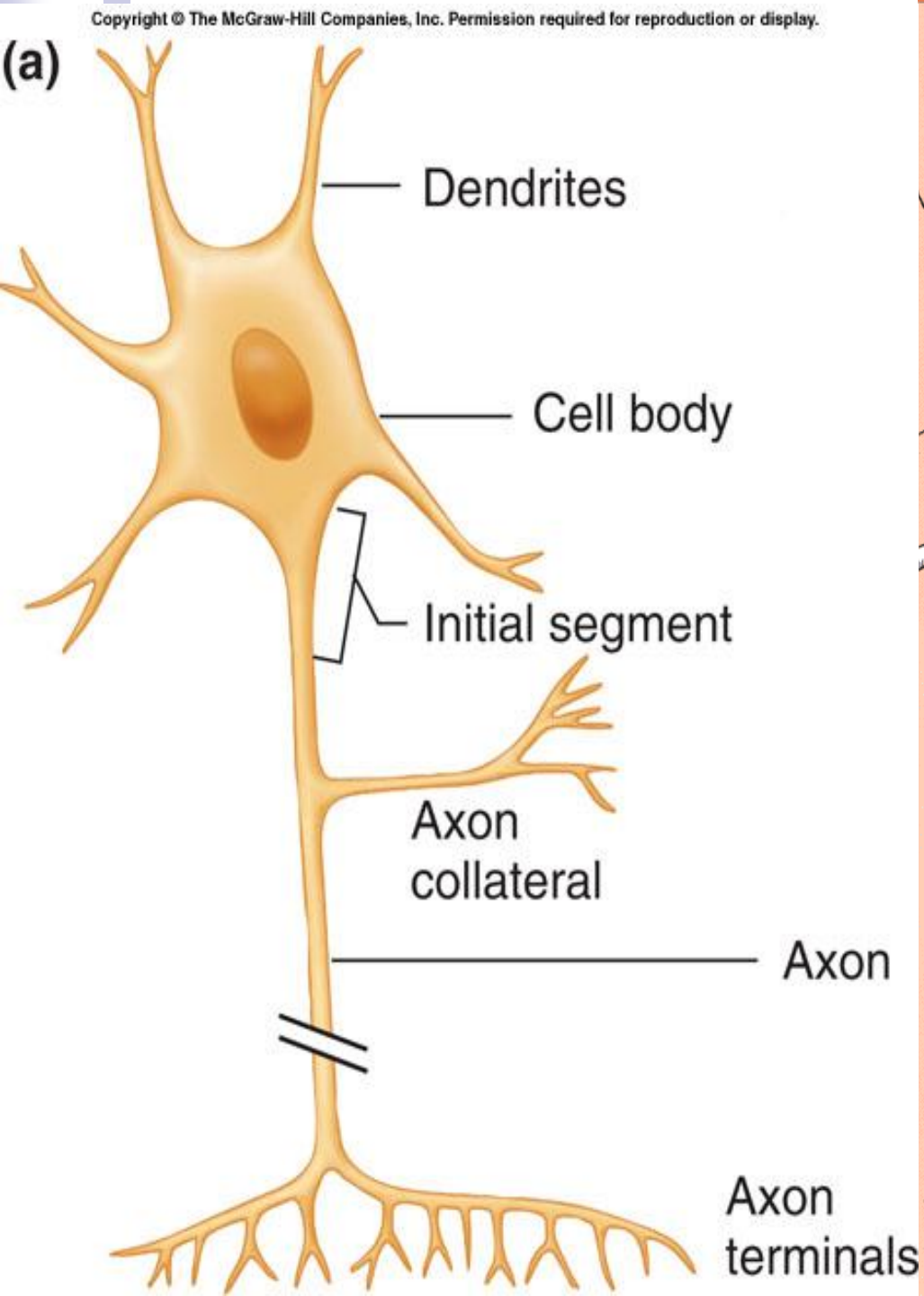


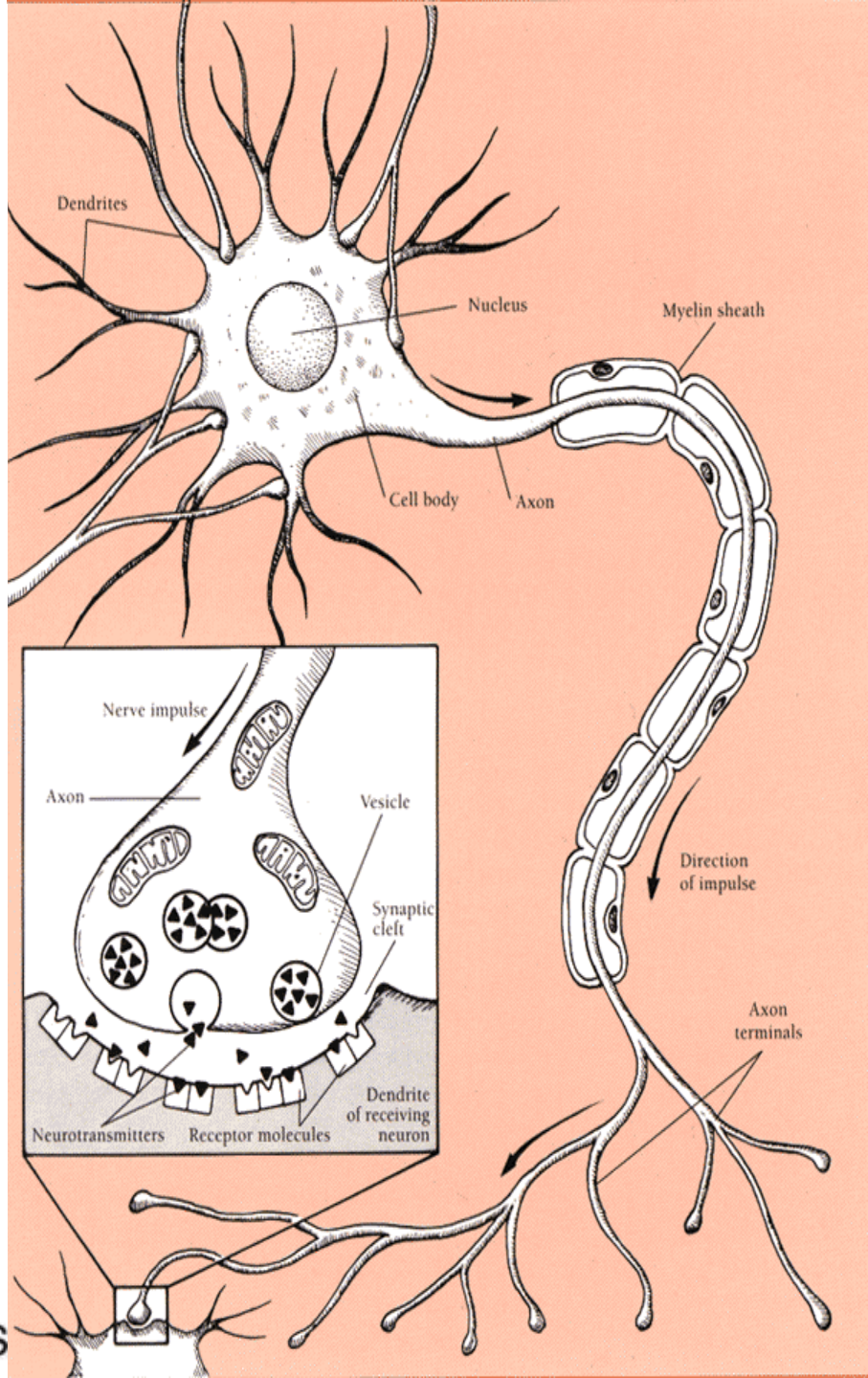


Structure of Neuron

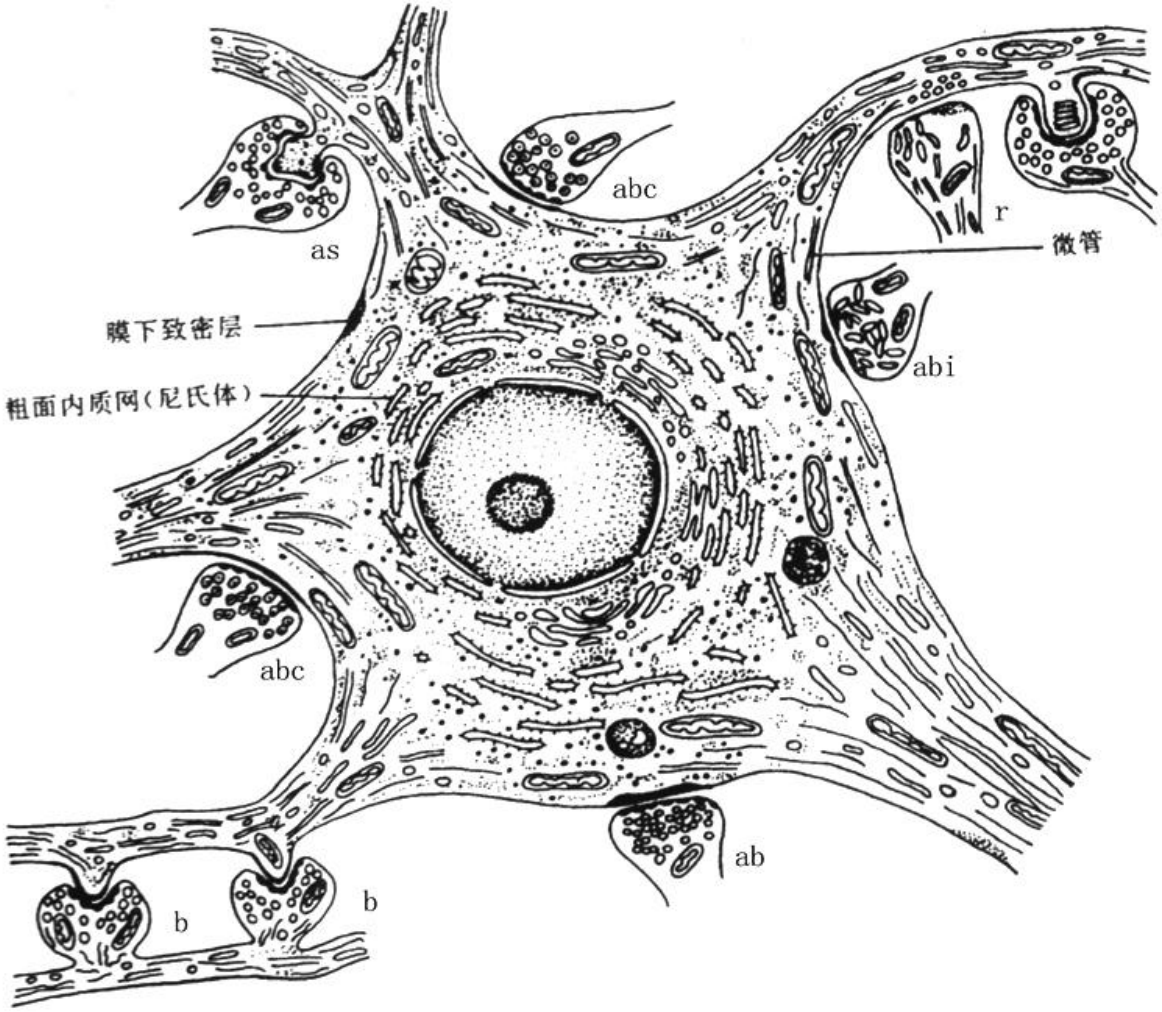
- Soma
- Axon
- Dendrite





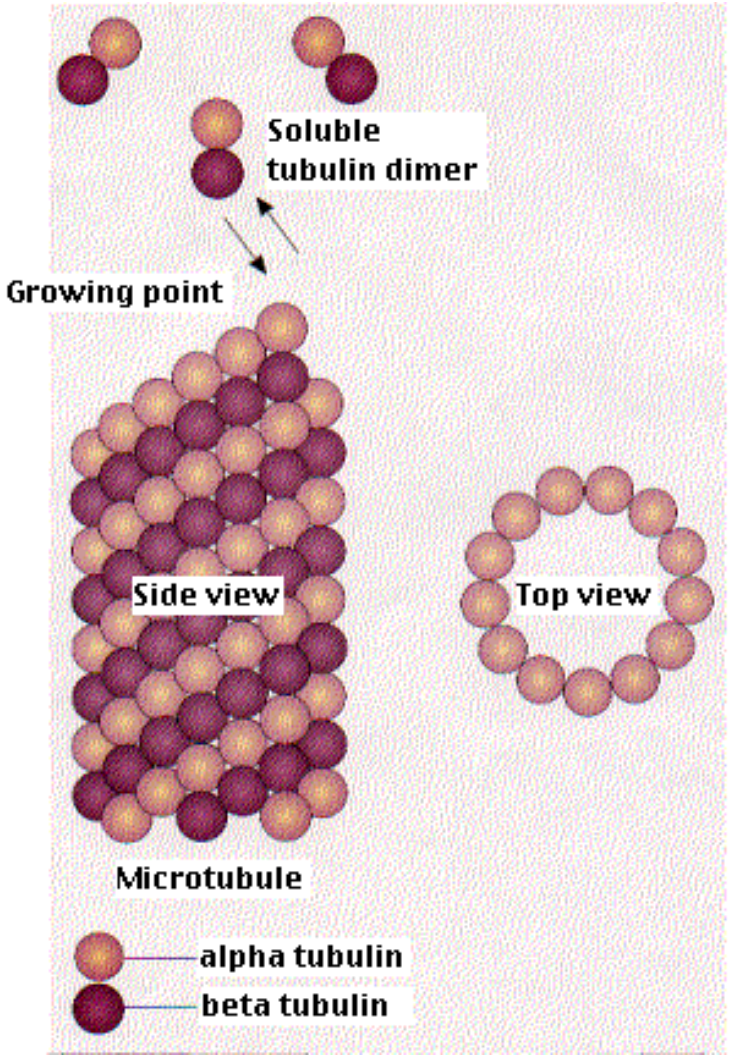


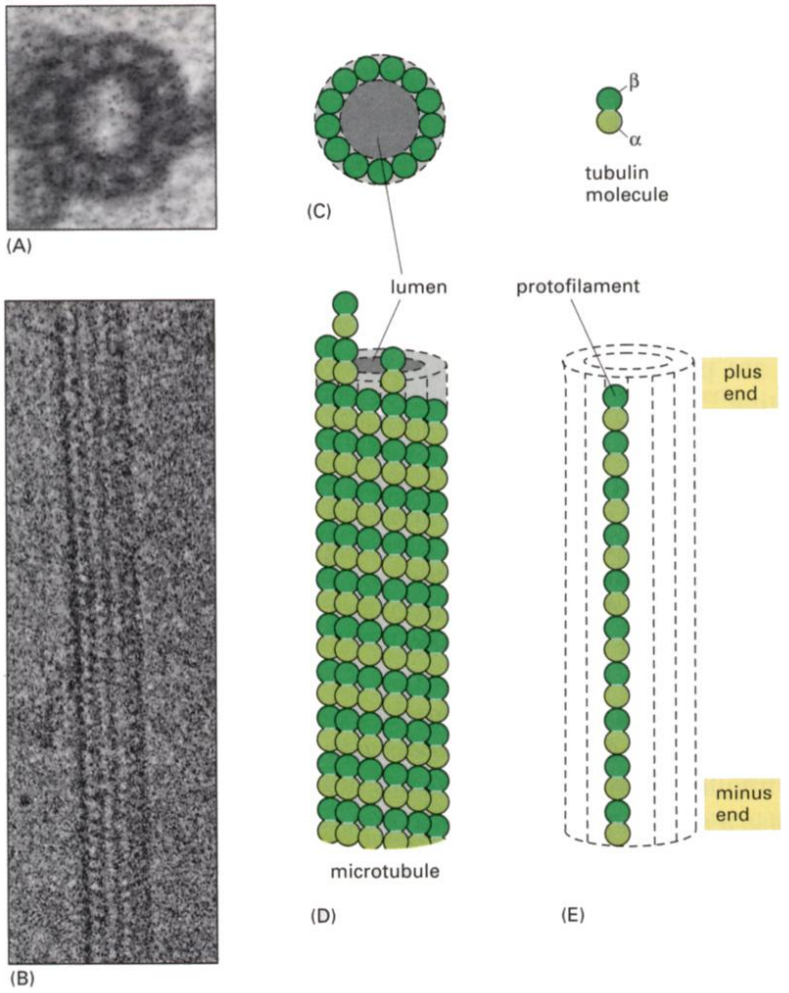
Ultrastructure of neuron



Microtubule

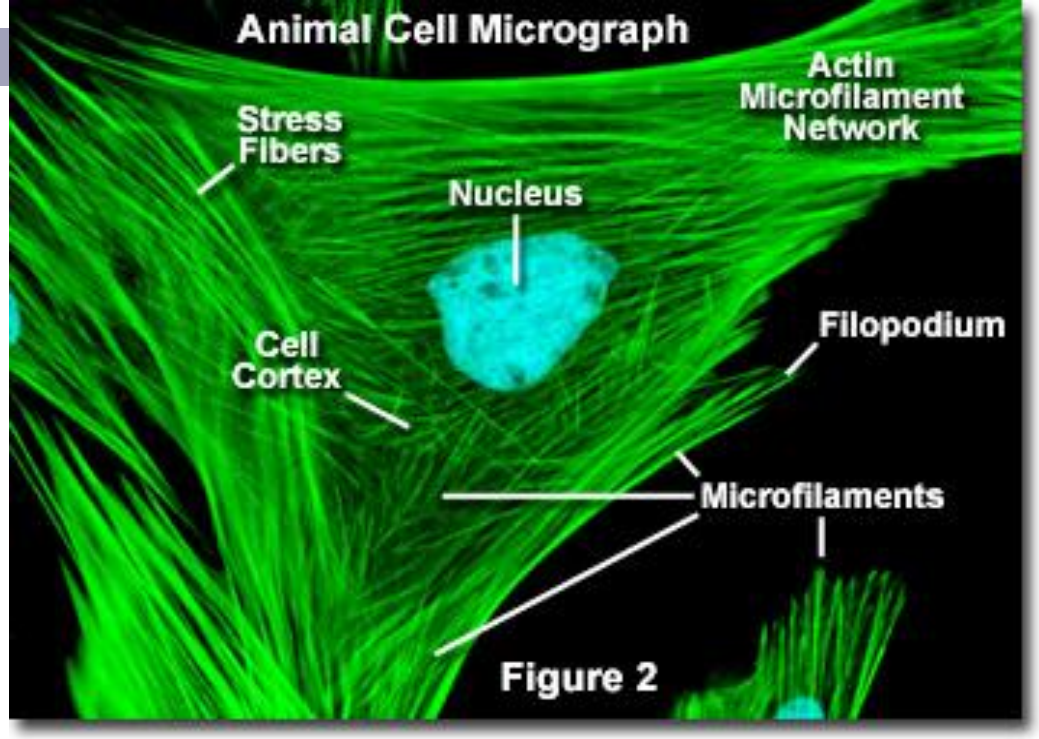
~ 20 nM in diameter which built from a protein building block called tubulin run longitudinally in axons and dendrites.

