ANP1105E Anatomy & Physiology I

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Tuesday, September 17, 2013

Topic 2.1 *Neurons, Part 1*

Nervous System Fundamentals. Marieb & Hoehn. 9E. Ch 11

Lecture Content

- ***Topic 2.1. Neurons, Part 2***
  - Marieb & Hoehn. 9E. Chapter 11, *pp* 386-95:
    - Functions/Divisions of Nervous System
    - Histology of Nervous Tissue

Nervous Tissue

- ***Which of these students has "nervous tissue"?***

❑ A

❑ B

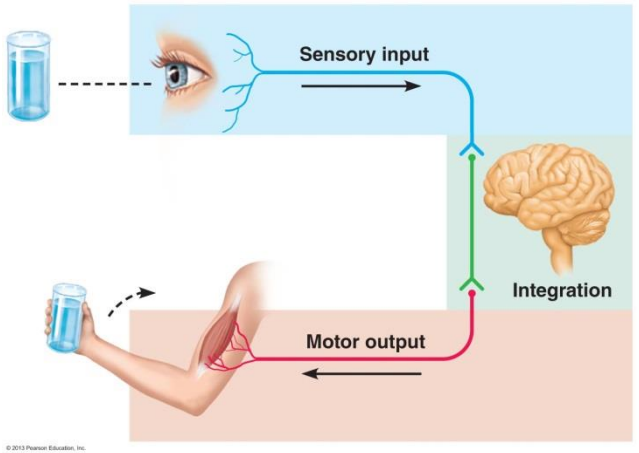
❑ C

❑ D

Functions and Divisions of the Nervous System

Nervous System Functions

- ***Master controlling and communicating system:***
  - Governs *every* thought and action
  - Hundreds of billons of neurons (nerve cells) that communicate *electrically* and *chemically*
    - Rapidly and specifically, with immediate response
  - Three overlapping functions:



1. **Sensory input**
   - Monitor in/outside changes
2. **Integration**
   - Processes/interprets input
   - Decides what should be done
3. **Motor output**
   - Activates effector organs (*eg* muscles, glands), other neutrons, *etc* to cause a response

Nervous System Divisions

- ***One highly integrated system with <u>two parts</u>:***

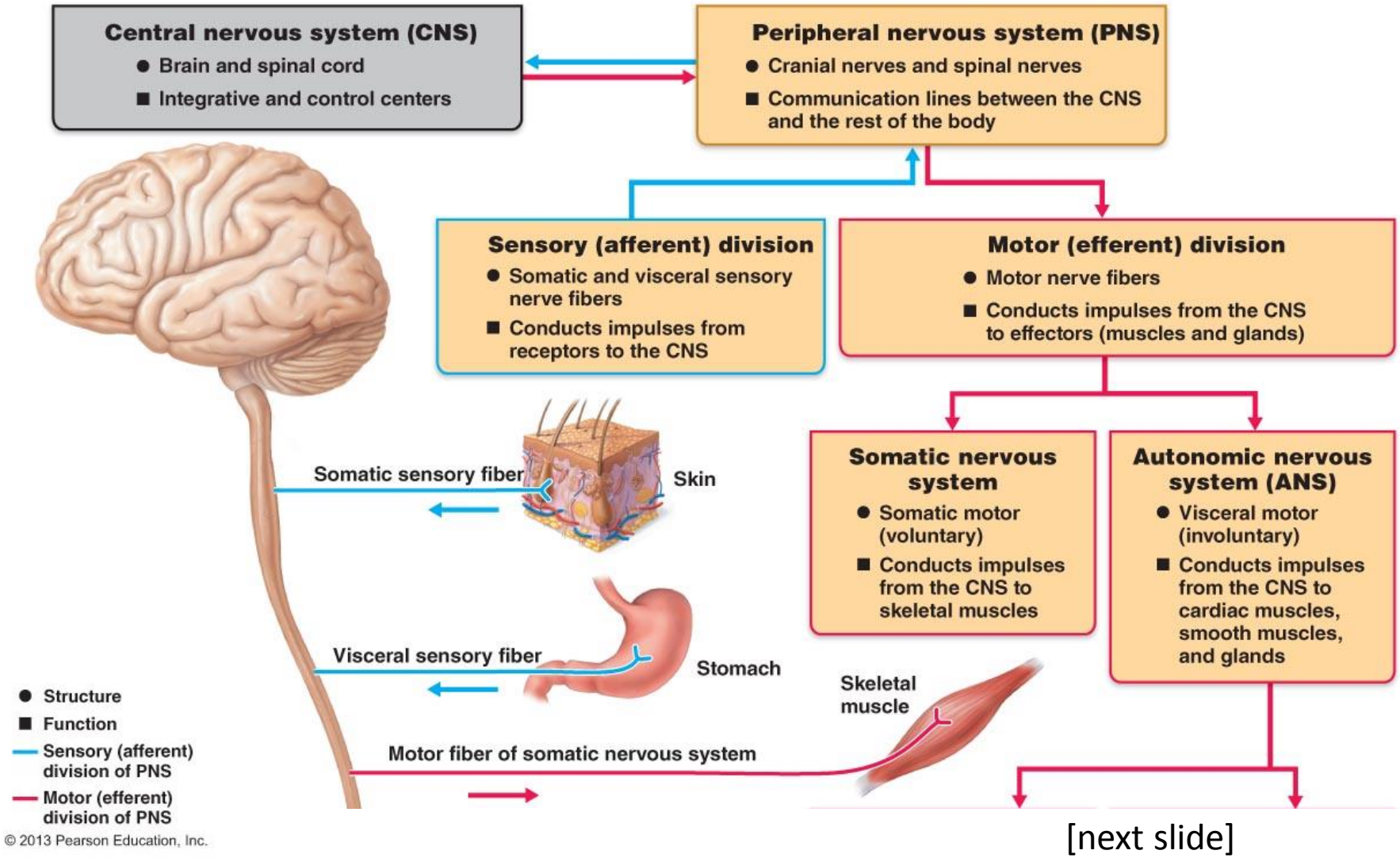
1. Central Nervous System (CNS)

- *Brain*
- *Spinal cord*

2. Peripheral Nervous System (PNS – outside CNS)

- **Sensory/afferent division** ➔ CNS
  - *Somatic sensory fibers*
  - *Visceral sensory fibers*
- **Motor/efferent division** ➔ CNS
  - **Somatic/voluntary nervous system**
  - **Autonomic/involuntary nervous system** (**ANS**)
    - ✓ **Sympathetic division** (Ch 14, ANP1106)
    - ✓ **Parasympathetic division** (Ch 14, ANP1106)

