

M U N I

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3

Intracranial compartment, Cellular base of nervous system

Compartmentalization

- Cellular specialization leads to compartmentalization on several levels
 - Tissue level
 - Organ level
 - Organ system level
- There are barriers in between compartments
- Properties/content may vary among different compartments

Compartmentalization

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 - Organ level
 - Organ els
- There are
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The brain homeostasis is maintained within a narrow range thanks to hematoencephalic barrier and astrocyte activity

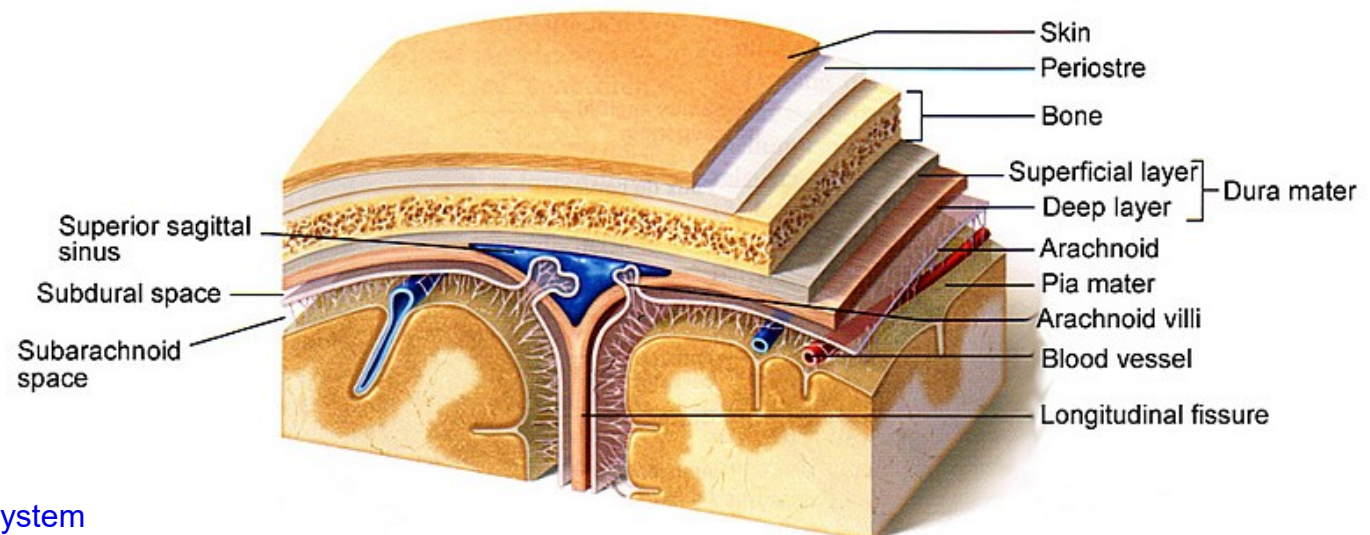
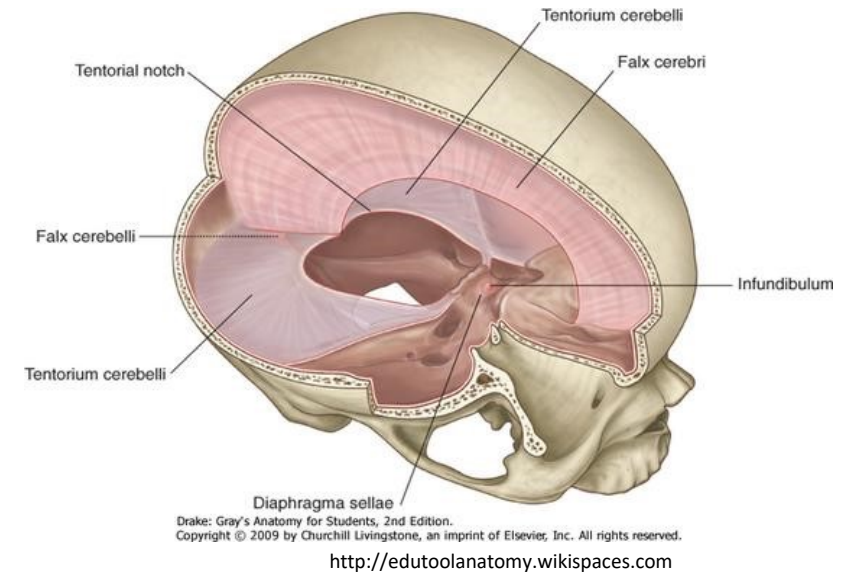
Compartmentalization