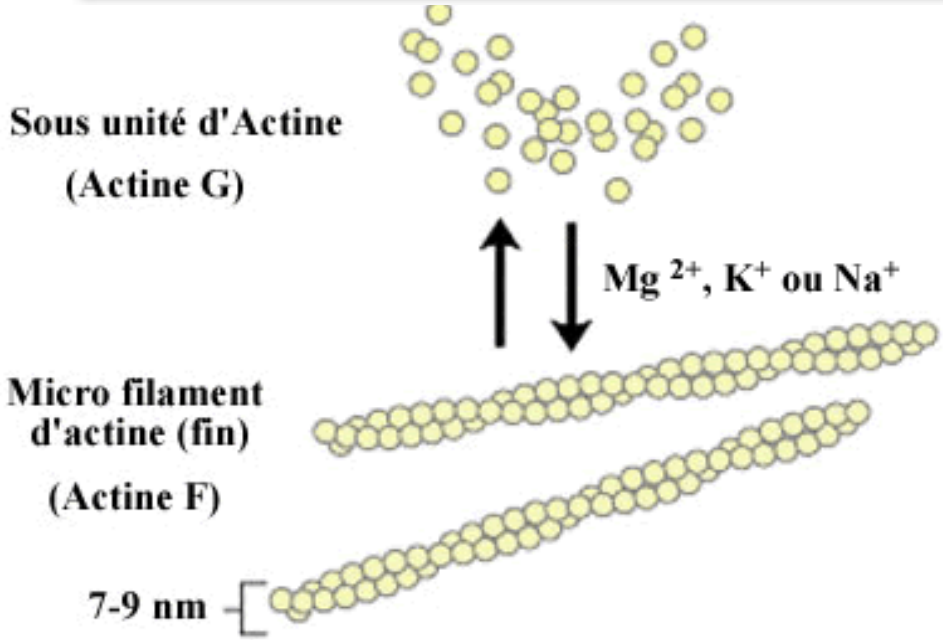




Microfilament

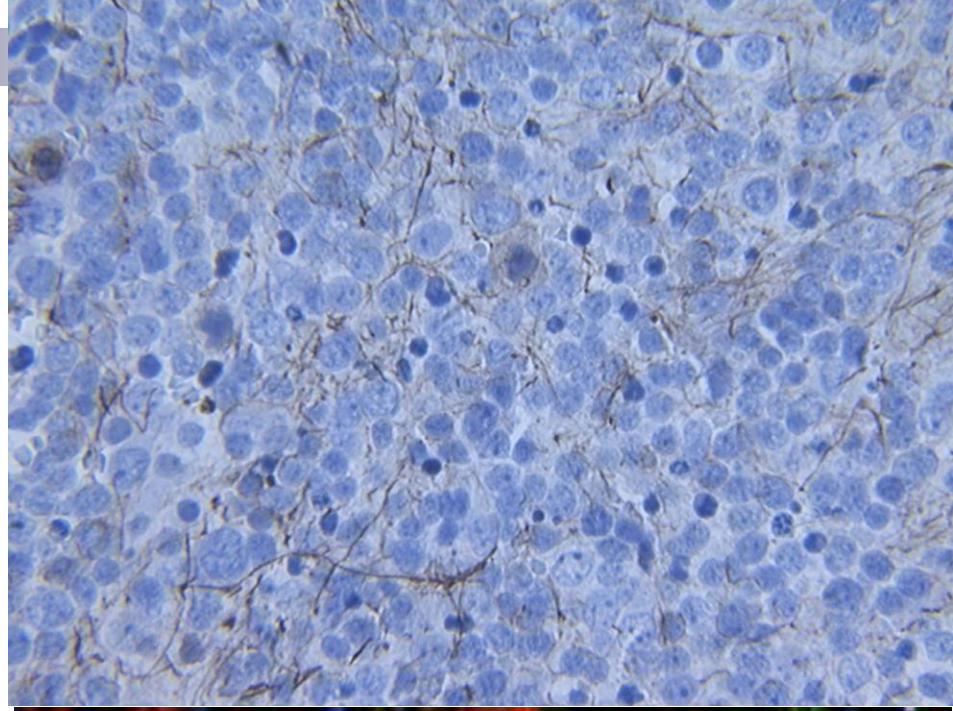
•~ 5 nM in diameter
•found throughout the neuron, but particularly abundant in axons and dendrites
•believed to play a role in adjusting cell shape

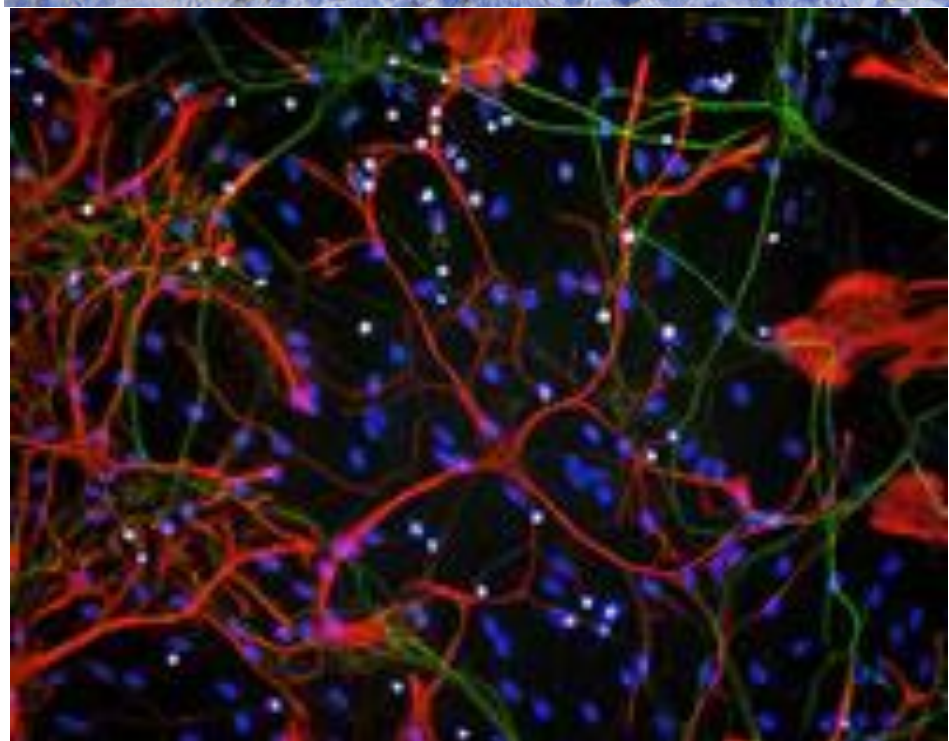




- Neurofilaments

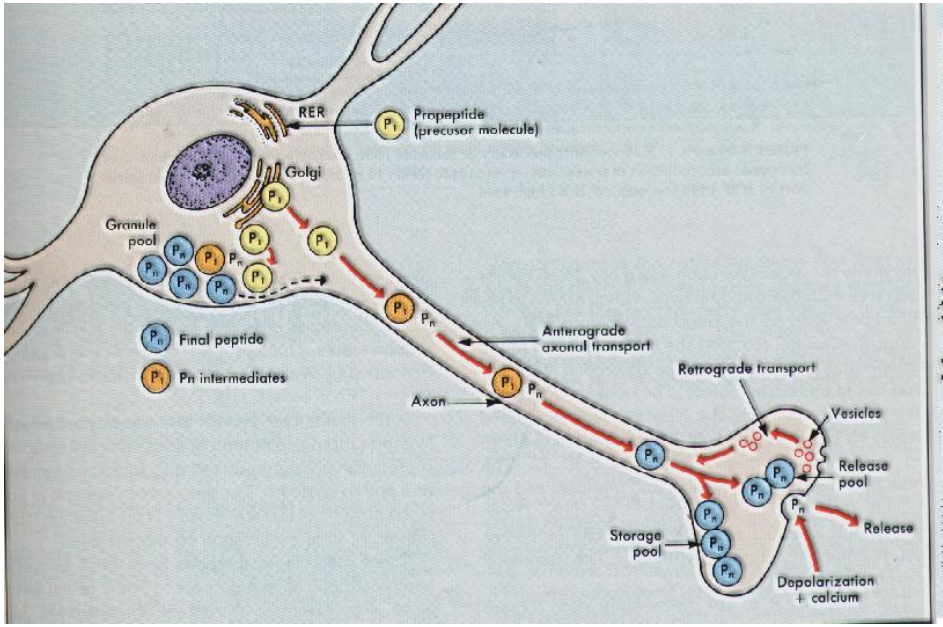
- ~ 10 nM in diameter
  - believed to compose a more stable structure than the microtubules and microfilaments
  - particularly prominent in axons
  - produced in excess in people suffering from Alzheimer's disease

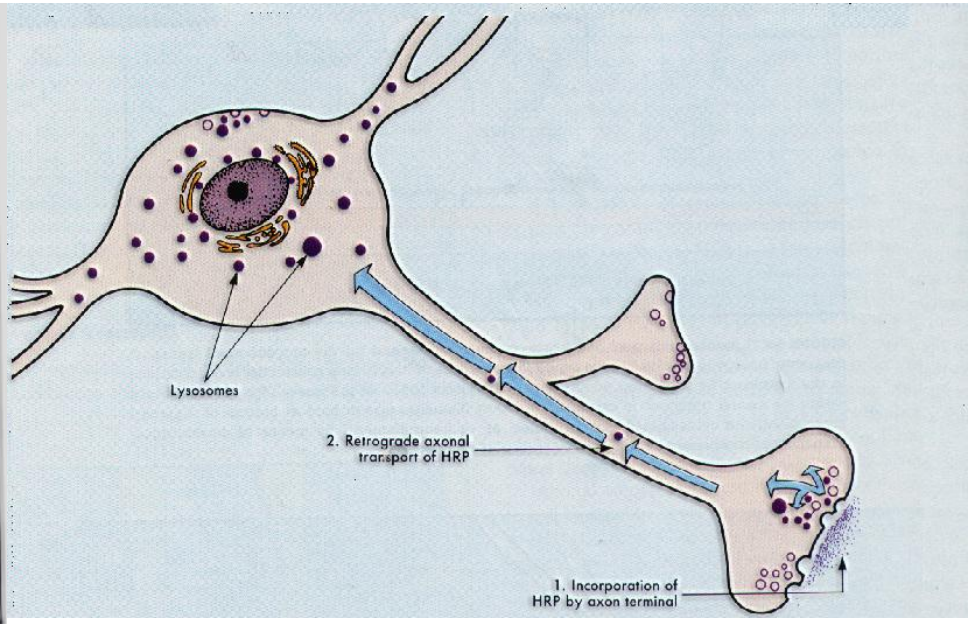




Axoplasmic transport

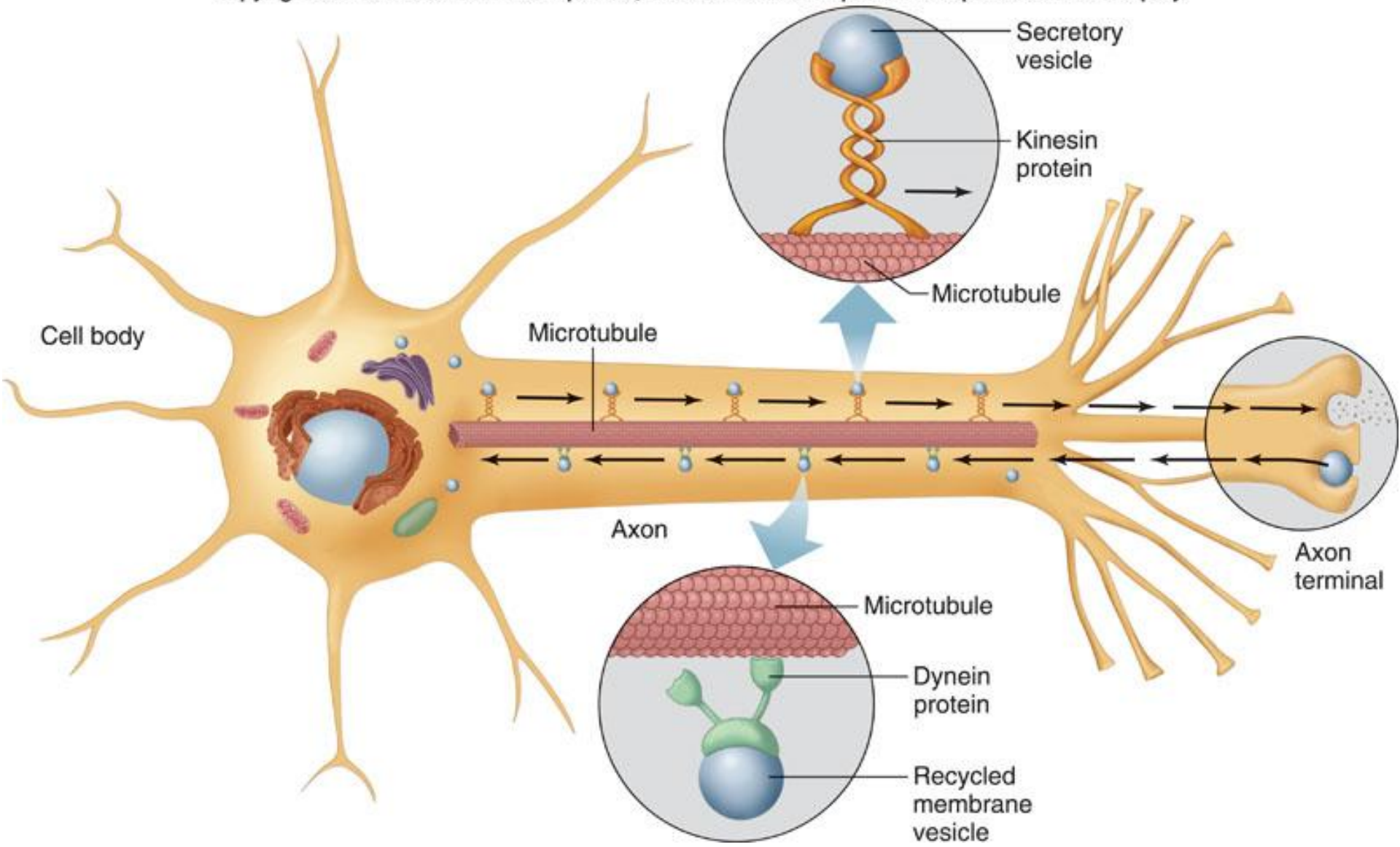
- Anterograde axoplasmic transport
- Retrograde axoplasmic transport