Levels of Organization in Nervous System/1



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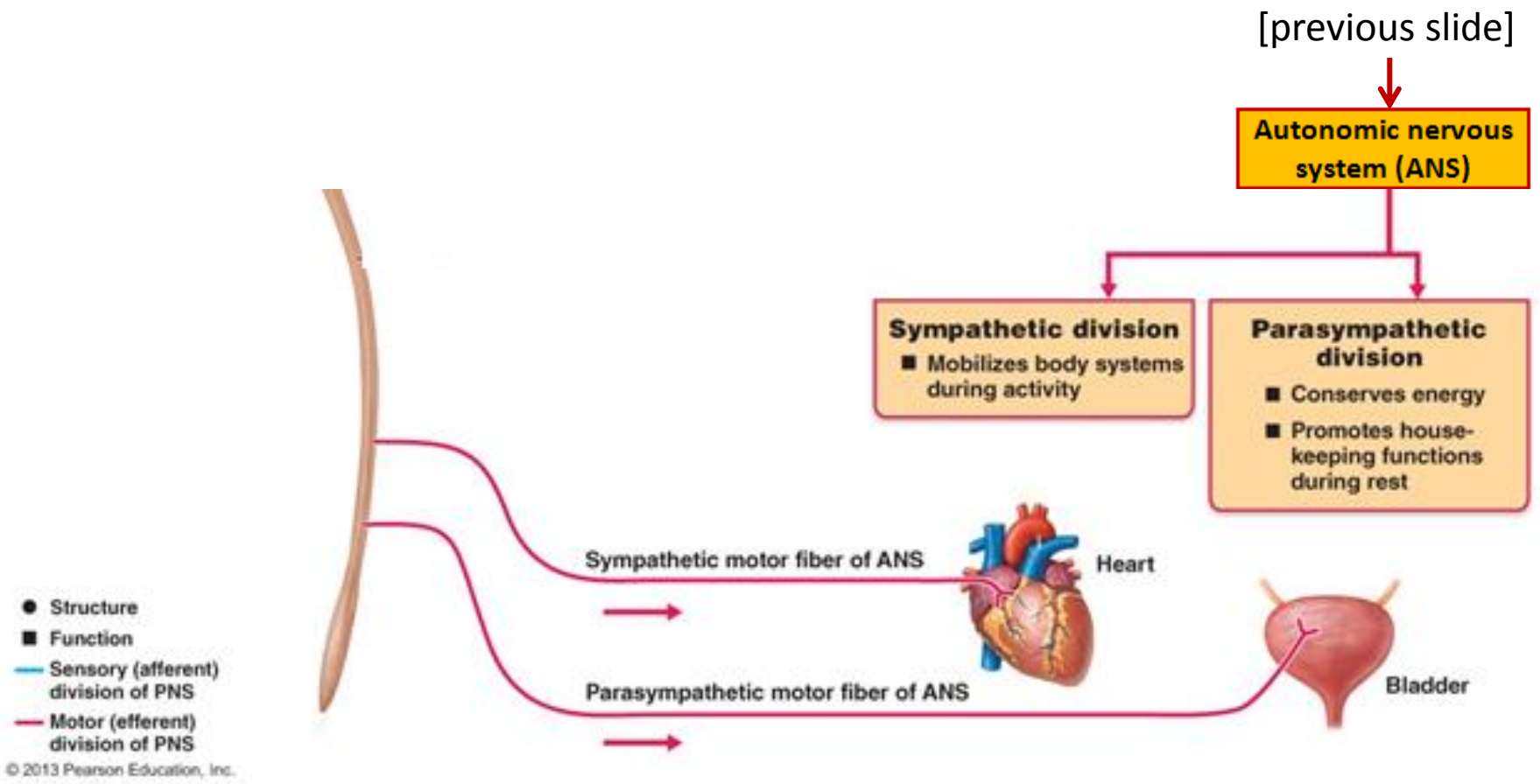
Levels of Organization in Nervous System/2



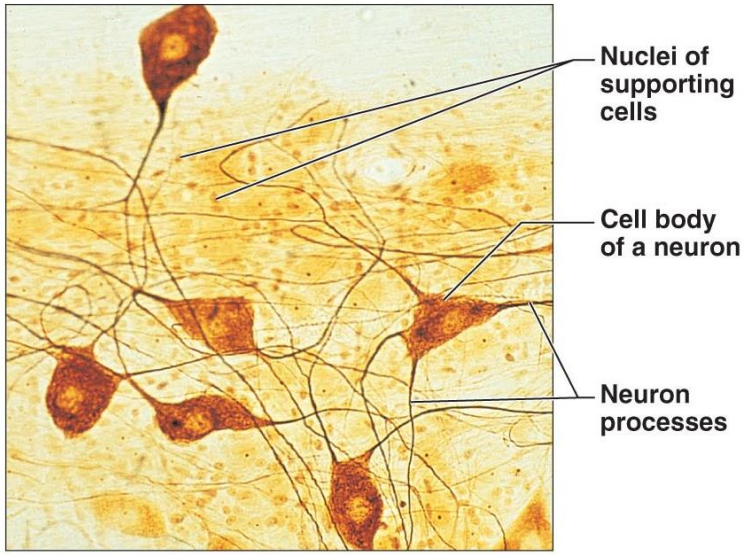
Histology of Nervous Tissue

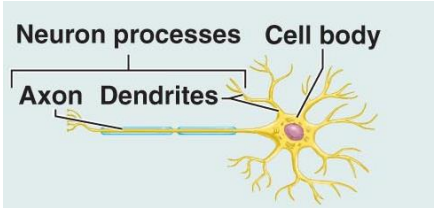
Types of Cells in the Nervous System

- ***Nervous system tissue highly cellular:***
  - < 20% extracellular space
  - Cells densely packed, highly intertwined
- ***Two principal types of cells:***

[1] Neuroglia – supporting cells
- Surround and wrap more delicate neurons

[2] Neurons – actual nerve cells
- **Excitable** – responsive to stimuli
- Transmit electrical signals