- Cellular specialization leads to compartmentalization
 - Tissue level
 - Organ level
 - Organ system level
- There are barriers between compartments
- Properties/capabilities vary among different compartments

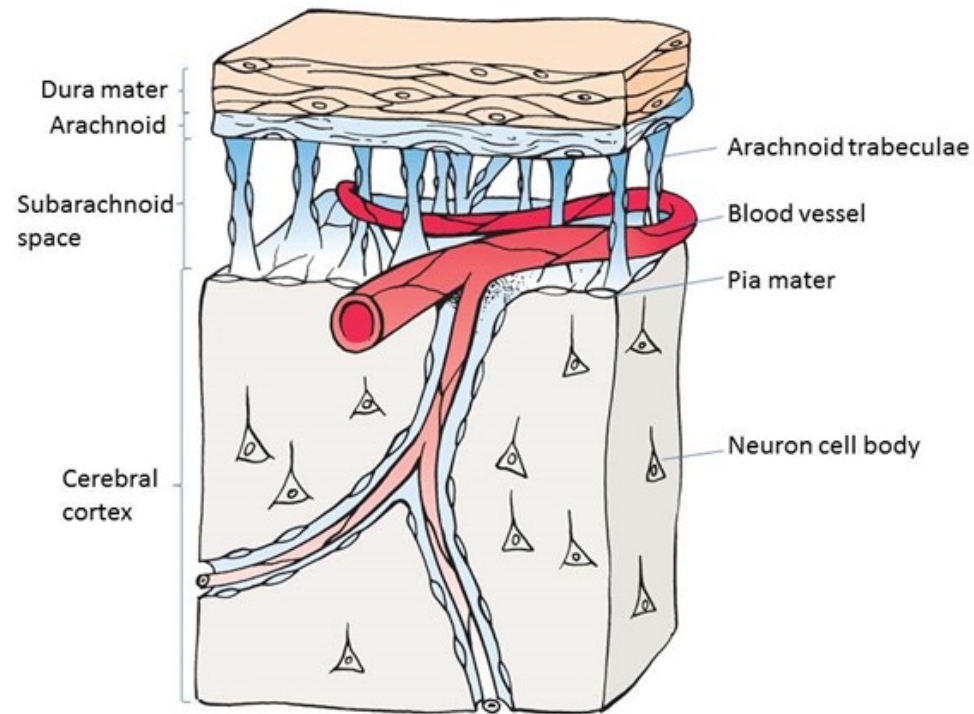
The brain homeostasis is maintained within a narrow range thanks to hematoencephalic barrier and astrocyte activity
This allows neuronal cells to live for the entire life of the individual

Intracranial compartment

- ✓ „Very specific region“
- ✓ Brain
- ✓ Cerebrospinal fluid
- ✓ Blood (intravascular)
- ✓ Barriers
 - Meningeal
 - Hematoliquor
 - Hematoencephalic

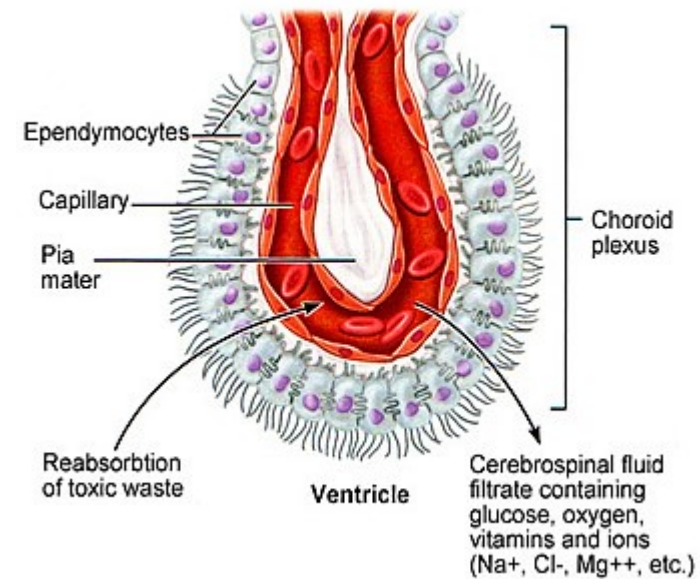


Meningeal and hematoliquor barrier



Adopted from: M.H.Ross and W. Pawlina. Histology: a text and atlas, Lippincott Williams & Wilkins, 2011