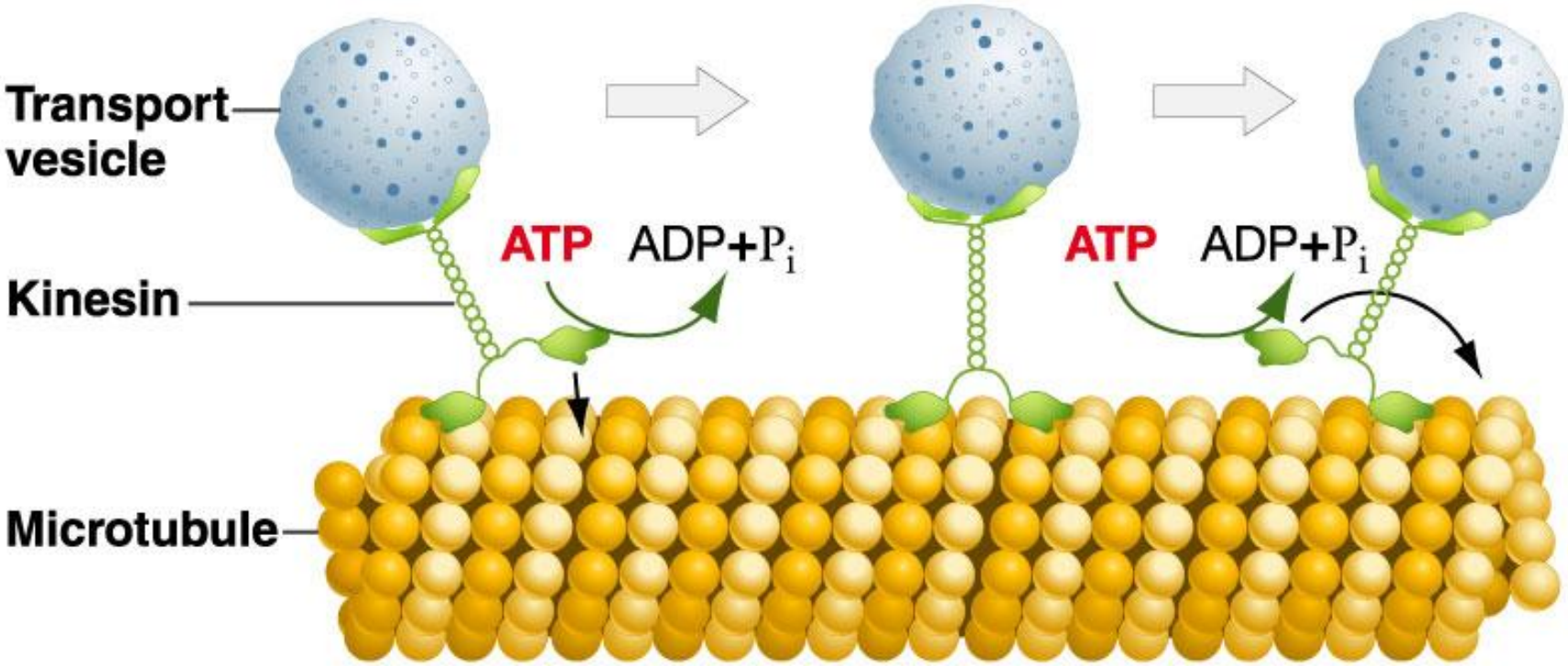


Differing speeds of axonal transport

Component	Rate (mm/day)	Structure and composition of transported substances
fast transport		
anterograde	200–400	small vesicles, neurotransmitters, membrane proteins, lipids
mitochondria	50–100	mitochondria
retrograde	200–300	lysosomal vesicles, enzymes
slow transport		
slow component a	2–8	microfilaments, metabolic enzymes, clathrin complex
slow component b	0.2–1	neurofilaments, microtubules

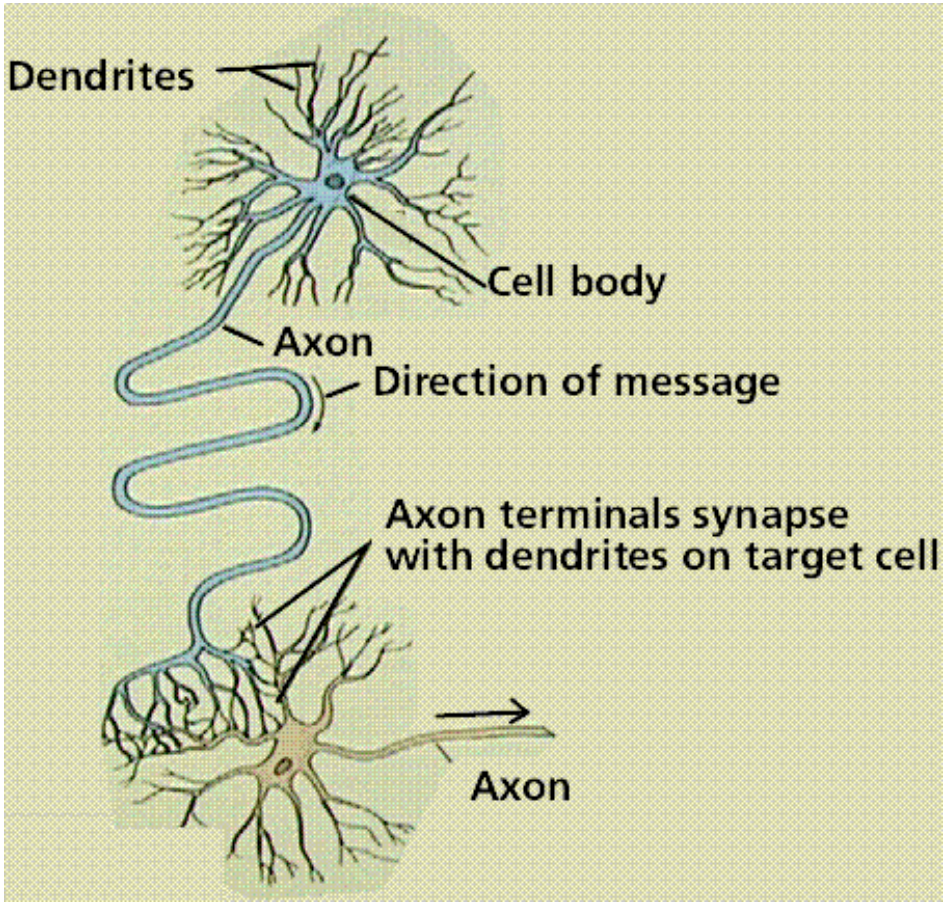


Kinesin "walks" along a microtubule track



Function of Neuron

- **Processing of information**
- **Soma**: integrate the message
- **Axon**: carries the impulse away from the cell body
- **Dendrite**: receive the nervous impulse

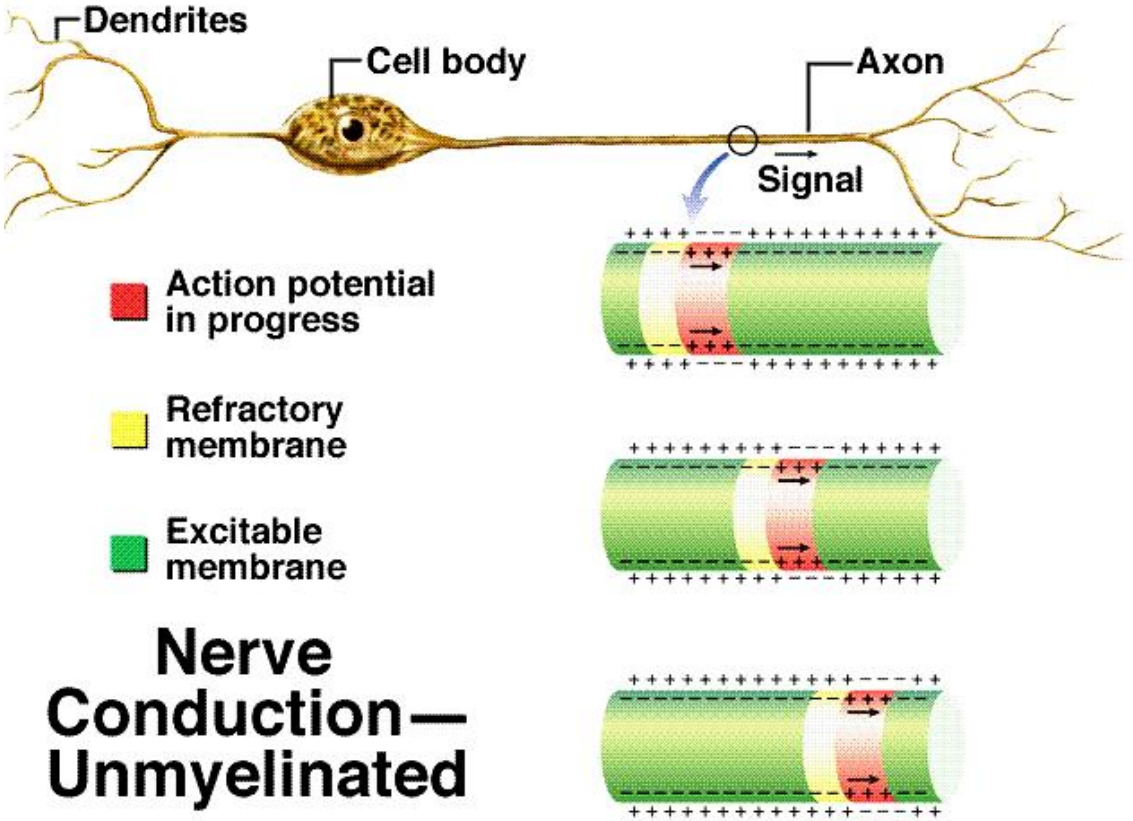


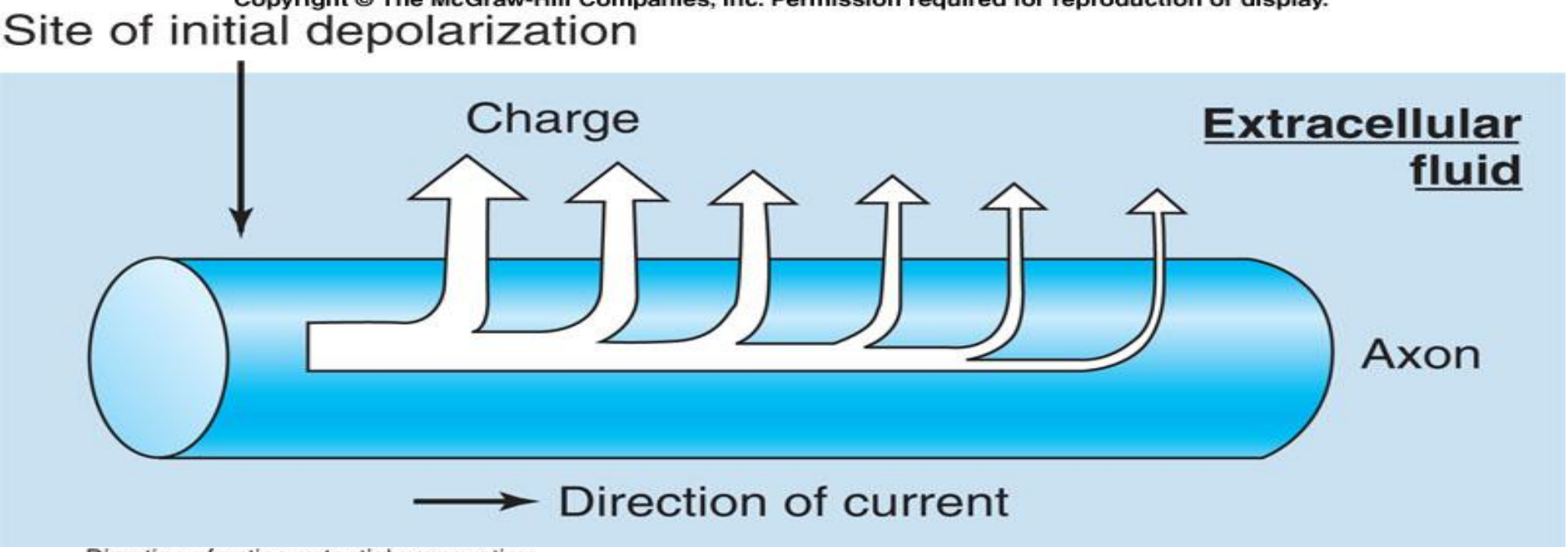
Structure of a neuron and the direction of nerve message transmission

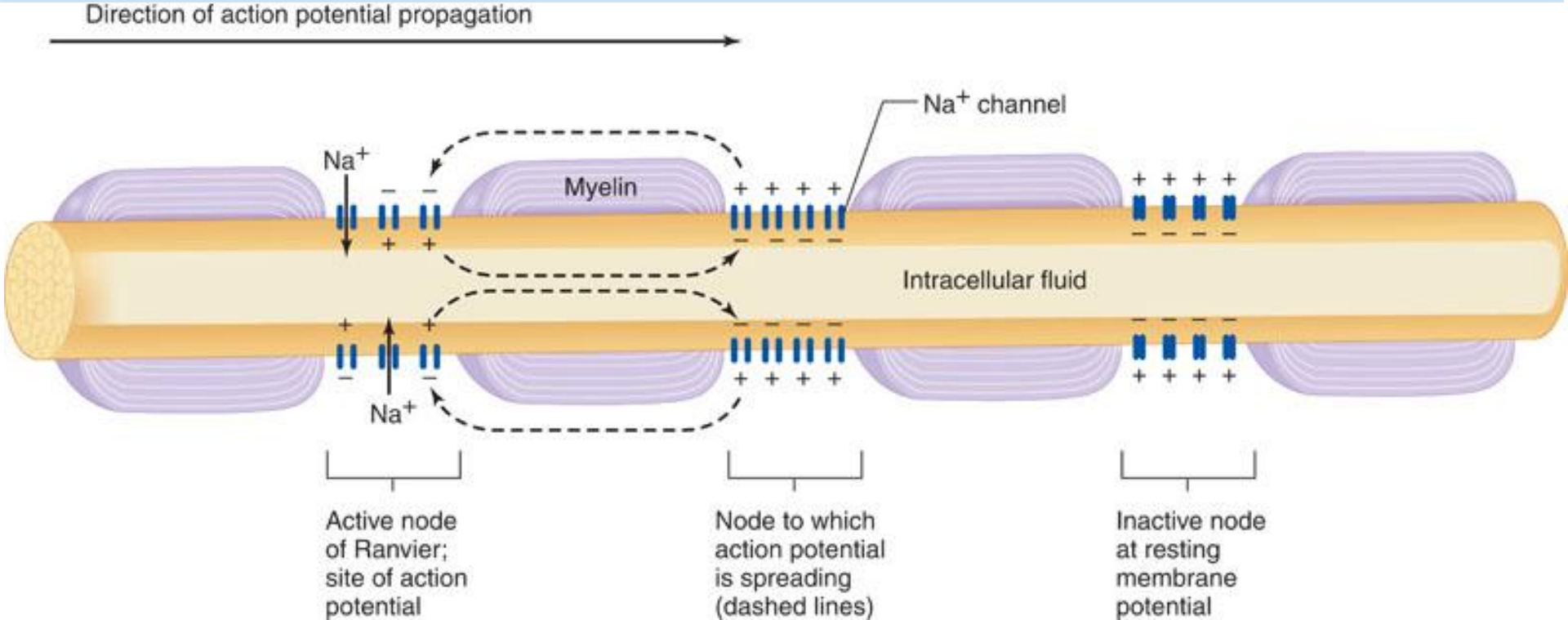
Nerve Fiber: Axons or Dendrites

- **Function**
  - Conducting AP

(Nerve impulse)





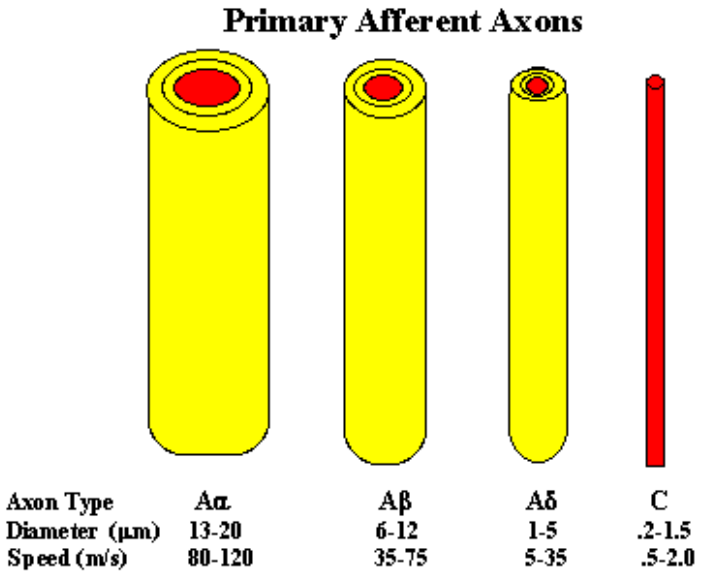


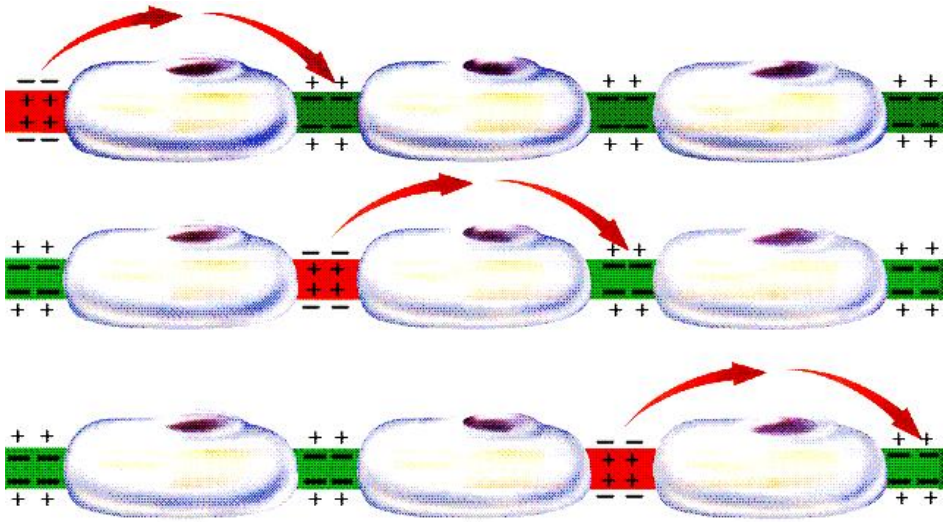
Characters of AP Conduction

- Anatomical and physiological integrity
- Two way conduction
- Not easy to be fatigue
- Conduct in a non-decremental fashion