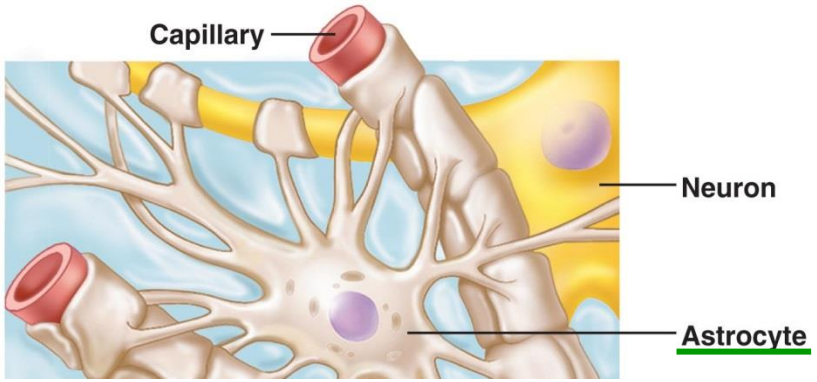


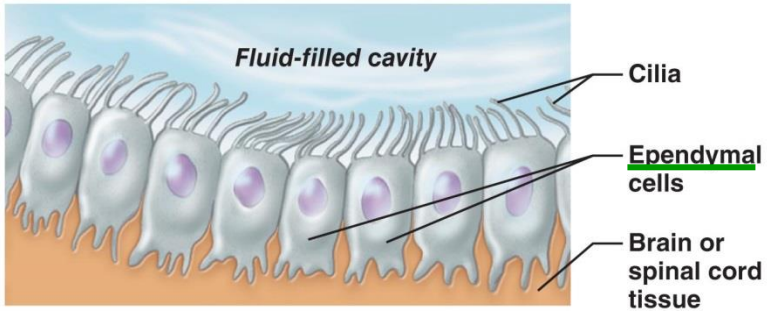


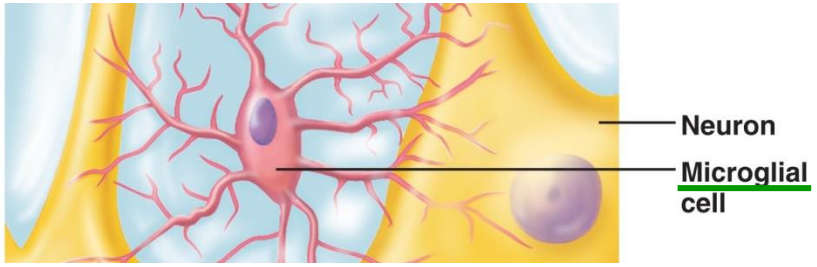
Nervous System Cells: [1] Neuroglia

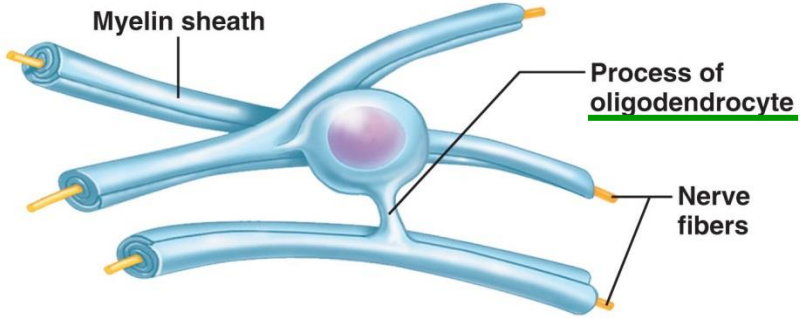
Nervous System Cells: Neuroglia

- ***Central Nervous System* – 4 types:**

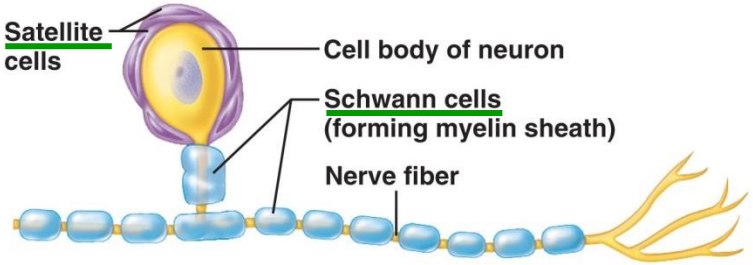






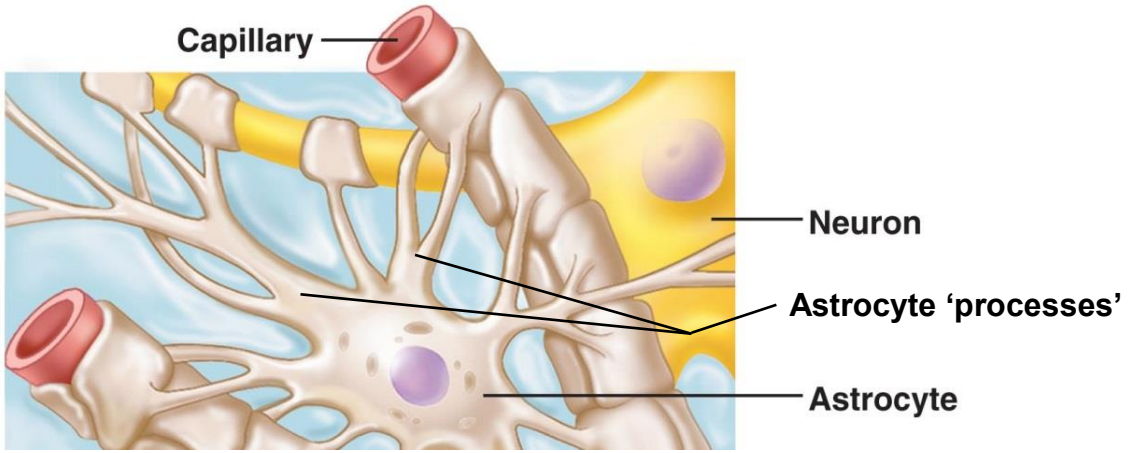


- ***Peripheral Nervous System* – 2 types:**



Central Nervous System Cells: Neuroglia

- ***Astrocytes***
  - Most abundant and versatile glial cells
  - Radiating *processes* cling to neurons/capillaries
  - Support and brace . . . *and* way *more*
  - Determine capillary permeability
    - Play role in capillary/neuron exchange
  - Guide ***migration of young neurons*** and formation of ***synapses*** (junctions) between neurons

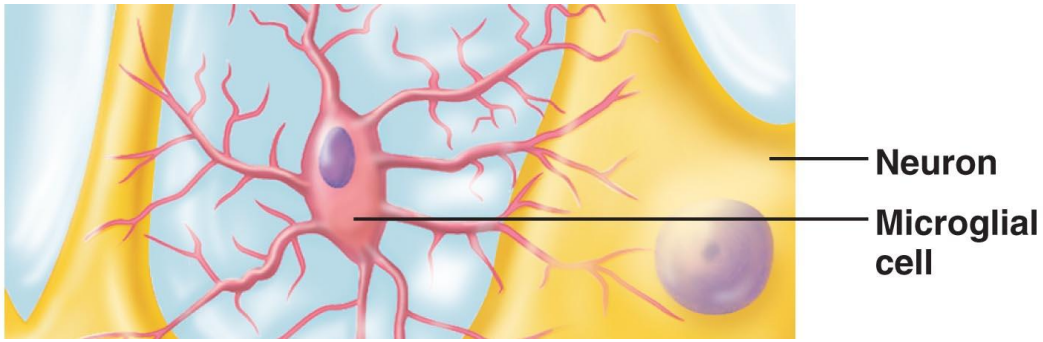


Central Nervous System Cells: Neuroglia

- ***Astrocytes/2***
  - "Mop up" leaked K^+, recycle neurotransmitters
  - Respond to nerve impulses and neurotransmitters!
  - Connected to each other by *gap junctions*
    - Signal to each other by taking in Ca^{++} (➔ intracellular *Ca^{++} waves*) and releasing "extracellular chemical messages"
  - Recent research: influence neuronal functioning
    - Therefore participate in brain information processing

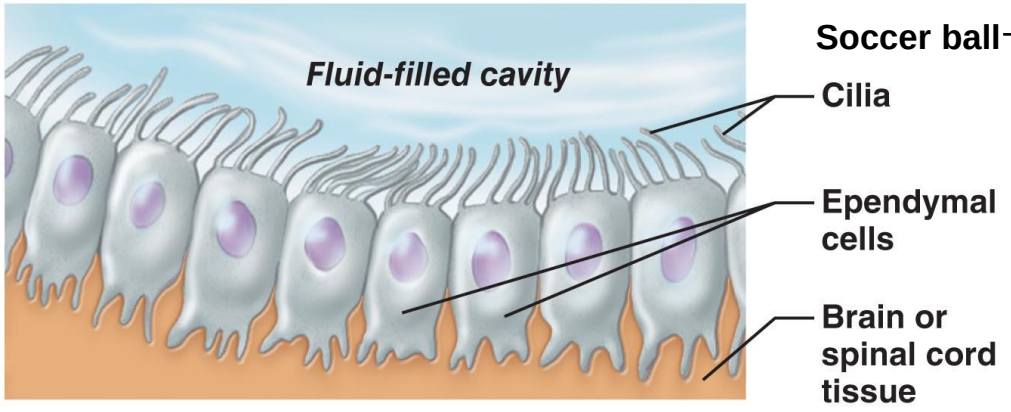
Central Nervous System Cells: Neuroglia

- ***Microglial Cells***
  - Small and ovoid with long "thorny" processes
  - Touch neurons and monitor their health
  - Migrate towards in neurons injured / "in trouble"
    - Become macrophage-like, phagocytize microorganisms / neuronal debris
    - Thus, mimic immune system, which has limited access to CNS



Central Nervous System Cells: Neuroglia

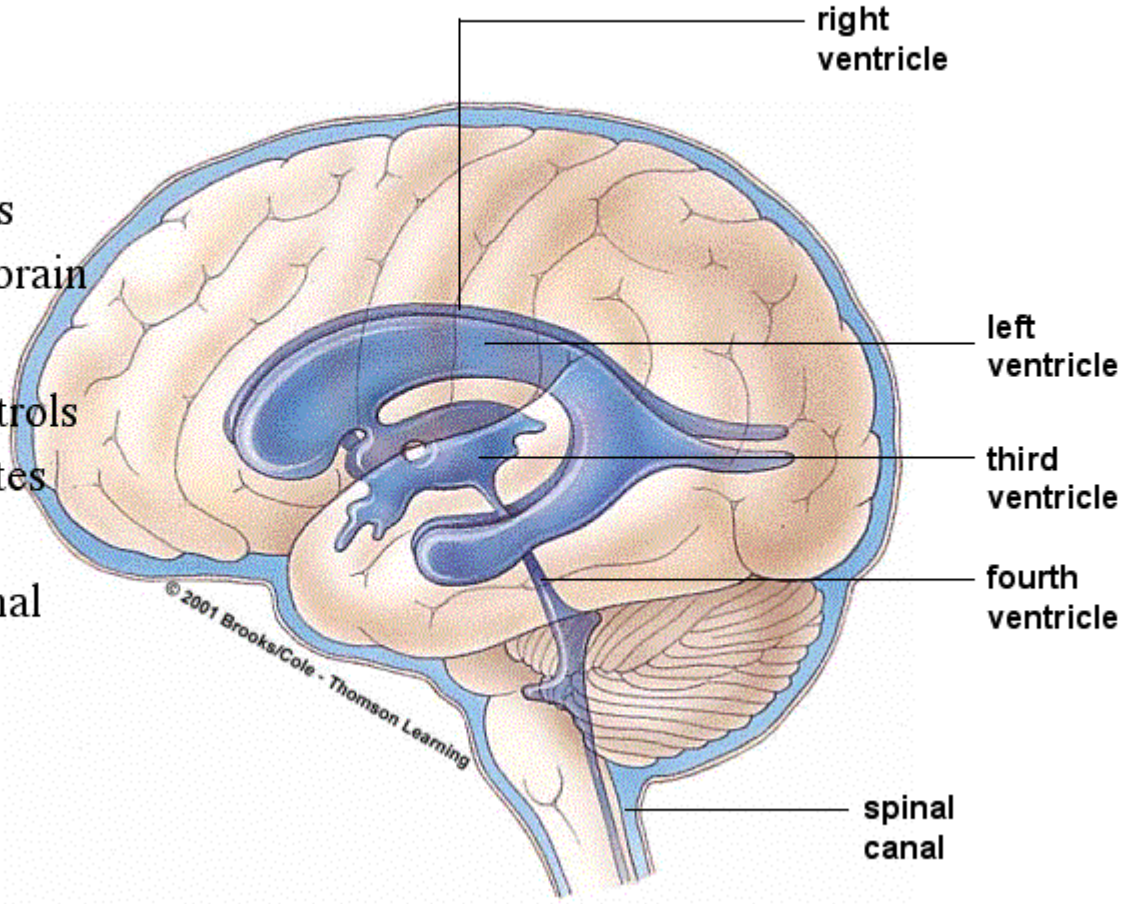
- ***Ependymal Cells***
  - Shape: squamous – columnar. Many ciliated
  - Line central cavities of brain and spinal cord
    - Permeable barrier: *cerebrospinal fluid* (CSF) within cavities **|** tissue that "bathes" CNS cells
  - Beating cilia circulates CSF and cushions brain and spinal cord