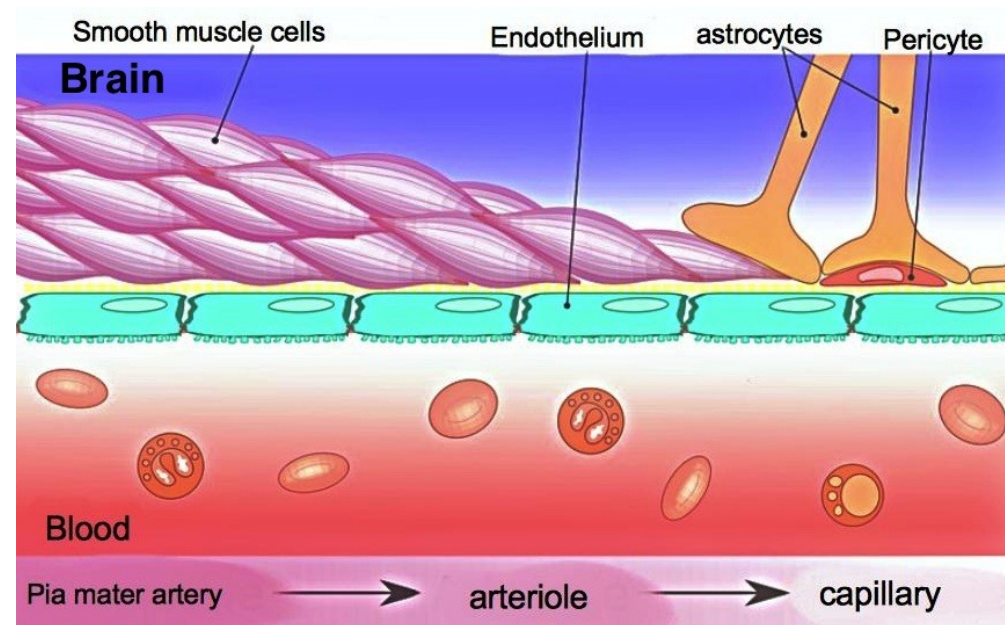
<https://sisu.ut.ee/histology/meninges>



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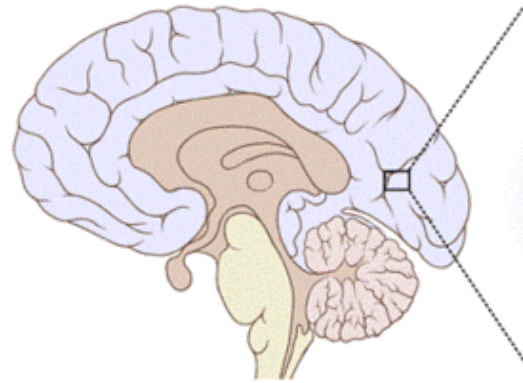
Hematoencephalic barrier

- Highly organised structure
 - Endothelial cells (low permeability thanks to zonula occludens)
 - Basal membrane
 - Astrocytes
 - Pericytes

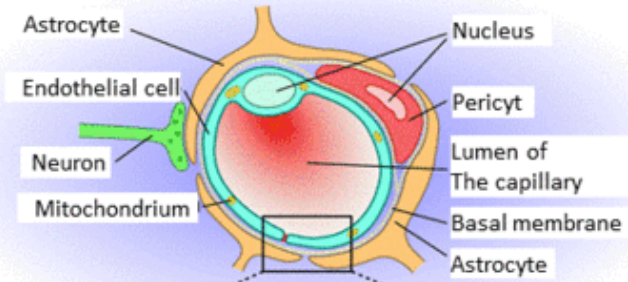


https://upload.wikimedia.org/wikipedia/commons/1/12/Blood_vessels_brain_english.jpg