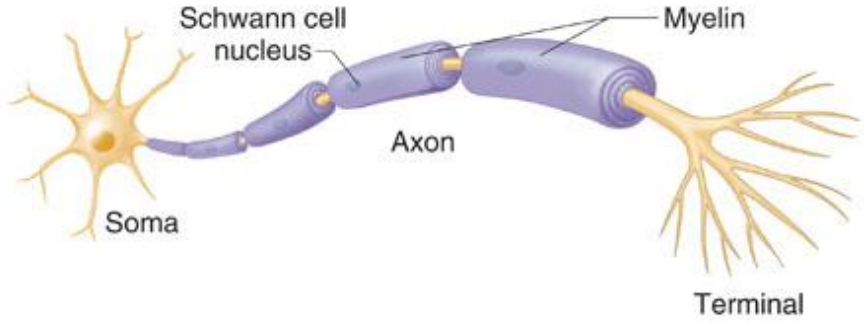
Conduction Velocity

- Diameter of the axon
- Myelinated or non-myelinated
- Temperature





(a)



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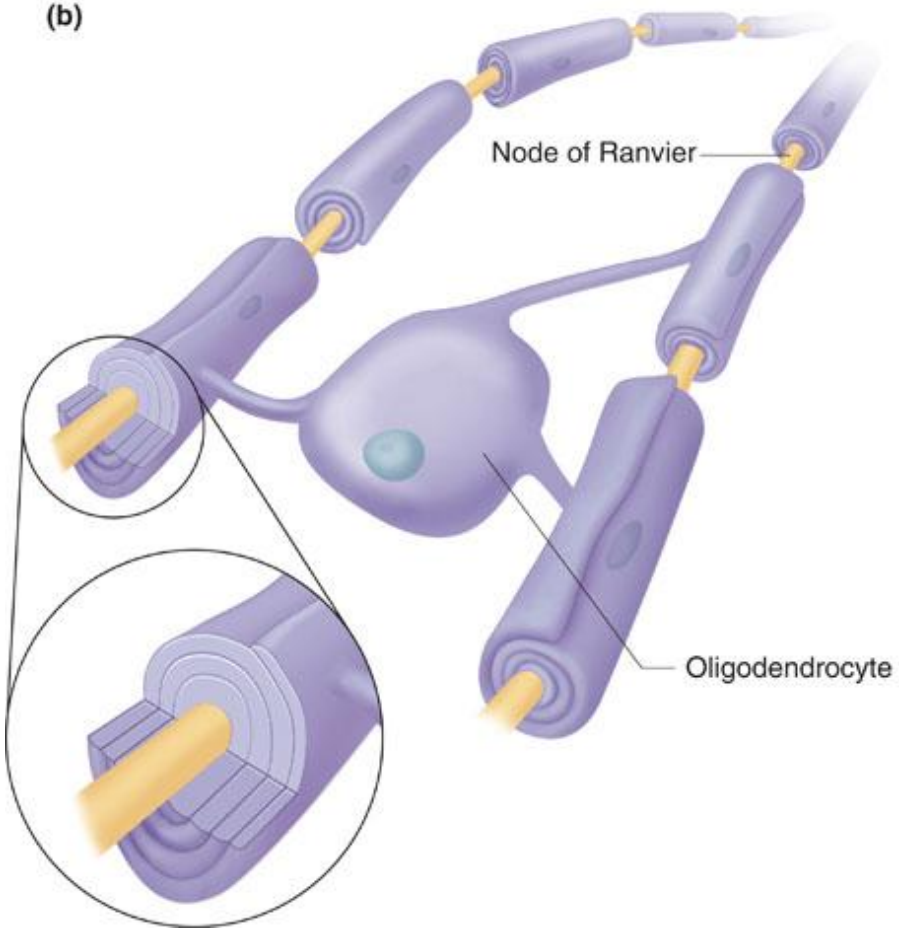

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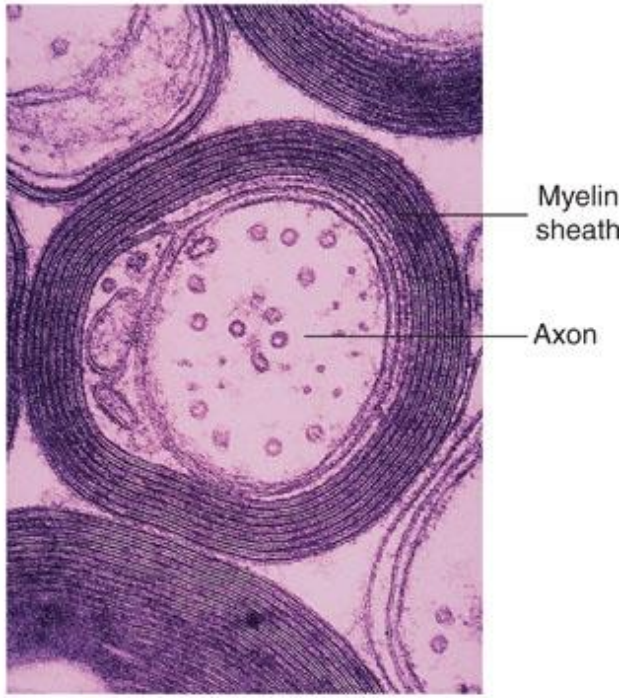


Classification of Nerve Fibers

Fiber Type	Function	Diameter (μm)	Conduction Velocity (m/s)	Spike Duration(ms)	Absolute Refractory Period(ms)
A α	Proprioception; somatic motor	12-20	70-120	0.4-0.5	0.4-1
β	Touch; pressure	5-12	30-70	0.4-0.5	0.4-1
γ	Motor to muscle spindles	3-6	15-30	0.4-0.5	0.4-1
δ	Pain, touch, temperature	2-5	12-30		
B	Preganglionic autonomic	<3	3-15	1.2	1.2
C	Pain, reflex responses	0.4-1.2	0.5-2	2	2
	Postaganglionic	0.3-1.3	0.7-2.3	2	2

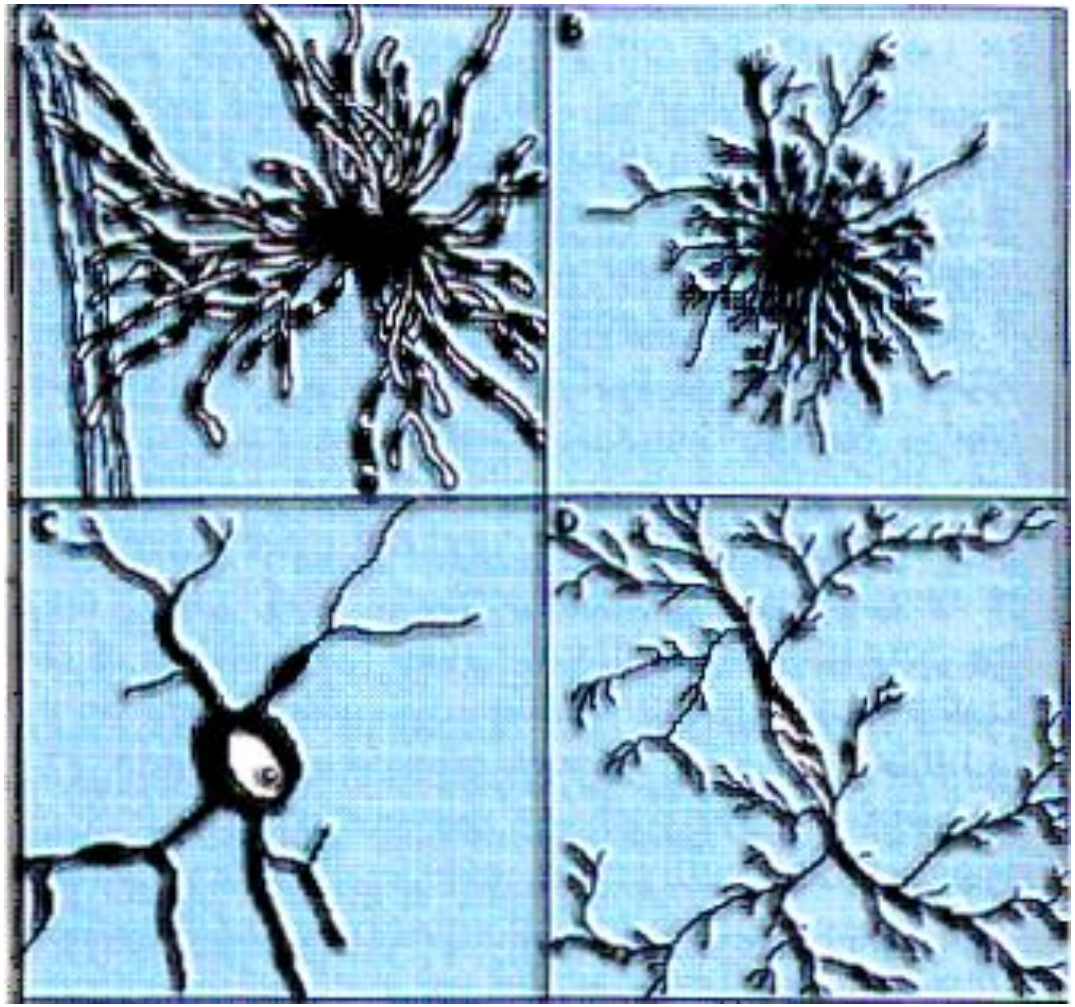
Classification of sensory nerve

Number	Origin	Fiber Type
I a b	Muscle spindle-annulospiral ending, Glogi tendon organ	Aα Aα
II	Muscle spindle-flower receptors, touch ,pressure	Aβ
III	Pain and temperature receptor, some touch receptors	Aδ
IV	Pain and other receptors	Dorsal root C

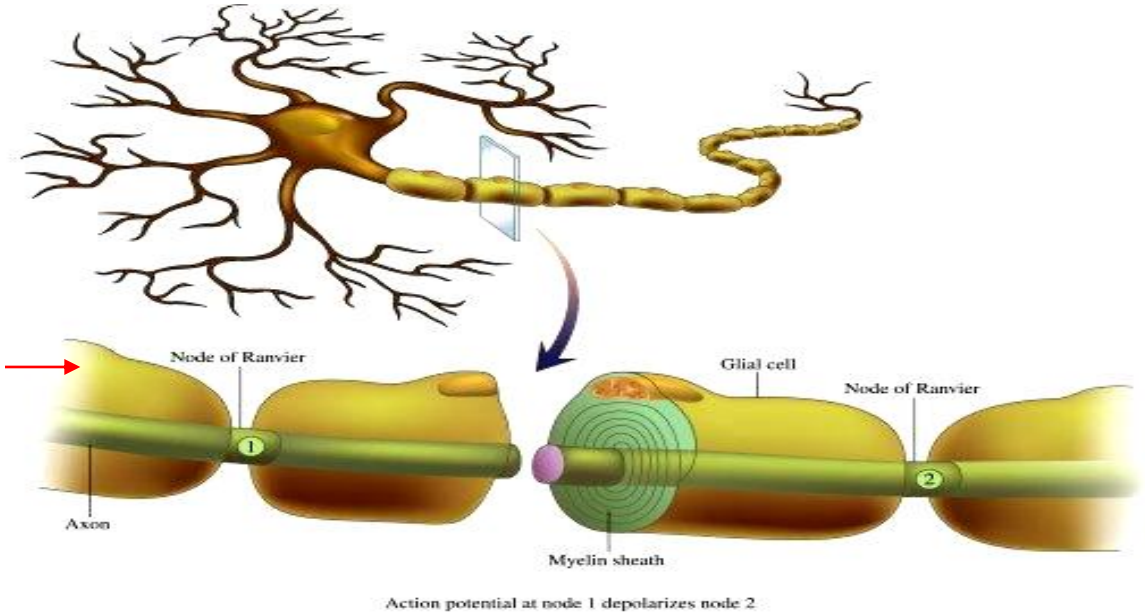
Types of Neuroglia

CNS

- Astrocyte
- Oligodendrocyte
- Microglia
- Ependymal cells



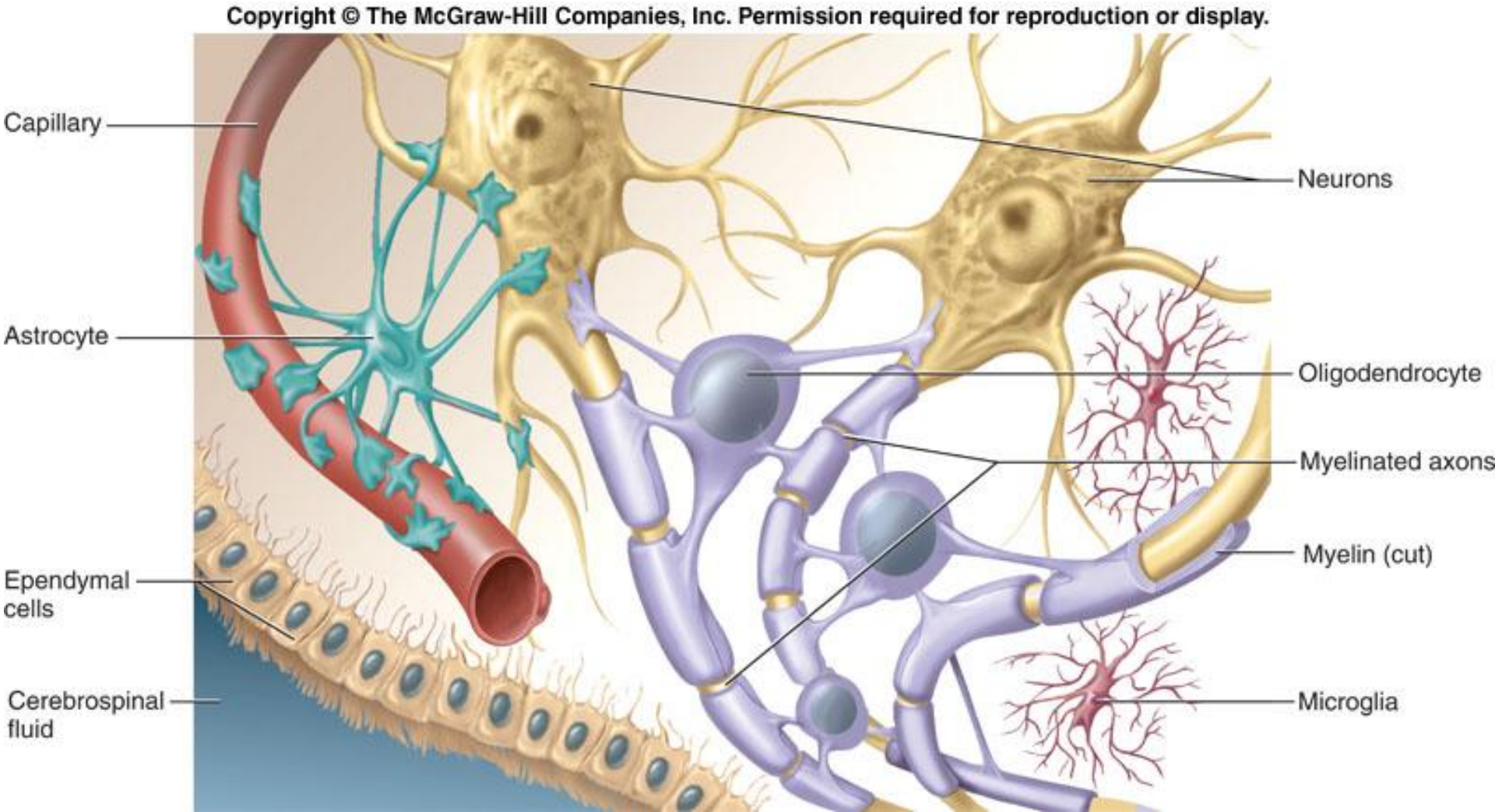
- **PNS**
  - **Schwann cell**
  - **Satellite cell**



Action potential at node 1 depolarizes node 2

Function of Neuroglia

- Support, nourish and protect neurons



Part 3.