Aside: Cerebrospinal Fluid (CSF)

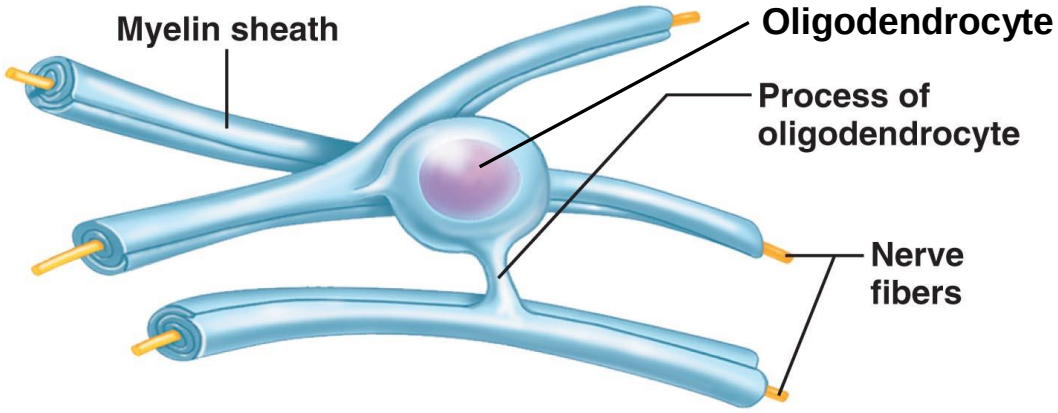
Cerebrospinal Fluid

- Surrounds the spinal cord
- Fills ventricles within the brain
- Blood-brain barrier controls which solutes enter the cerebrospinal fluid



Central Nervous System Cells: Neuroglia

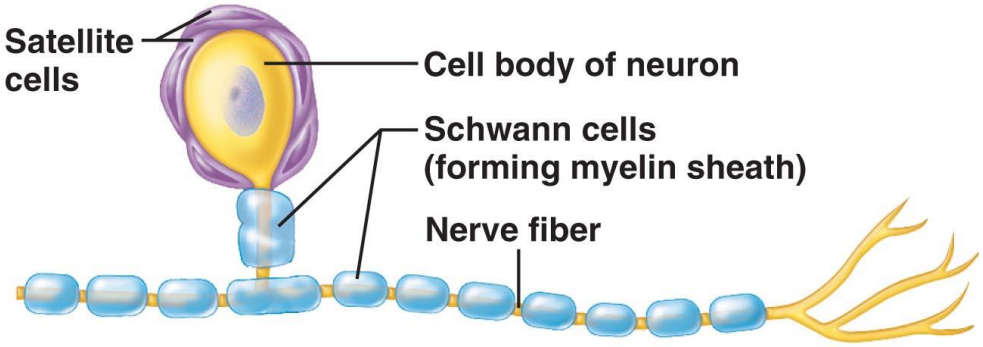
- ***Oligodendrocytes***
  - Branch, but fewer processes than *eg* astrocytes
  - Line up along thicker nerve fibers in CNS
  - Processes wrap tightly around fiber, form a protective cover (***myelin sheath****)



* See slides 31-33

Peripheral Nervous System Cells: Neuroglia

- ***Satellite Cells***
  - Surround cell bodies in PNS
  - Many of same functions as astrocytes in CNS
- ***Schwann Cells***
  - Surround all nerve fibers in PNS
  - Form myelin sheaths* around thicker fibers – analogous to oligodendrocytes in CNS
  - Vital to regeneration of damaged peripheral nerves



* See slides 31-33

Nervous System Cells: [2] Neurons

Neurons

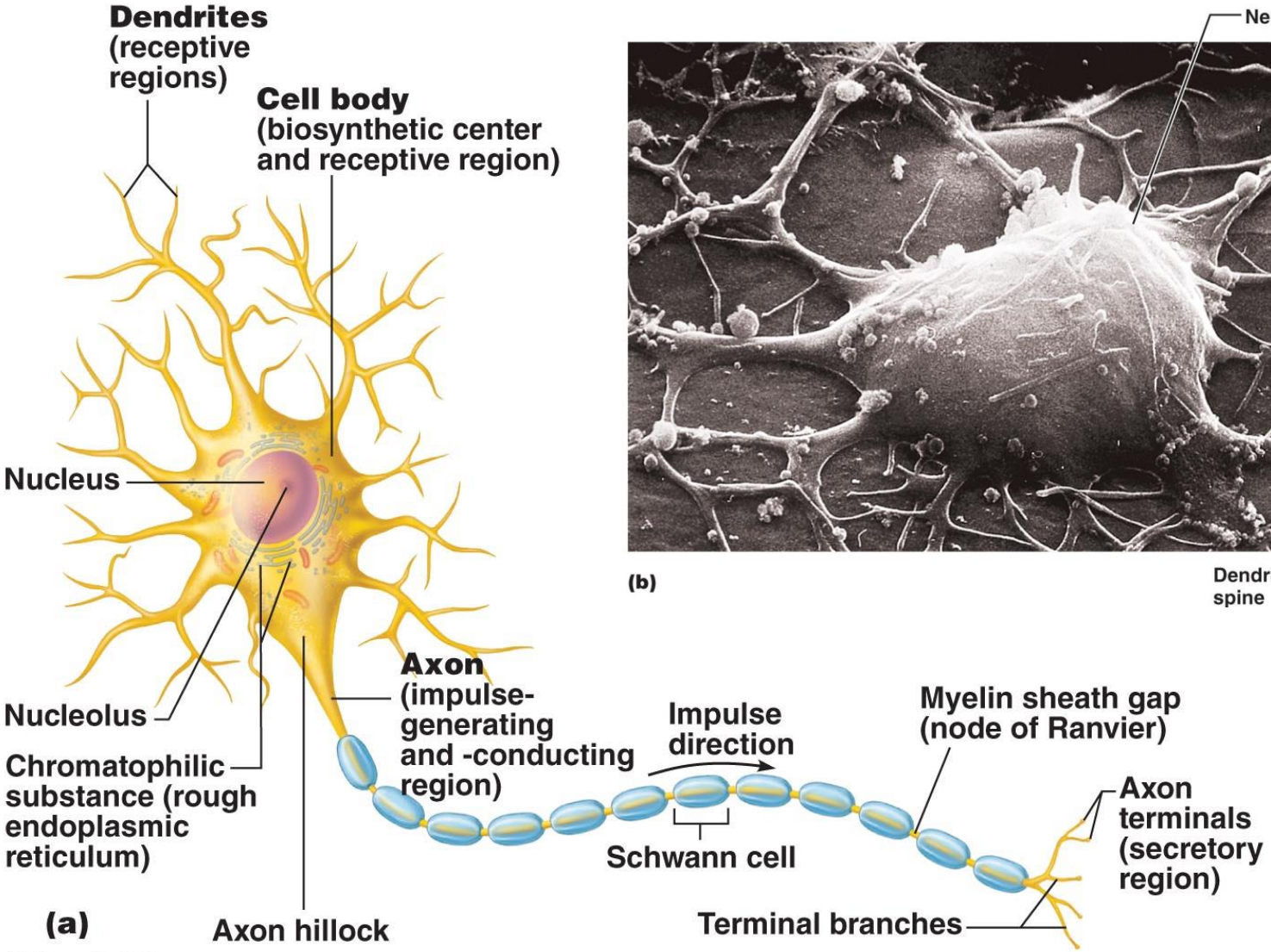
- ***Characteristics of neurons / aka nerve cells:***
  - Number in the hundreds of billions
  - Large
  - Highly specialized structural units of nervous system
  - Conduct messages – nerve impulses – through body
  - Three special properties:

    1] Extreme longevity
    - Can function optimally over a >100 yr lifetime

    2] *Amitotic*: cannot divide / be replaced if destroyed
    - Exceptions: olfactory epithelium, hippocampus (memory) have stem cells

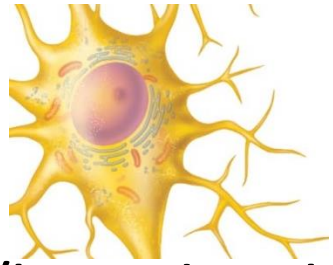
    3] Exceptionally high metabolic rate
    - Demand O_2/glucose <u>continuously</u>
    - Cannot survive for > few minutes without O_2

Prototype Structure: Motor Neuron

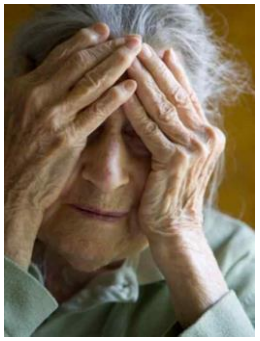


Nerve Cell Body [*aka* Perikaryon / Soma]

- ***Components:***



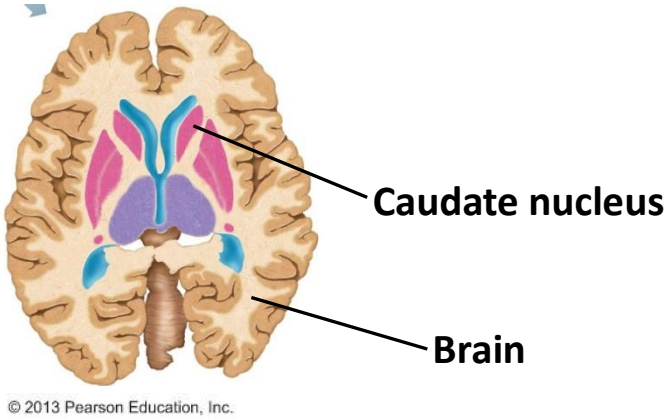
  - Nucleus/nucleolus/cytoplasm
  - Cell body (5-140 µm)
  - Protein synthesis most active/best developed in body:
    - Ribosomes, rough ER ('***chromatophilic substance***/ *Nissl bodies*'), Golgi apparatus
  - Mitochondria scattered throughout
  - Microtubules/**neurofibrils** (*neurofilament* bundles) network: cell shape/integrity

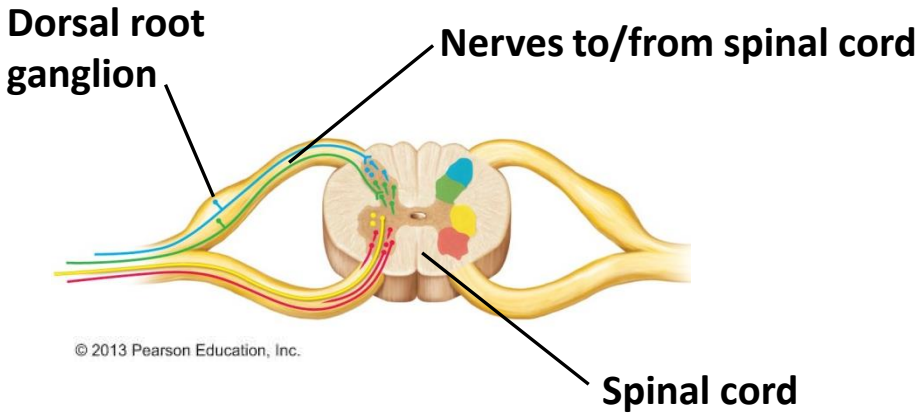


  - Pigment inclusions: melanin, red-Fe, *lipofuscin* (aging)
  - Plasma membrane helps receive other neuron info

Terminology

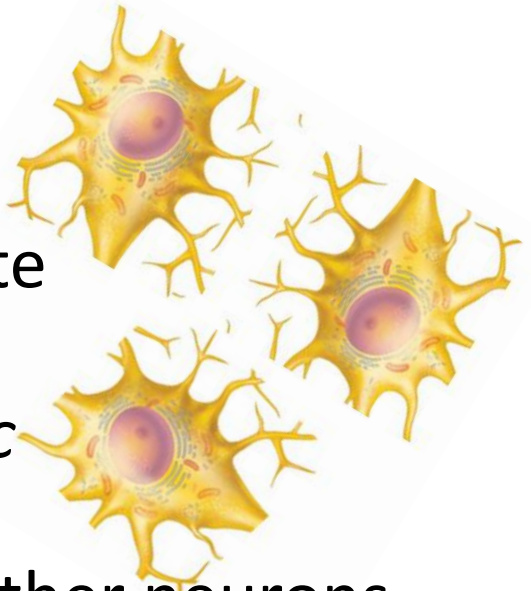
- ***Clusters of cell bodies:***
  - CNS "**Nuclei**"
  - PNS "**Ganglia**"





- ***Bundles of nerve processes:***
  - In CNS "**Tracts**"
  - In PNS "**Nerves**"