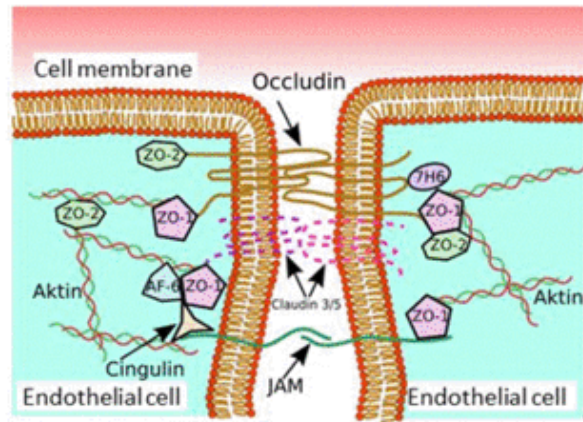
Hematoencephalic barrier



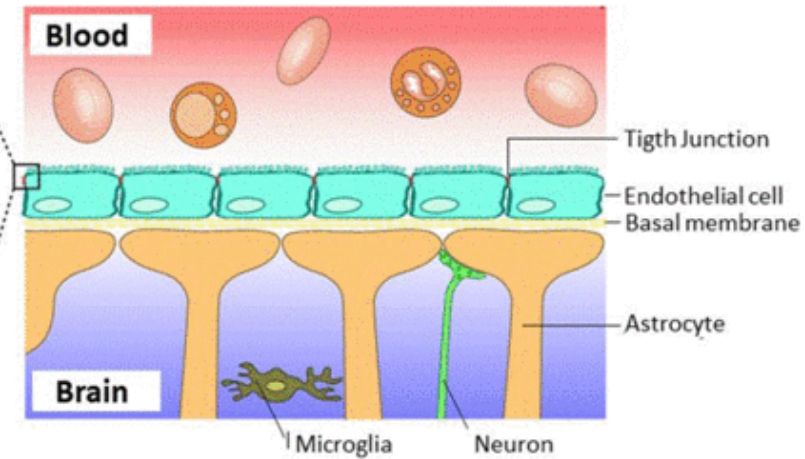
Cross section of blood vessel



Junction between Endothelial cells

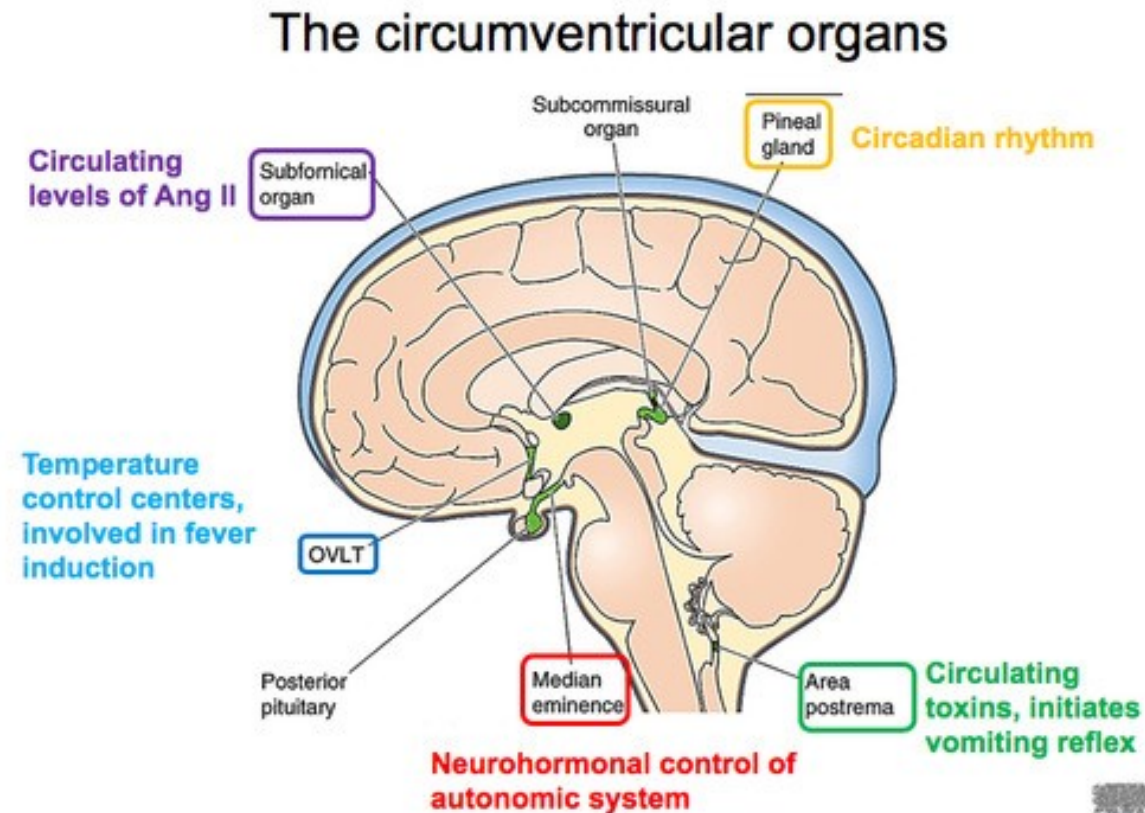