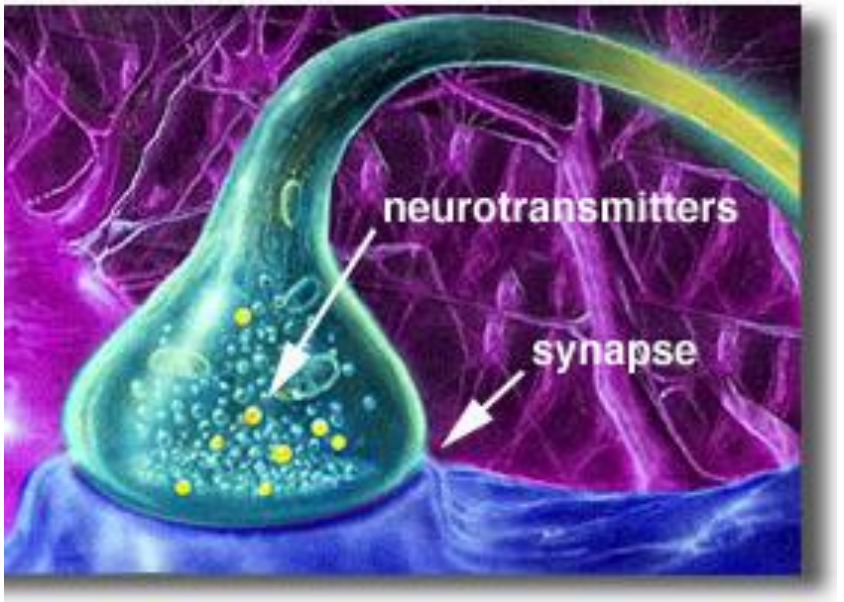
Transmission of Information Between the Neurons

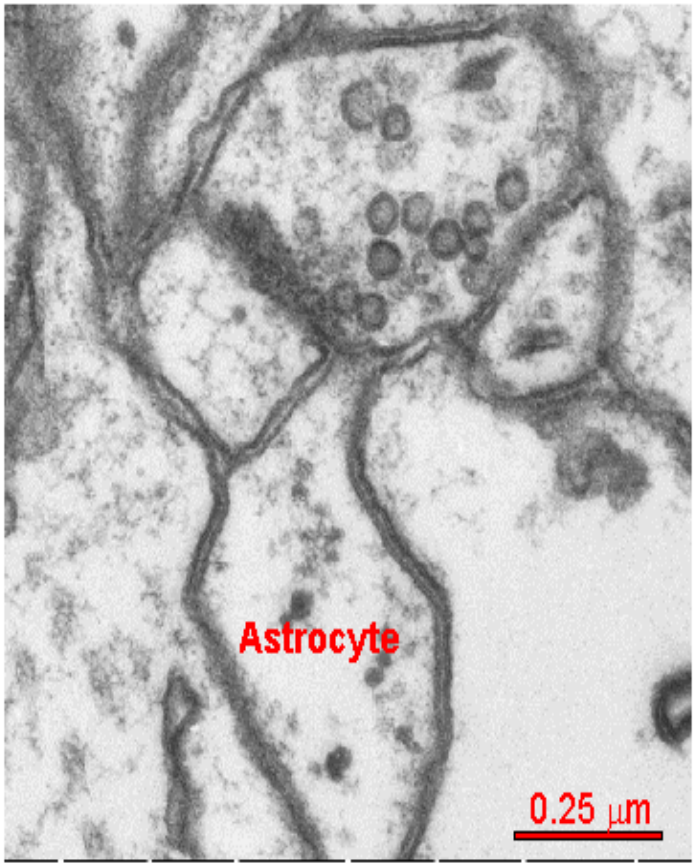
Transmission of Information Between the Neurons

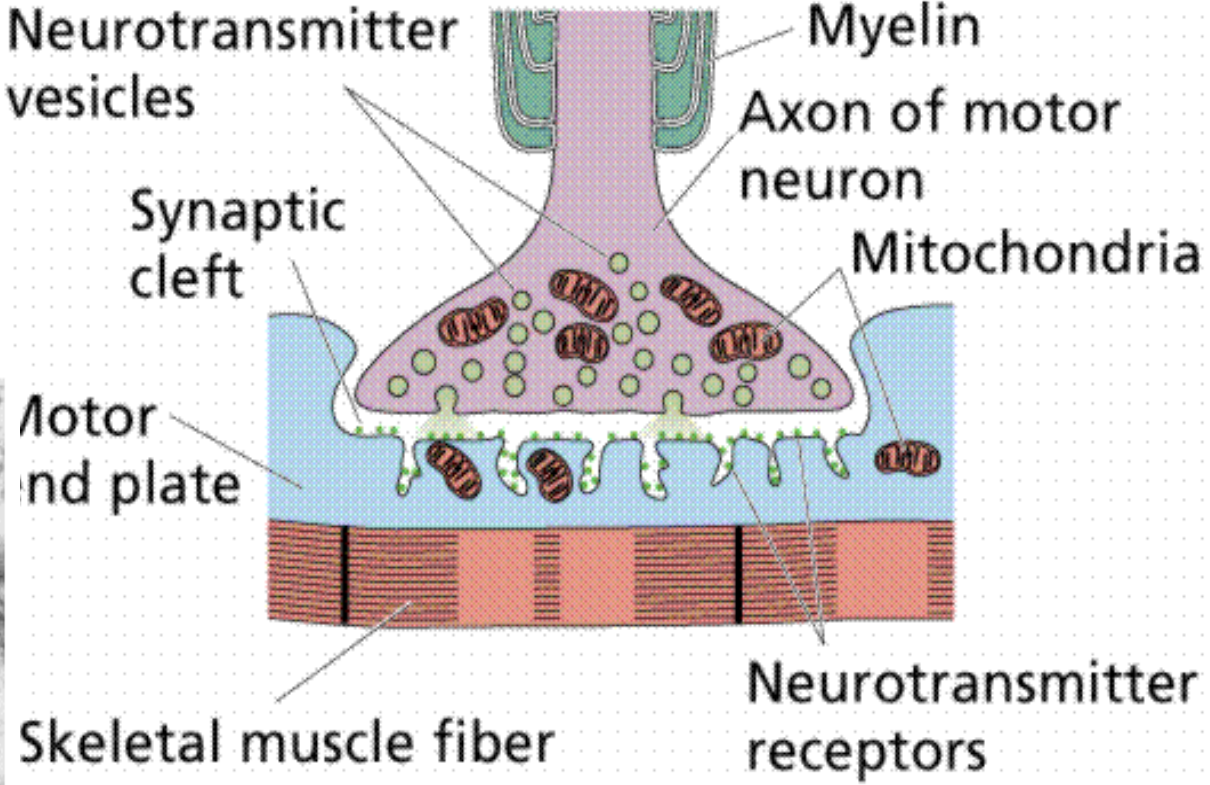
- **Chemical transmission**
  - **Classical synapse**
  - **Non-synaptic chemical transmission**
- **Electrical transmission**
  - **Gap junction**

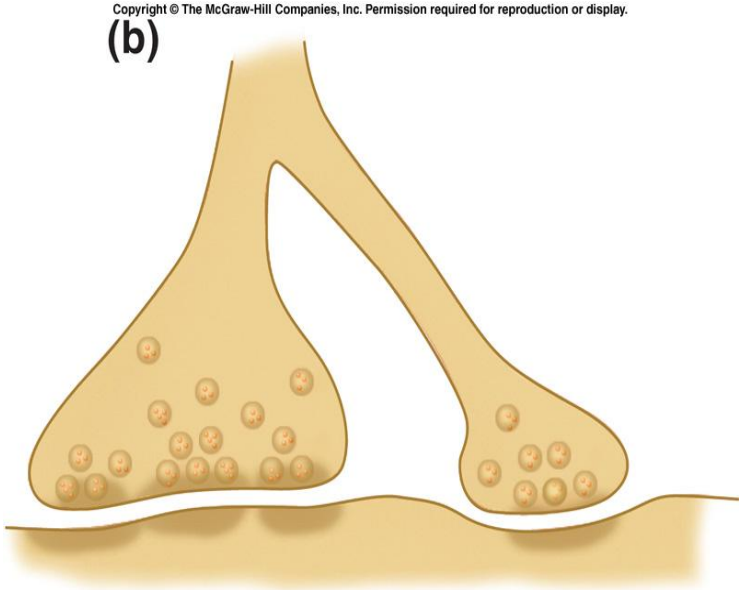
Classical synapse

- **Structure**
  - Presynaptic membrane
    - Voltage-gated Ca^{2+} channels
    - Transmitter vesicles
  - Synaptic cleft
  - Postsynaptic membrane
    - Receptors



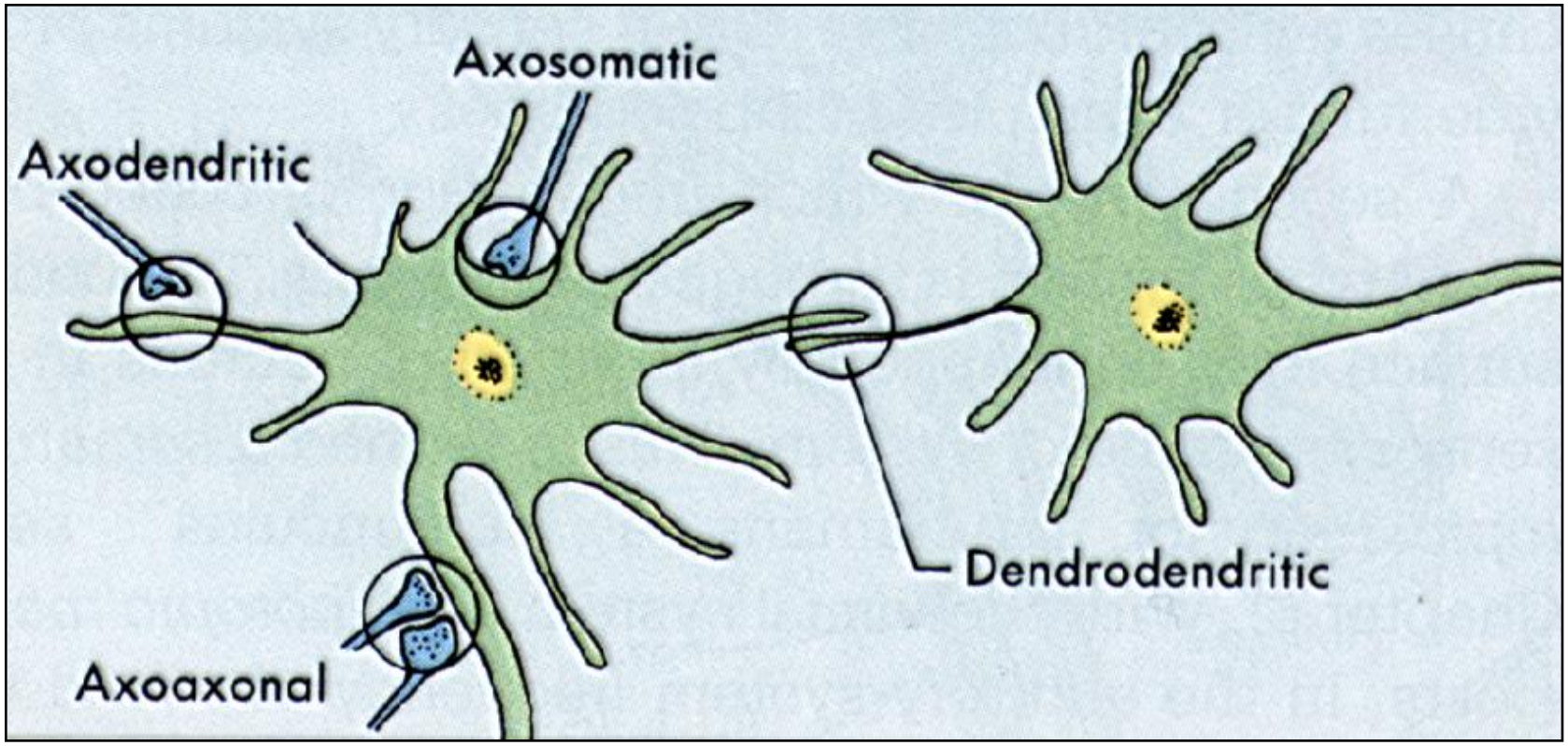






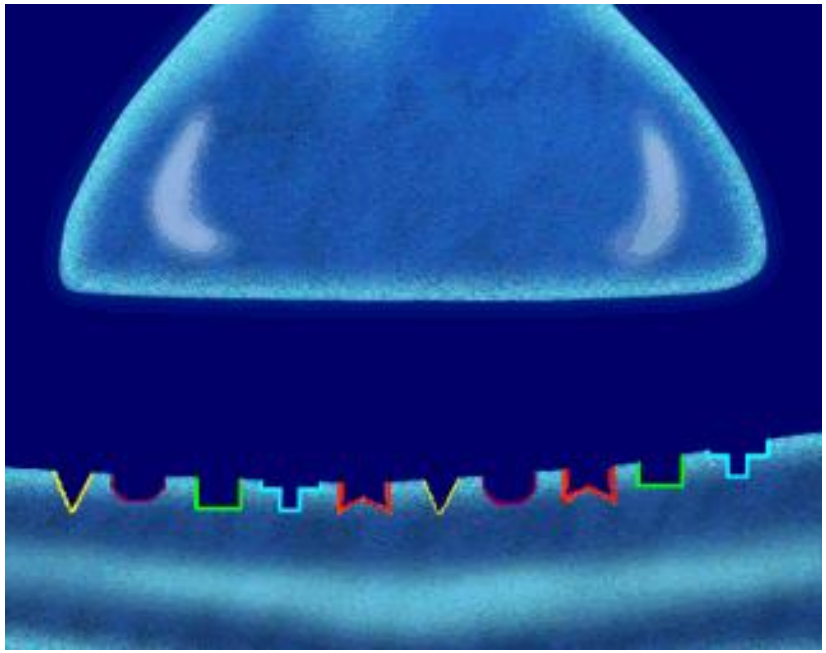
Redrawn from Walmsley et al.

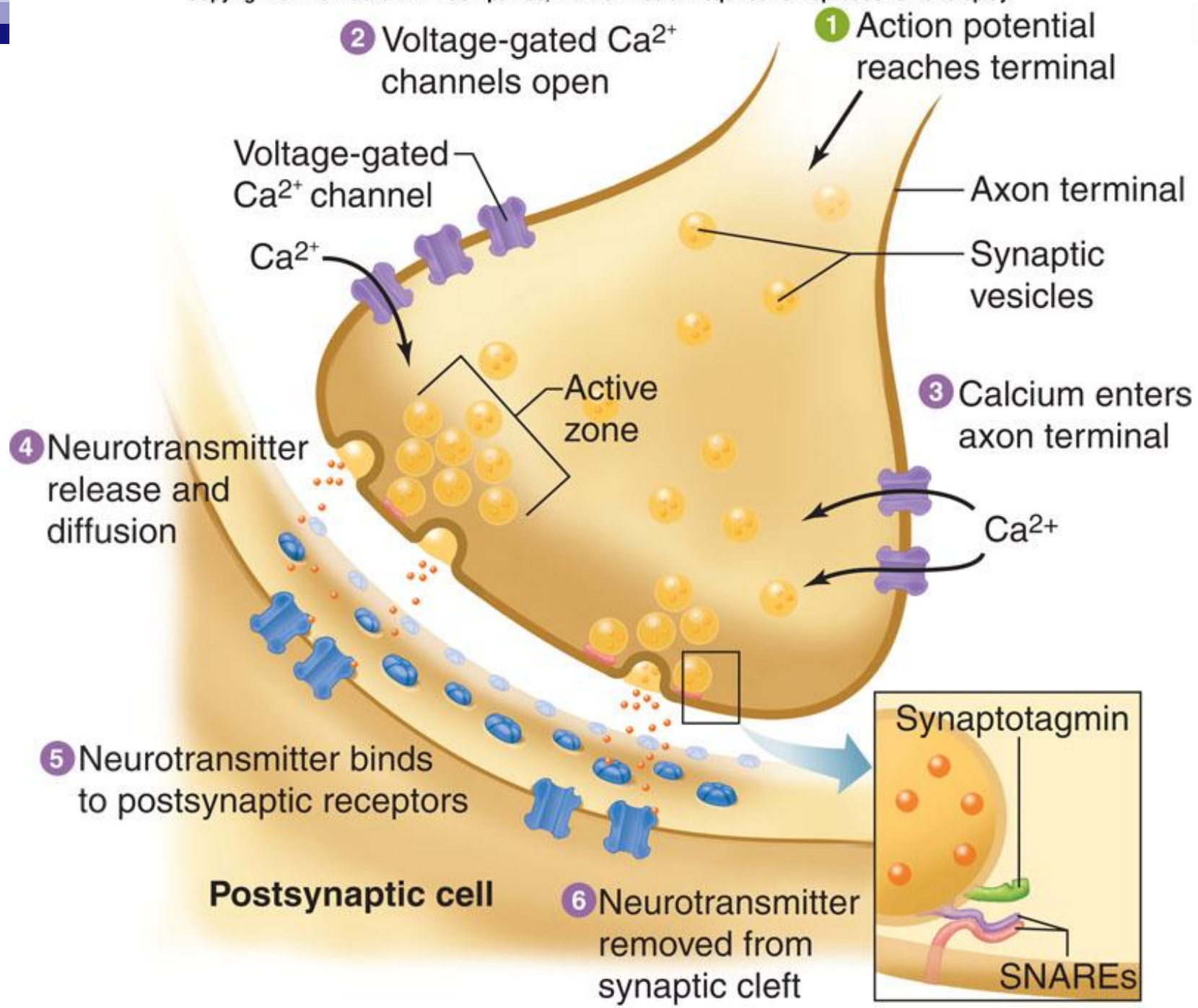
Connection of Synapse



Synaptic transmission: the principle of "one-way"conduction at chemical synapses

- Transmit signals from presynaptic neuron to postsynaptic neuron
  - **1. AP**
  - 2. Ca^{2+} channel open
  - 3. Transmitter release
    - Exocytosis
  - 4. Transmitter + receptor
  - 5. Postsynaptic potential (**AP**)
  - 6. Neurotransmitter removed from synaptic cleft





Neurotransmitter

- Molecules that are released on excitation by a presynaptic neuron into the synaptic cleft and cause a change in the postsynaptic membrane potential
- Binding to specific receptor
- Excitatory transmitter: opens cation channels directly or indirectly.