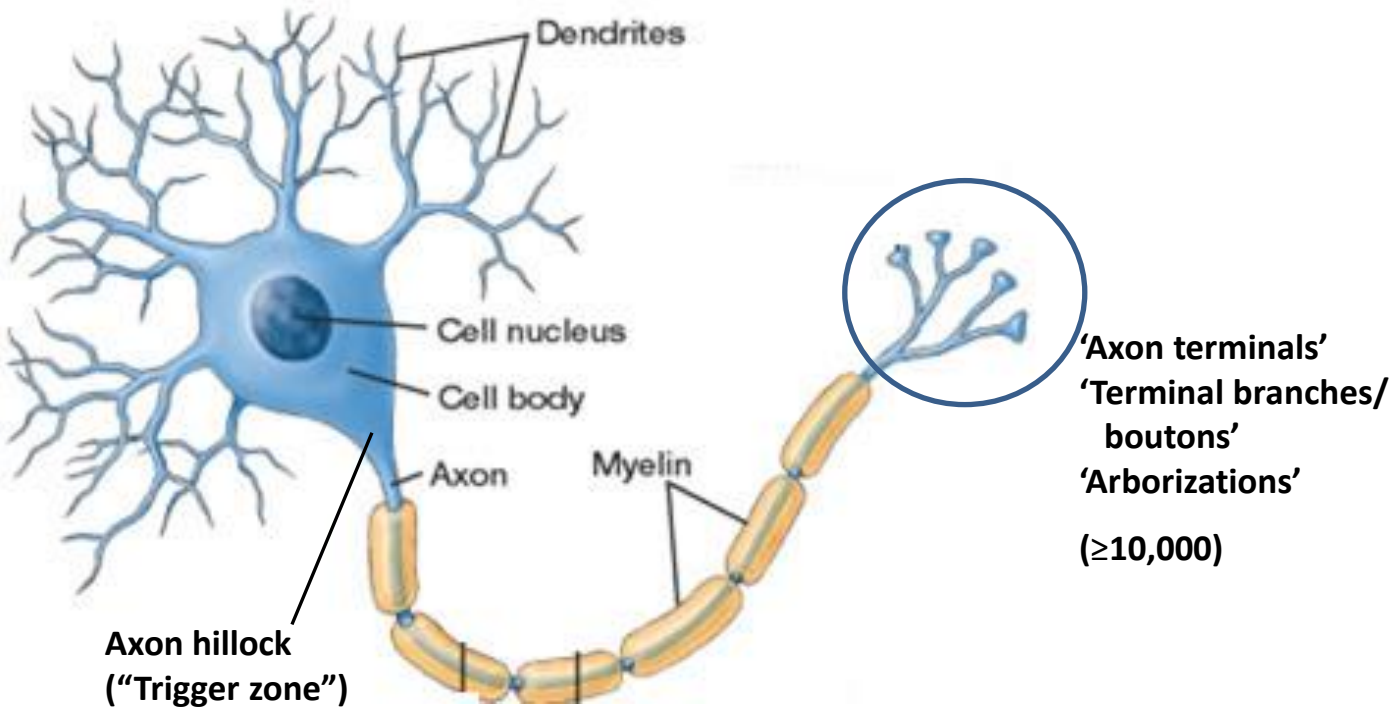
Neuron Processes: Dendrites



- ***Dendrites:***
  - Short, tapering, diffusely branched
  - All cell body organelles also in dendrite
  - Typically hundreds per neuron
    - In brain, bristle with tiny *dendritic spikes*
  - In close proximity *via* synapses with other neurons
  - Main **receptive** or **input region** for neuron
    - Enormous surface area for receiving signals
  - Convey incoming messages *towards* cell body
    - *Via* **graded potentials**, not **action potentials** (Friday Sep 20)

Neuron Processes: Axons

- ***Axon Structure:***
  - Each neuron has a single axon (and many dendrites)
    - Branches (not shown) call '***axon collaterals***'
  - Length varies: absent – 1 metre (spine ➔ toe)
    - Long axon called a '***nerve fiber***'



Neuron Processes: Axons

- ***Axon Functional Characteristics:***
  - **Conducting region** of neuron
  - *Generates/transmits nerve impulses* away from cell
    - Along plasma membrane (‘***axolema***’)
    - From *trigger zone* to terminal ***secretory region***
  - Impulse reaches terminal: *neurotransmitters* released
    - “Signalling chemicals” stored in vesicles
  - NTs enter extracellular space (*synapse*). Excite/inhibit nearby *effector neurons*-bind to *postsynaptic receptor*
  - Signals for neuron received from/ transmitted to many others: “multiple simultaneous conversations”
  - Axon lacks rough ER/Golgi: cell body must synthesize required proteins and transfer them along axon

“typically”

Aside: Neurotransmitters / Synapse

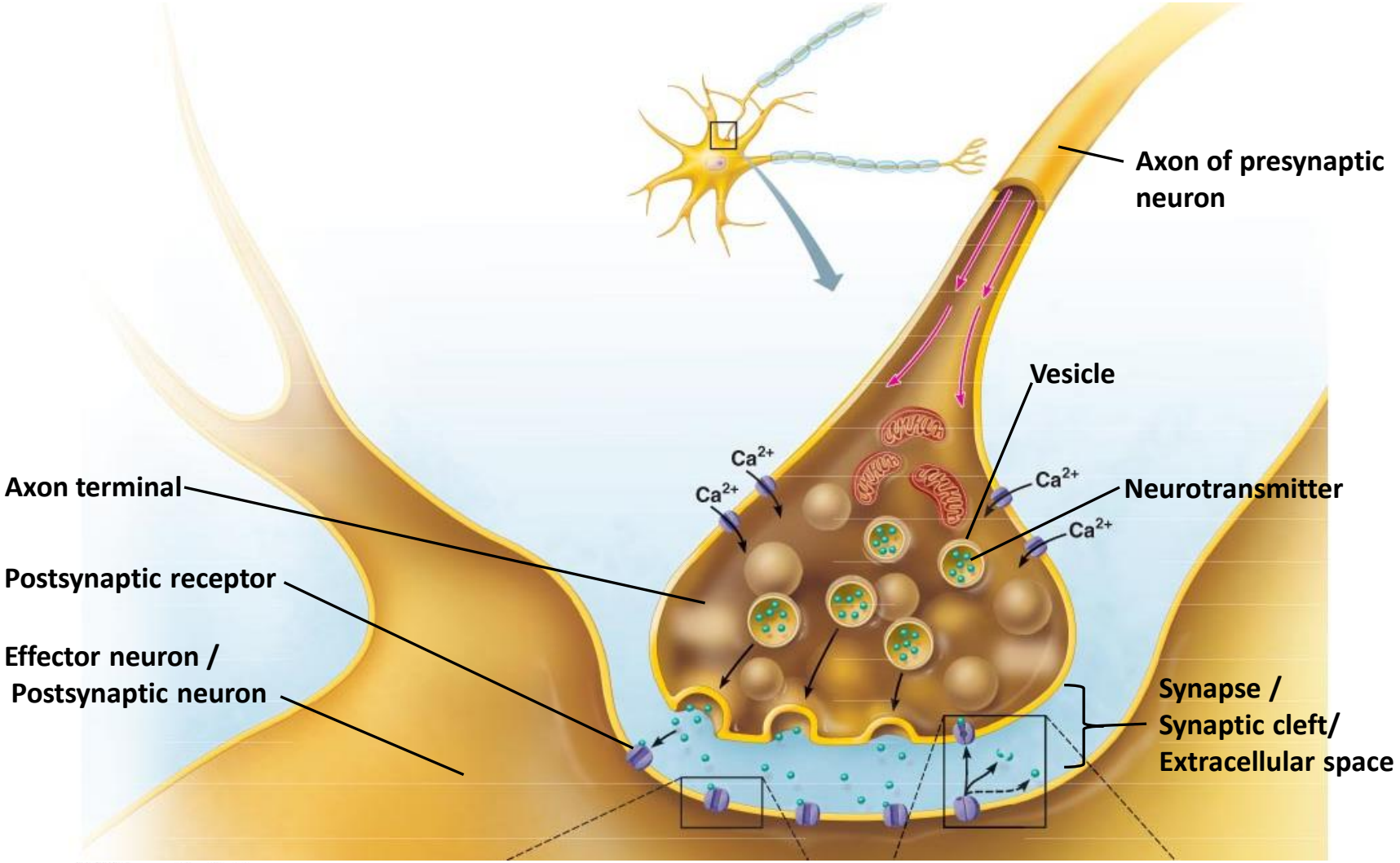


Figure 11.17 (Sept 24)

Neuron Processes: Axons

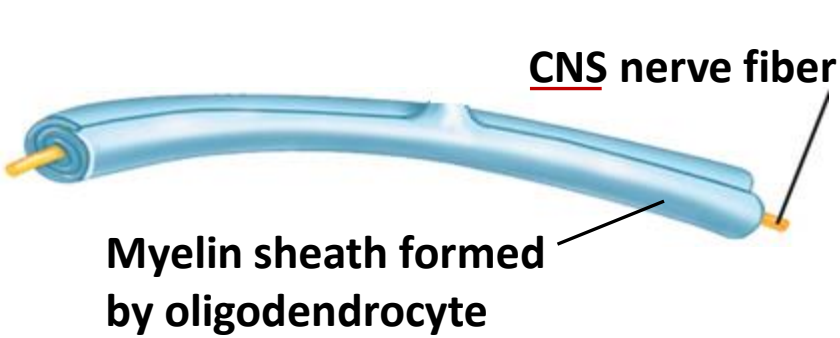
- ***Transport along the axon:***
  - *Anterograde movement* away from cell body:
    - Mitochondria, cytoskeletal elements, membrane components, enzymes to make NTs, certain NTs
  - *Retrograde movement* towards cell body:
    - Organelles for recycling, vesicles with signal molecules (*eg nerve growth factor* that activates nuclear genes), info on axon terminal condition
  - Uses ATP-dependent motor proteins *kinesin* / *dynein*
    - Components move along microtubules 40 cm/day