Longitudinal section of blood vessel



Circumventricular organs

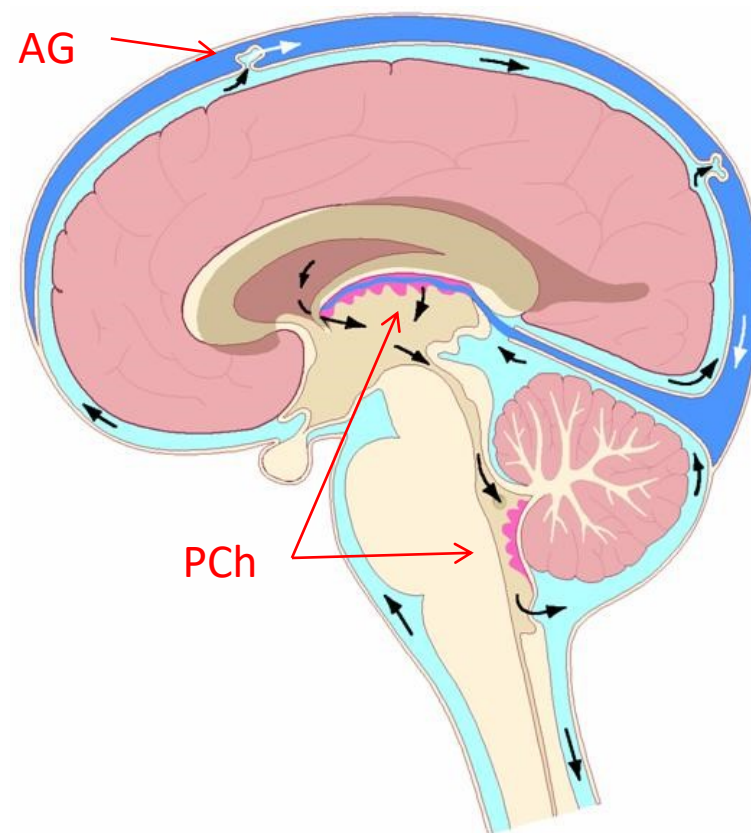
- Rich vascularisation
- Modified hematoencephalic barrier
- Sensors
- Secretion