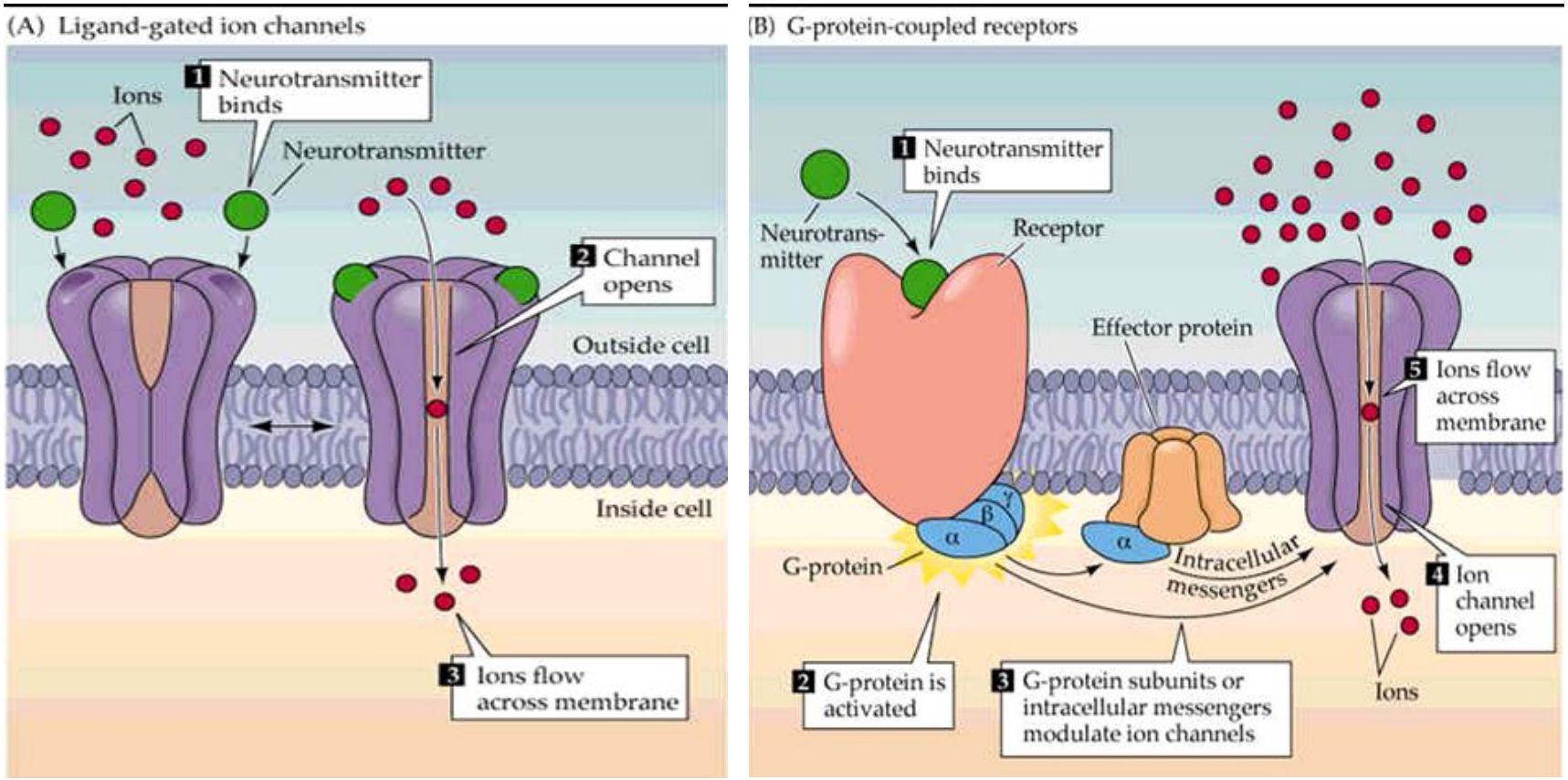
  Inhibitory transmitter: opens anion channels directly or indirectly.
- Change the membrane potential.
- Rapidly removed from synaptic cleft

Neuromodulator

- a chemical that alters the effects of

  neurotransmitters

Types of neurotransmitter receptor

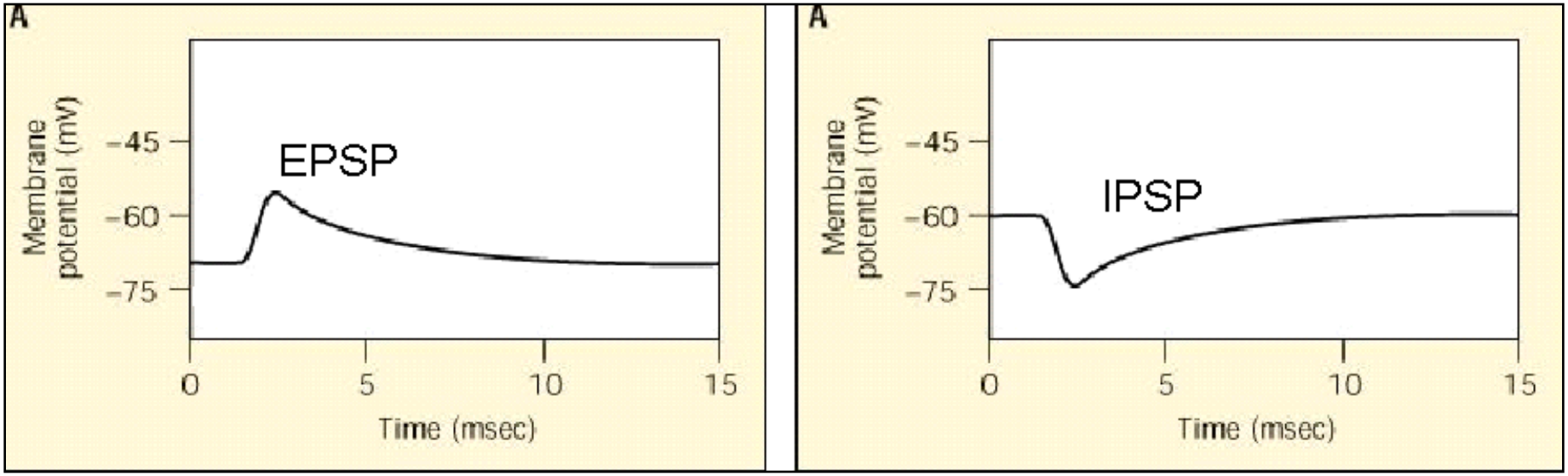


Some special characteristics of synaptic transmission

- One way conduction
- Fatigue of synaptic transmission
- Synaptic transmission is easy to be affected by acidosis and alkalosis, hypoxia, chemicals etc.
- Synaptic delay

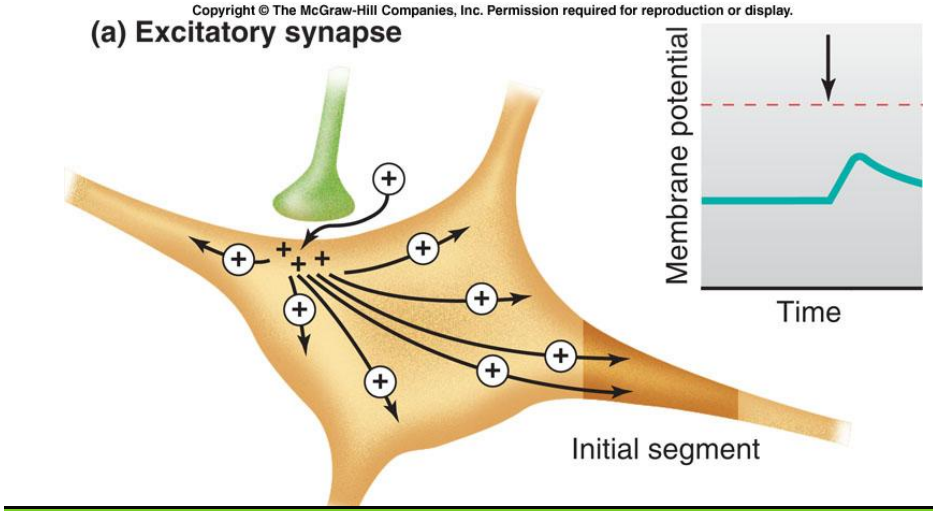
Postsynaptic Potential

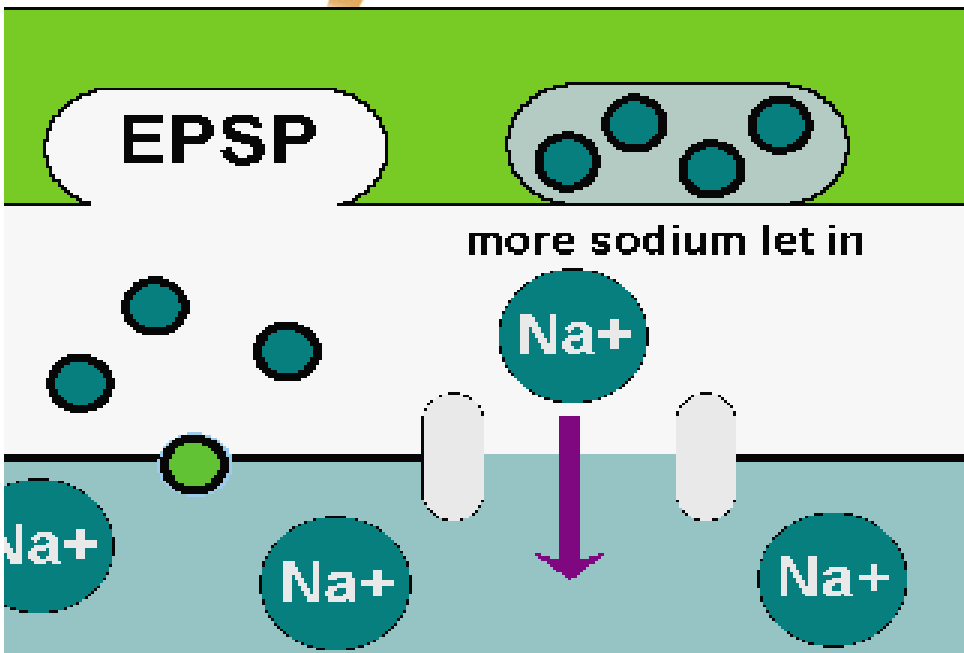
- **Types**
  - Excitatory postsynaptic potential(EPSP)
  - Inhibitory postsynaptic potential(IPSP)



Excitatory Postsynaptic Potential (EPSP)

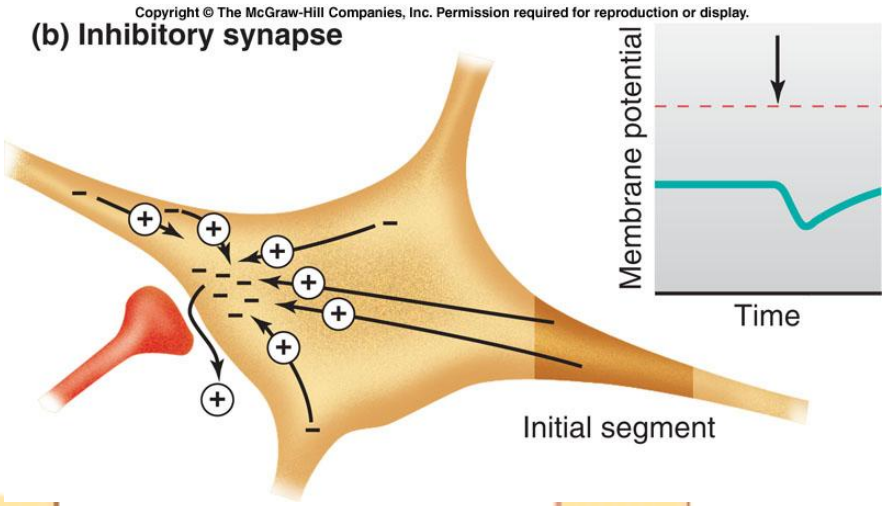
- Postsynaptic membrane
  - ↑Permeability to Na^+
  - **EPSP**: Depolarizing

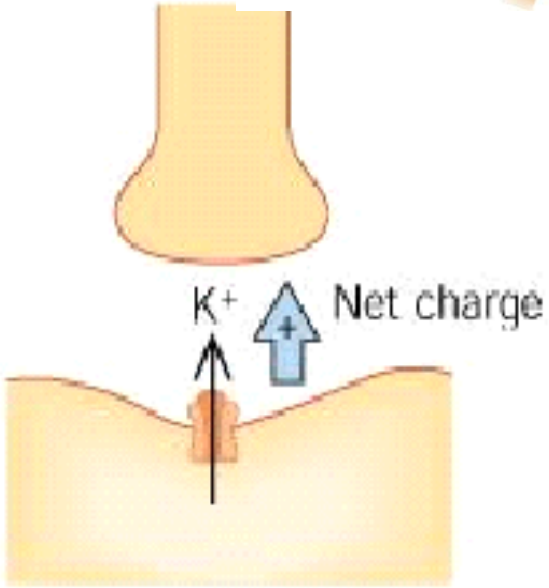


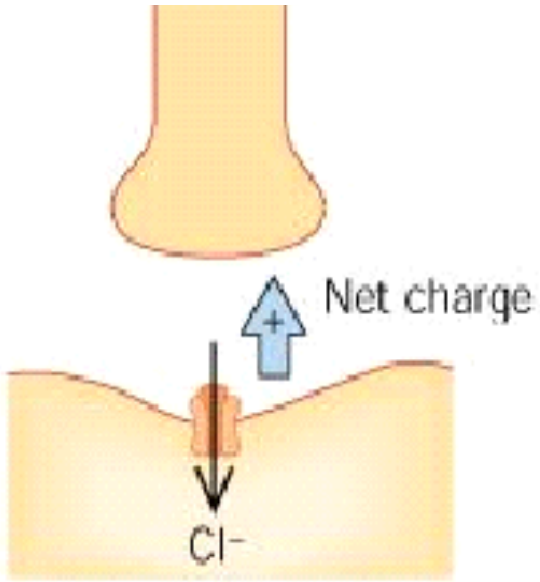


Inhibitory Postsynaptic Potential (IPSP)