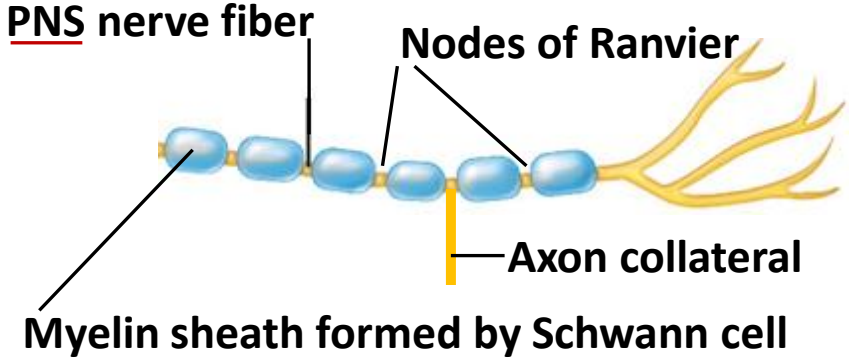
Neuron Processes: Axons

- ***Retrograde transport 'hijacked':***
  - 'Bad viruses' (polio/rabies/herpes viruses), tetanus toxin reach (and destroy) cell body *via* retrograde transport
  - 'Good viruses' transport "corrected genes" to cell body *via* retrograde transport and insert into DNA, or transport microRNA to suppress defective genes
    - Investigational treatments for certain genetic diseases

Neuron Processes: Myelin Sheath

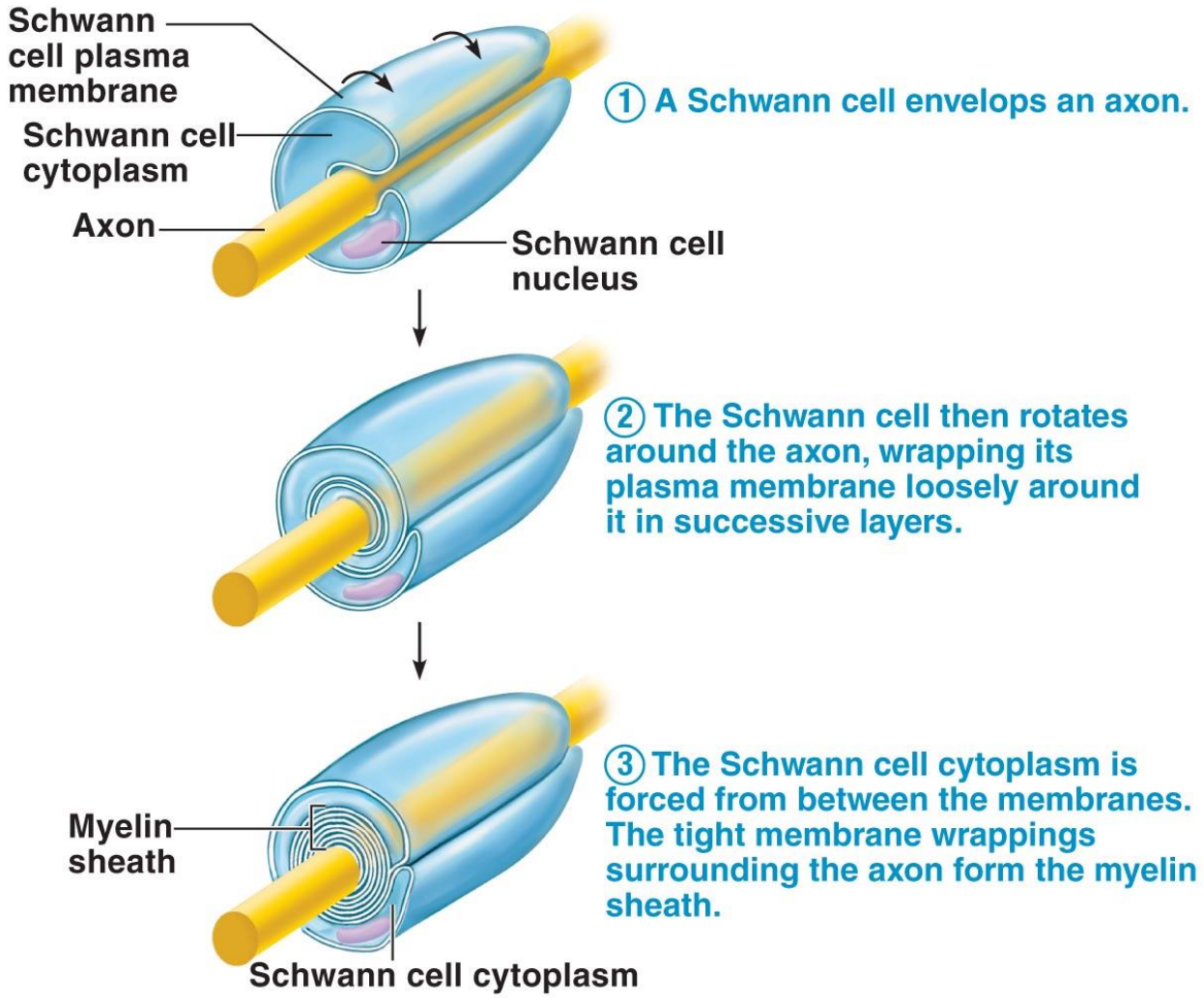
- ***Myelin Sheath:***
  - Many nerve fibres in CNS/PNS, especially larger / longer ones, covered with segmented myelin sheath
  - Composition: lipids + proteins
  - Functions:
    - Protects
    - Electrically insulates
    - Increases speed of nerve transmission
  - Axons form myelinated fibers/dendrites nonmyelinated





Neuron Processes: Myelin Sheath

Myelination of a Nerve Fibre in the PNS



Neuron Processes: Myelin Sheath

- ***Myelin Sheath Proteins:***
  - Plasma membranes of myelinating cells lack carrier and channel proteins ➔ very good insulators
  - Velcro-like proteins interlock between adjacent layers
- ***PNS/CNS Differences:***
  - PNS
    - Typically, 1 Schwann cell wraps 1 axon
    - Can loosely enclose ≥15 thin fibers–'nonmyelinated'
  - CNS
    - Often, 1 oligodendrocyte wraps up to 60 fibres
    - Cytoplasm/nucleus on <u>inside</u> (cf ❸ previous slide)
    - *White matter*: dense collections of myelinated fibers
    - *Grey matter*: nonmyelinated fibers/nerve cell bodies

Classification of Neurons

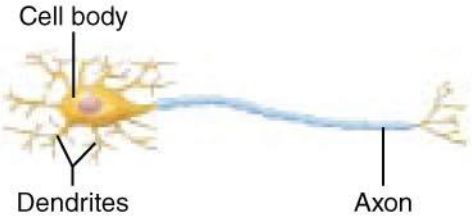
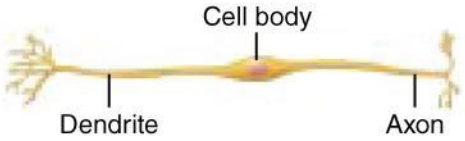
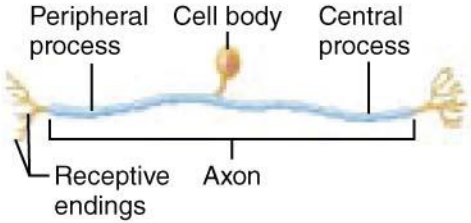
- ***Structural Classification:***
  - Multipolar neurons (99%): 1 axon/many dendrites
  - Bipolar neurons: 1 axon/1 dendrite
  - Unipolar neurons: 1 process: axon + "receptive" axon

dendrite ???

- ***Functional Classification:***
  - Sensory neurons : impulses ➔ CNS
  - Motor neurons: impulses CNS ➔
  - Interneurons: lie between motor/sensory neurons

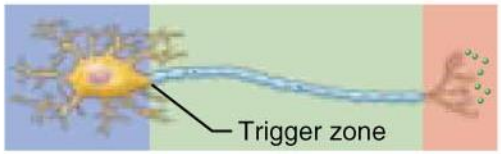
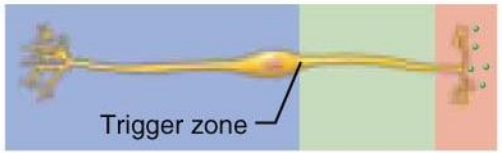
Classification of Neurons

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		
Many processes extend from the cell body. All are dendrites except for a single axon.	Two processes extend from the cell body. One is a fused dendrite, the other is an axon.	One process extends from the cell body and forms central and peripheral processes, which together comprise an axon.
		