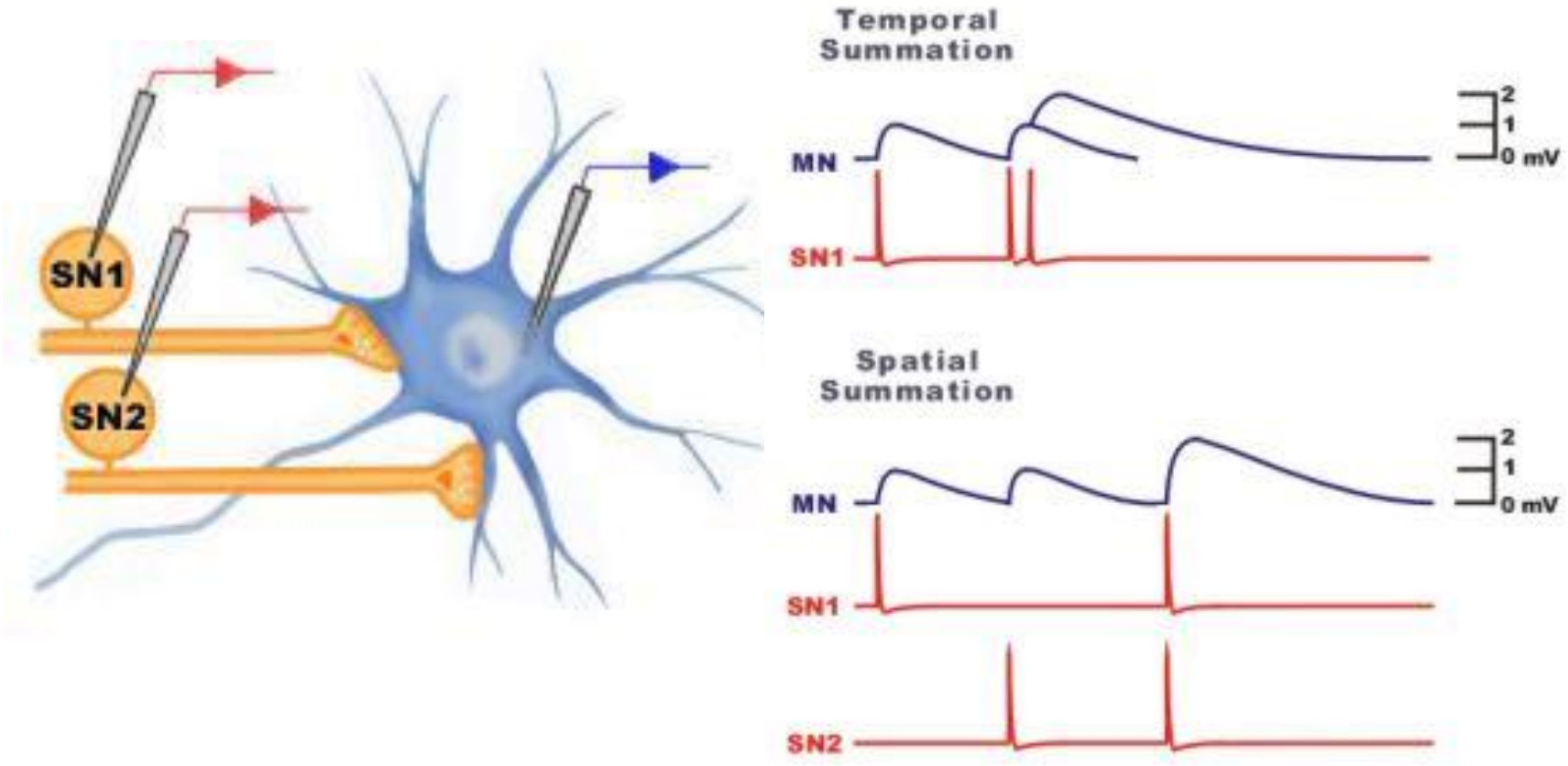
- Postsynaptic membrane
  - ↑Cl^- influx and K^+ efflux
  - **IPSP**: Hyperpolarizing



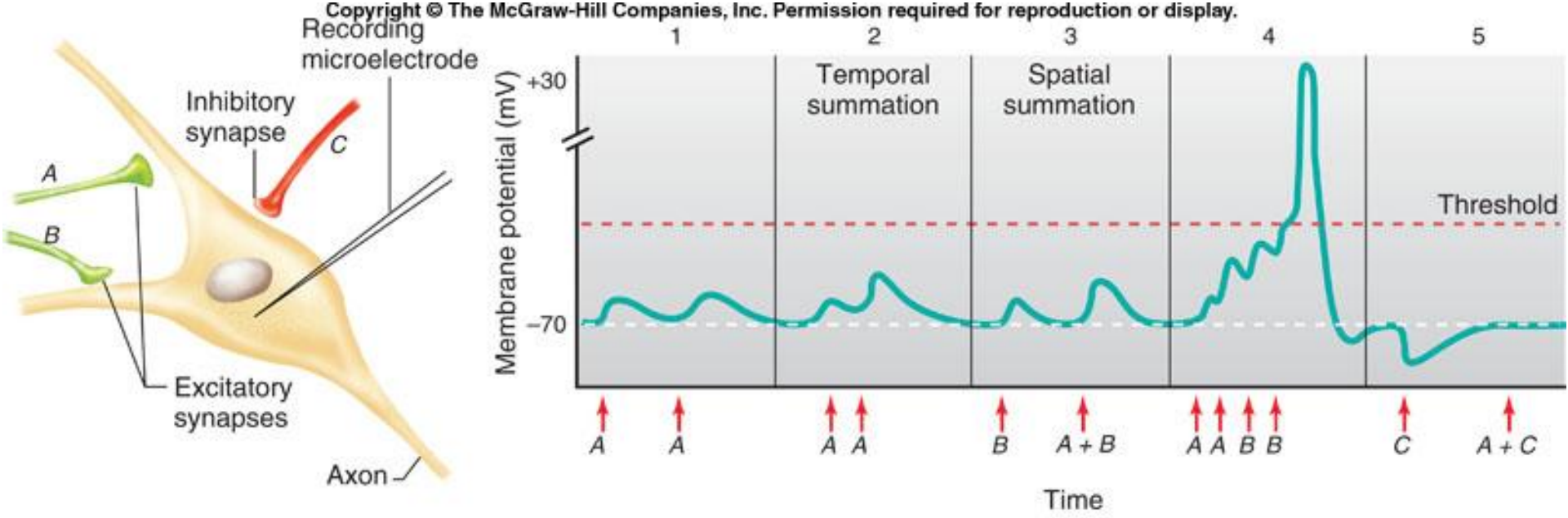




Summation of EPSP or IPSP



The processes by which the multiple EPSPs (IPSPs) from presynaptic neurons summate over time and space are called temporal and spatial summation



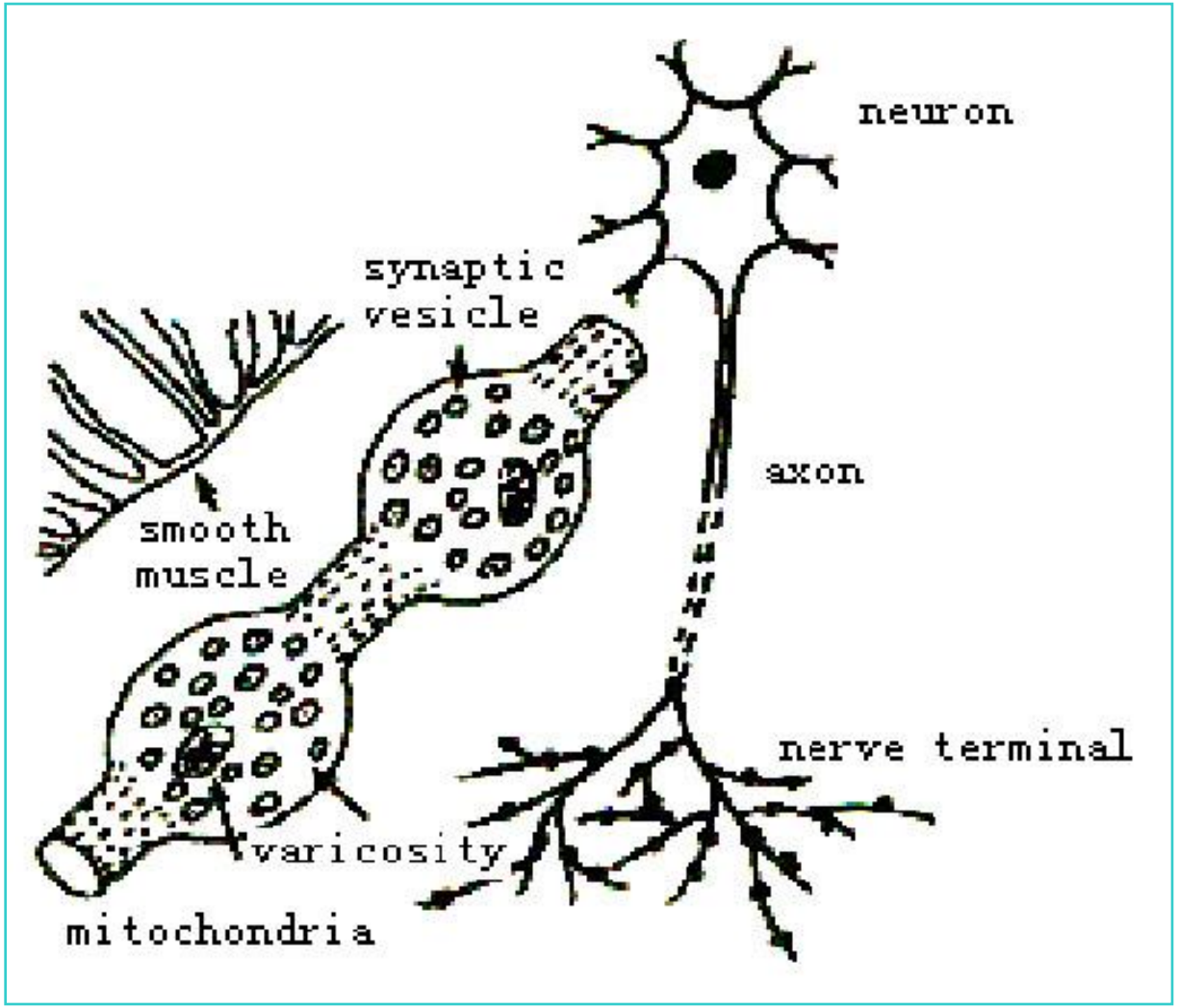
Synaptic potential is a graded potential that has much difference from action potential.

TABLE 6–4 *Differences between Graded Potentials and Action Potentials*

GRADED POTENTIAL	ACTION POTENTIAL
Amplitude varies with size of the initiating event.	All-or-none. Once membrane is depolarized to threshold, amplitude is independent of the size of the initiating event.
Can be summed.	Cannot be summed.
Has no threshold.	Has a threshold that is usually about 15 mV depolarized relative to the resting potential.
Has no refractory period.	Has a refractory period.
Is conducted decrementally; that is, amplitude decreases with distance.	Is conducted without decrement; the depolarization is amplified to a constant value at each point along the membrane.
Duration varies with initiating conditions.	Duration is constant for a given cell type under constant conditions.
Can be a depolarization or a hyperpolarization.	Is only a depolarization.
Initiated by environmental stimulus (receptor), by neurotransmitter (synapse), or spontaneously.	Initiated by a graded potential.
Mechanism depends on ligand-gated channels or other chemical or physical changes.	Mechanism depends on voltage-gated channels.

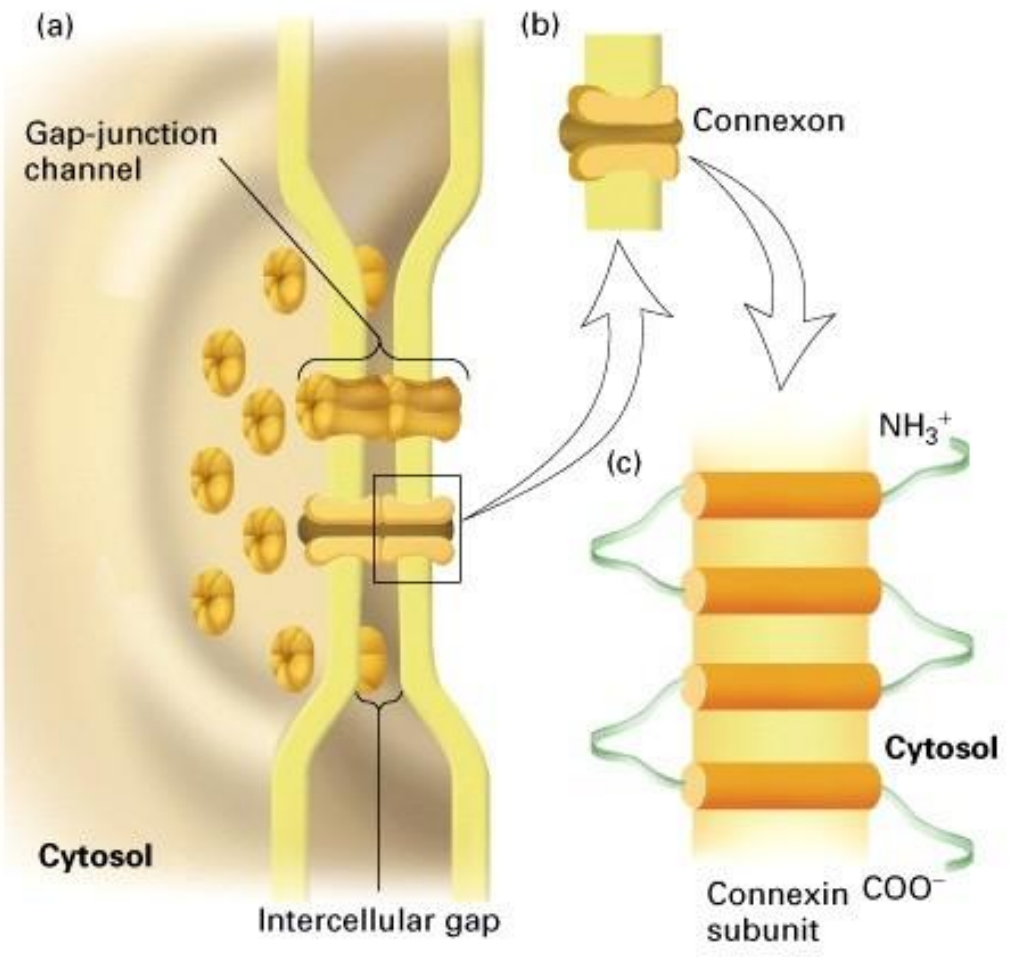
Non-synaptic Chemical Transmission

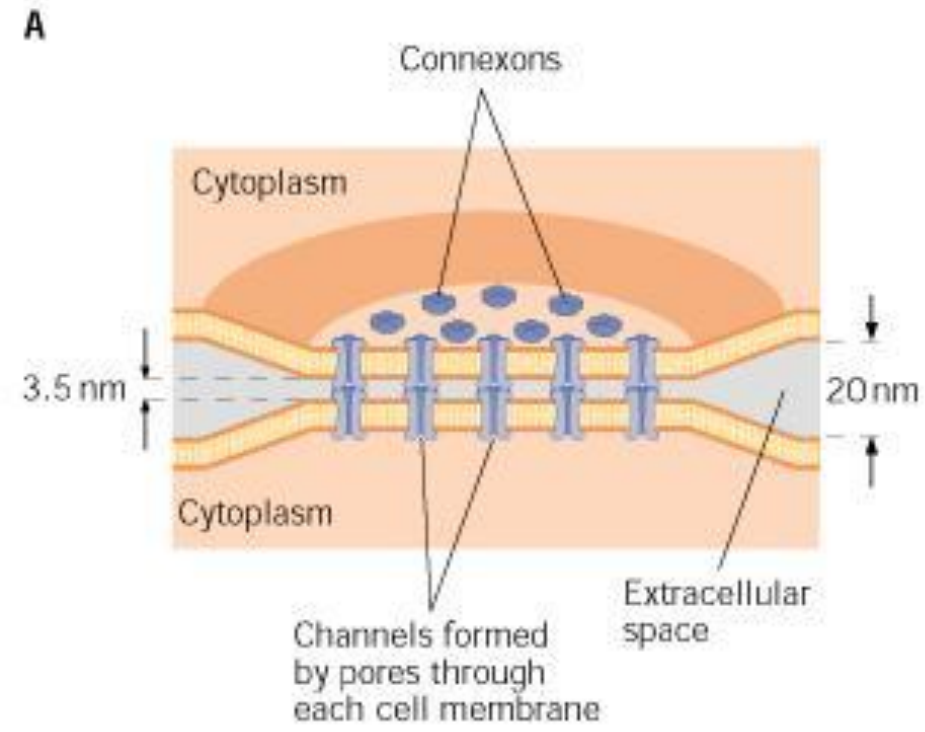
- Varicosity
- Working diffusely rather than locally

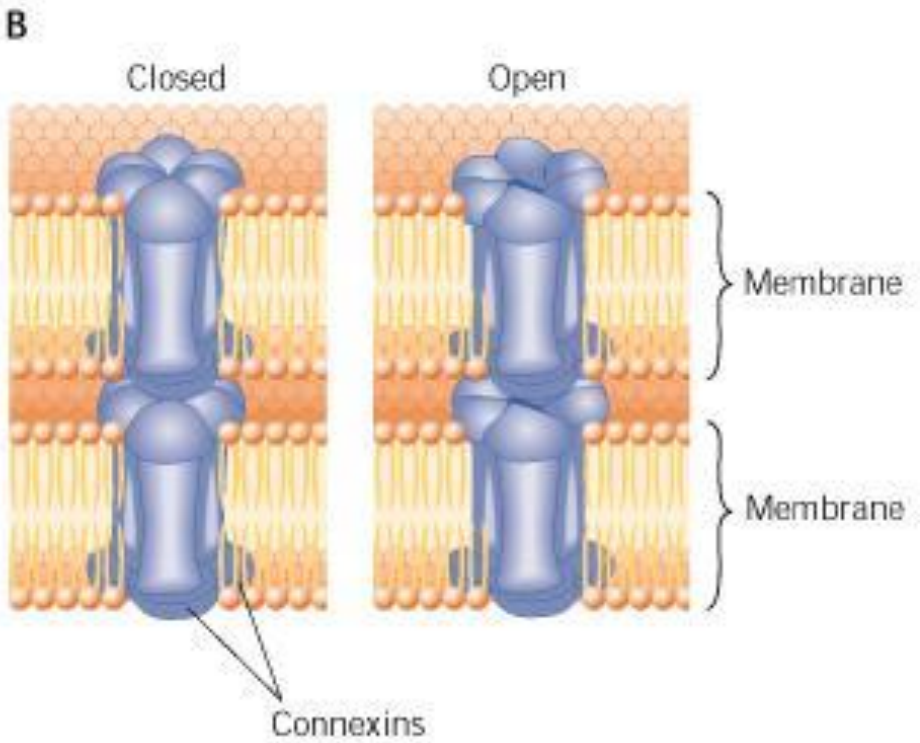


Gap Junction

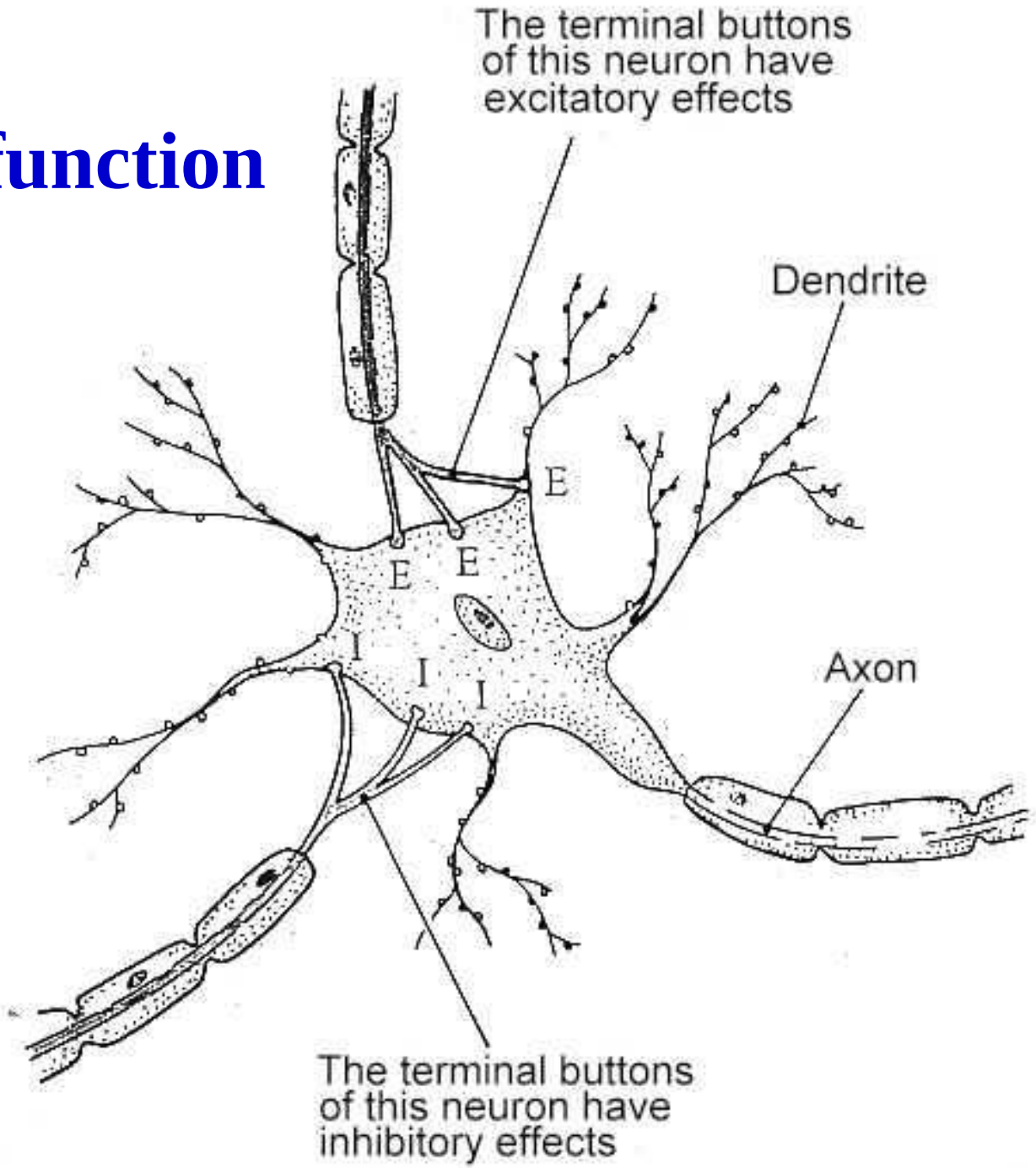
1. Electrical synapses represent cytoplasmic continuity and synchrony among neurons.
2. Molecules <1000 daltons can pass through
3. No synaptic delay -- Rapid communication




A
Connexons
Cytoplasm
3.5 nm
20 nm
Cytoplasm
Extracellular space
Channels formed by pores through each cell membrane


B
Closed
Open
Membrane
Membrane
Connexins

Integrative function of neuron



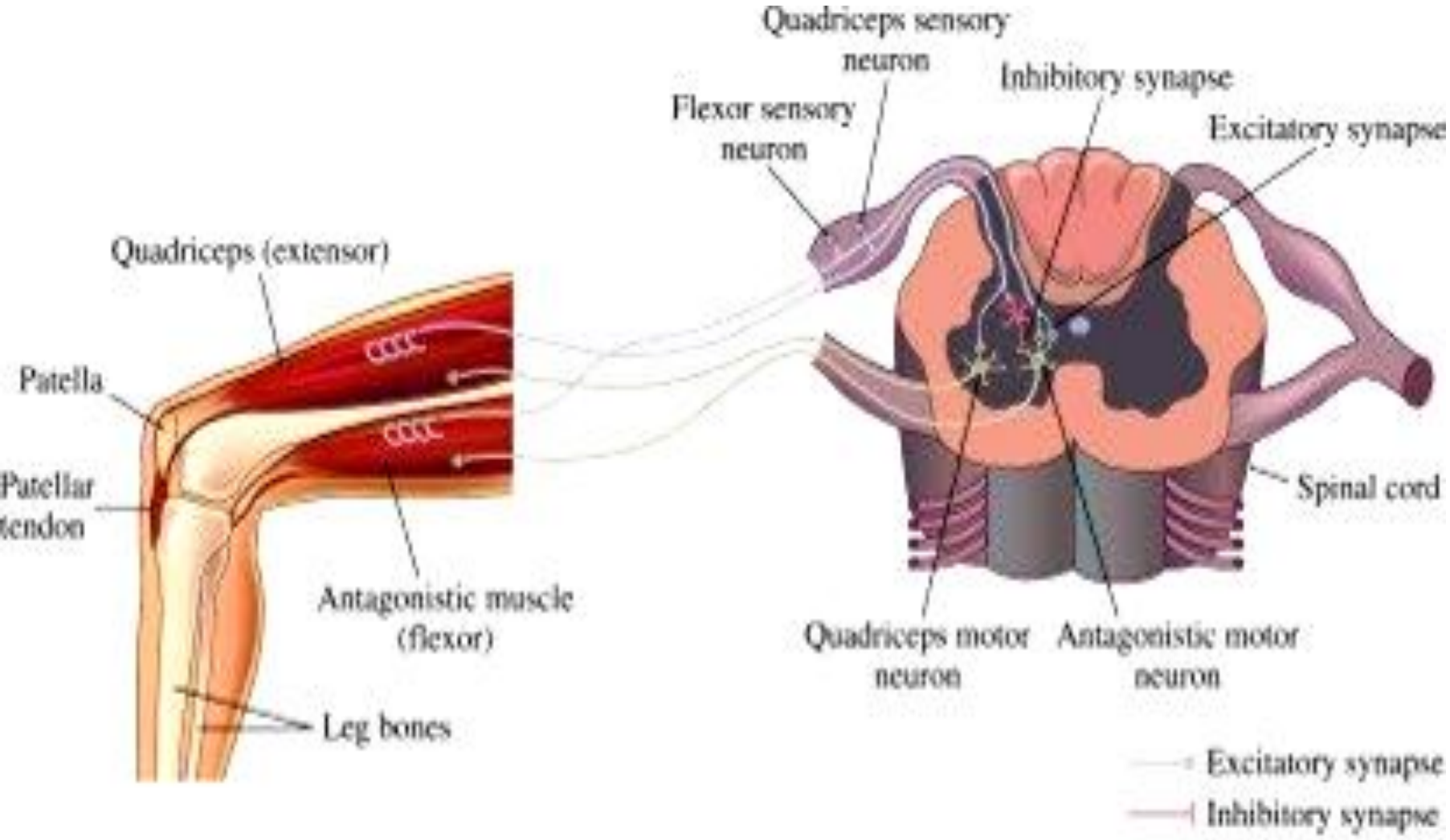
Synaptic Inhibition

- Postsynaptic inhibition:
  - Afferent collateral inhibition
  - Recurrent inhibition
- Presynaptic inhibition

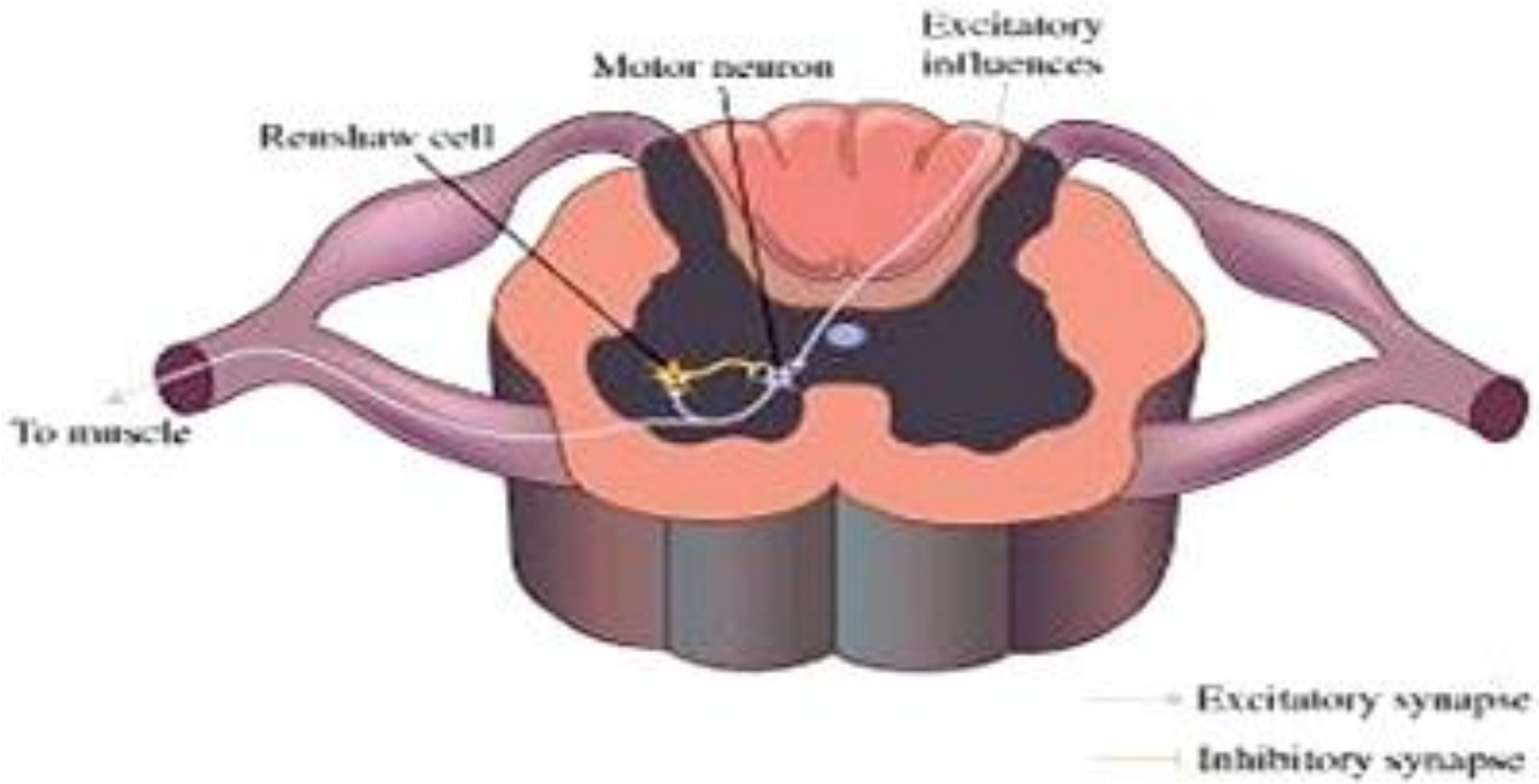
Postsynaptic inhibition

- Involves direct contact between inhibitory synapse and neuron being inhibited
- Typically involves hyperpolarization- **IPSP**
- Inhibitory inter-neuron

Afferent Collateral Inhibition

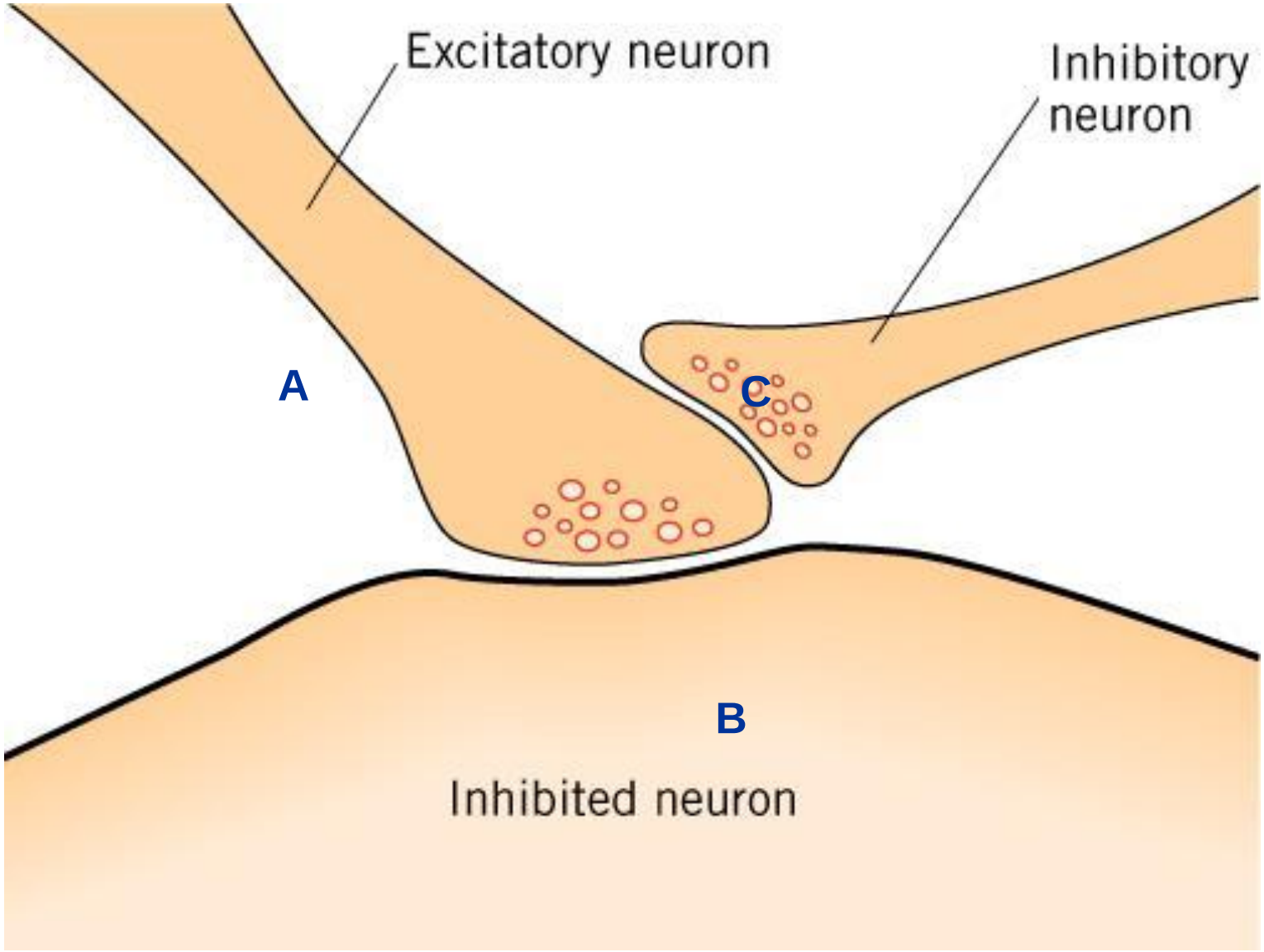


Recurrent Inhibition



Presynaptic Inhibition

- Inhibitory synapse onto presynaptic terminal of excitatory synapse
- Presynaptic inhibition reduces amount of neurotransmitter released from an excitatory terminal, not ability of cell to respond to excitatory input
- Works by reducing Ca^{2+} influx into presynaptic terminal, therefore reducing amount of released neurotransmitter.


Excitatory neuron
Inhibitory neuron
A
C
B
Inhibited neuron

Questions

- Axoplasmic transport
- Excitatory postsynaptic potential
- Inhibitory postsynaptic potential
- Gap junction

- Please describe the steps of synapse transmission.
- What is the central inhibition? Please describe postsynaptic inhibition and presynaptic inhibition .