Classification of Neurons

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

	NEURON TYPE	
MULTIPOLAR	**BIPOLAR**	**UNIPOLAR (PSEUDOUNIPOLAR)**
Relationship of Anatomy to the Three Functional Regions		
Receptive region (receives stimulus). Conducting region (generates/transmits action potential). Secretory region (axon terminals release neurotransmitters). 	 (Many bipolar neurons do not generate action potentials. In those that do, the location of the trigger zone is not universal.)	

Classification of Neurons

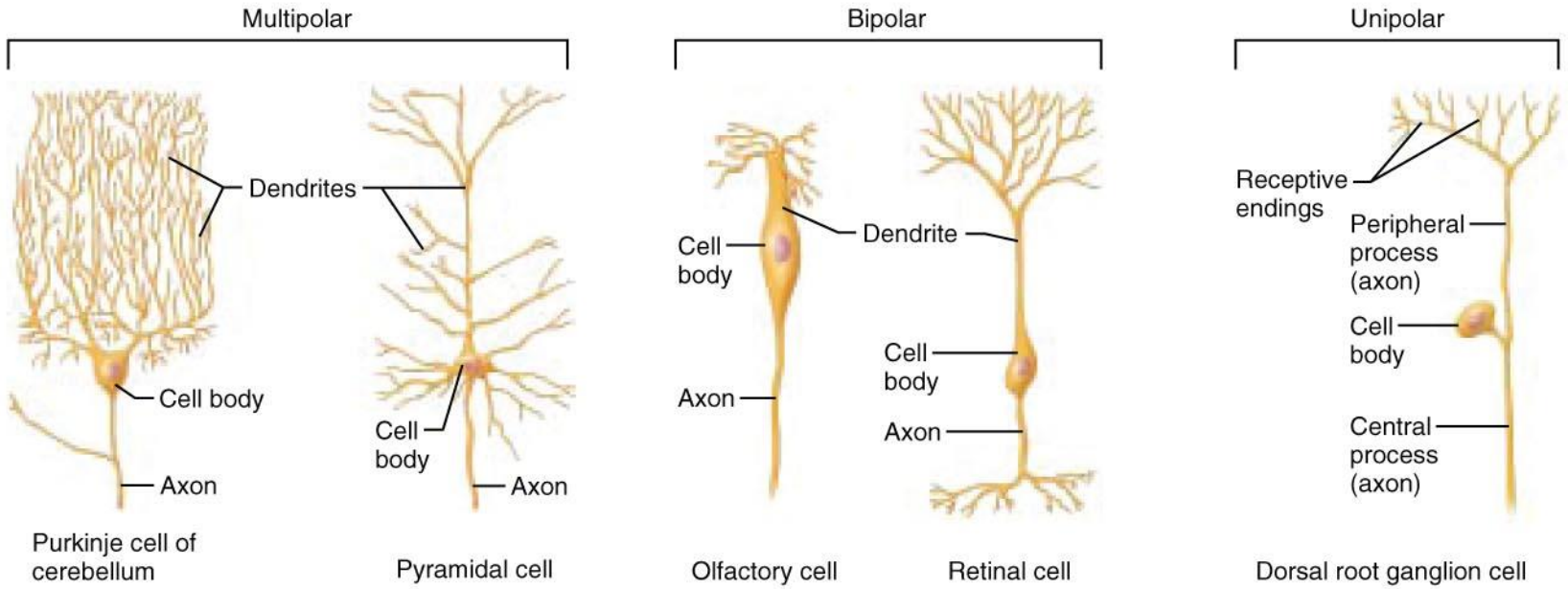
Table 11.1 Comparison of Structural Classes of Neurons *(continued)*

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.

Classification of Neurons

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

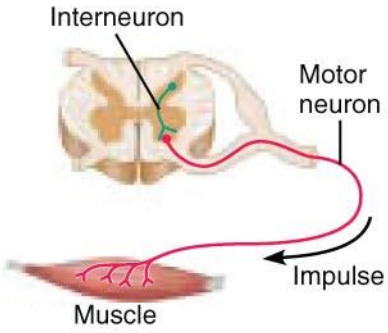
	NEURON TYPE	
MULTIPOLAR	**BIPOLAR**	**UNIPOLAR (PSEUDOUNIPOLAR)**
Structural Variations		

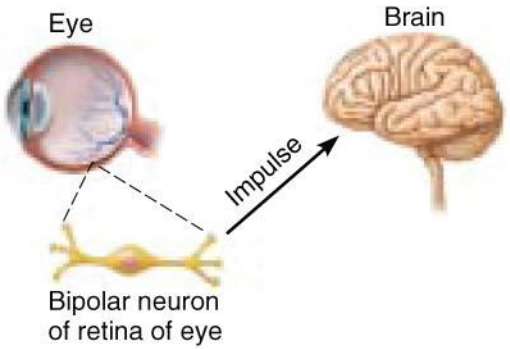


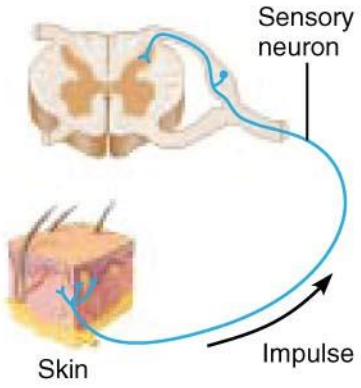
Classification of Neurons

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** 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 transmitting 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.)







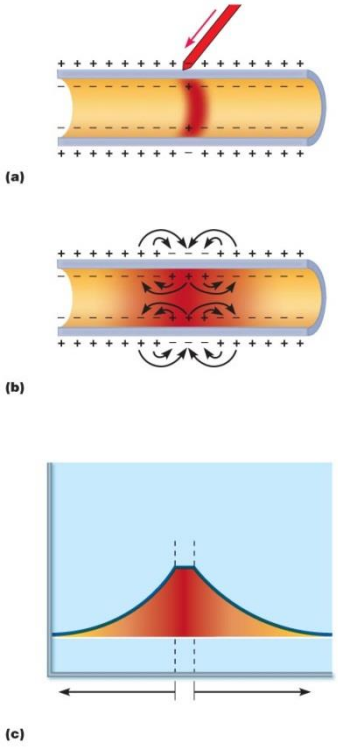
Assignment #3

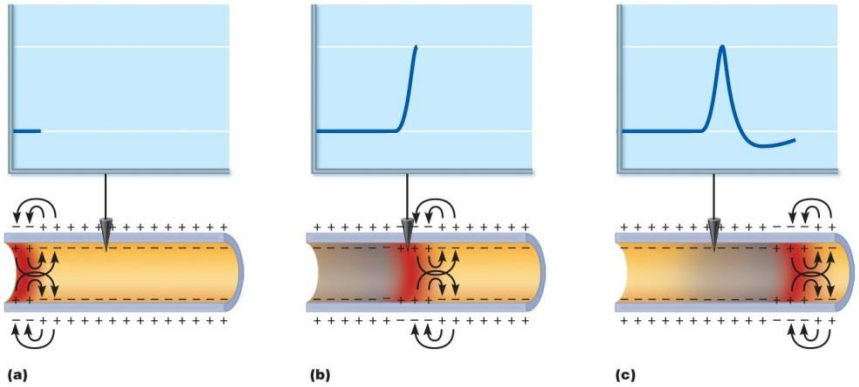
- ***Topic:***
  - Neurons (Sep 17, 21, 24, 27[First Half])
- ***Available:***
  - Friday Sep 27 at ~10 PM
- ***Due:***
  - Wednesday, Oct 2 at 11:59 PM

Had been Monday, Sep 30

Material for Next Lecture – Fri Sep 20

- ***Topic 2.1. Neurons, Part 2***
  - Marieb & Hoehn. 9E. Chapter 11, *pp* 395-407:
    - Membrane Potentials





Mentoring

- ***Faculty of Health Sciences Mentoring***

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  - Study group for ANP1105
  - Mentor will speak to us briefly on Friday Sep 20

- ***Faculty of Medicine Mentoring***

http://altitudementoring.ca/

  - 1-on-1 mentoring with a medical student
  - Mentor spoke to ANP1105B on Sep 4