http://www.neuros.org/index.php?option=com_photos&view=photos&oid=hafizbilal

Cerebrospinal fluid

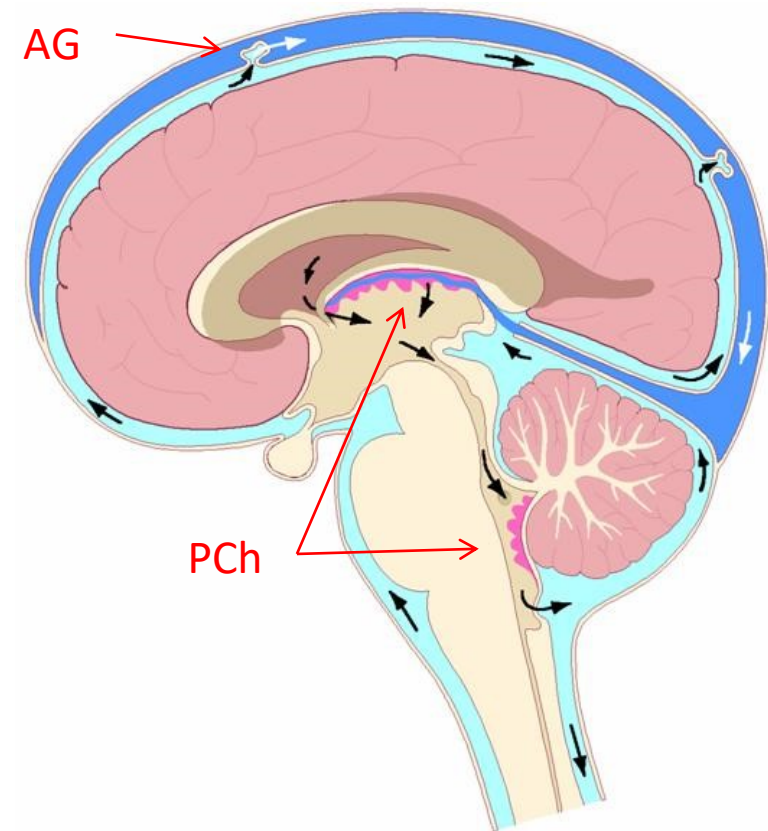
- Content
 - ✓ High levels of Mg^{+} and Na^{+}
 - ✓ Low levels of K^{+} and Ca^{2+}
 - ✓ Almost no cells (max 5/ml)
- Function
 - ✓ Protection
 - ✓ Microenvironment of neurons and glia
 - Metabolic function
 - Immunologic function
 - Transport function and so on



<http://www.control.tfe.umu.se>

Cerebrospinal fluid

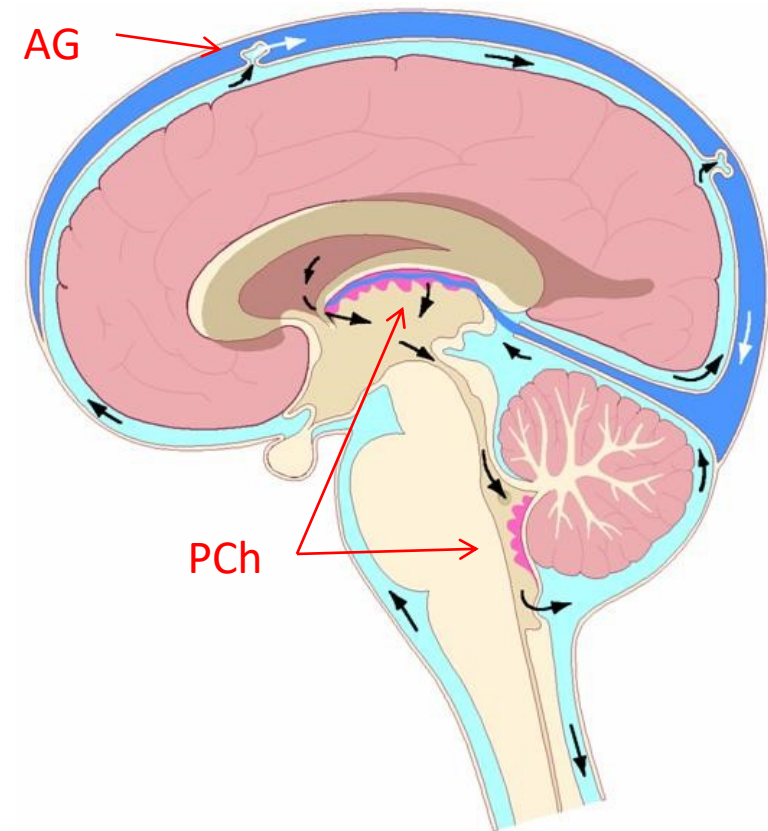
- Clear fluid produced by active secretion
- Liquor space
 - lined by ependymal cells
 - 150-250 ml



<http://www.control.tfe.umu.se>

Cerebrospinal fluid

- Clear fluid produced by active secretion
- Liquor space
 - lined by ependymal cells
 - 150-250 ml
- Production
 - ✓ Plexus choroideus (PCh) -70%
 - ✓ Cell metabolism
 - ✓ Capillary filtration
 - 450-750 ml/day
- Resorption
 - ✓ Archnoid granulations (AG)

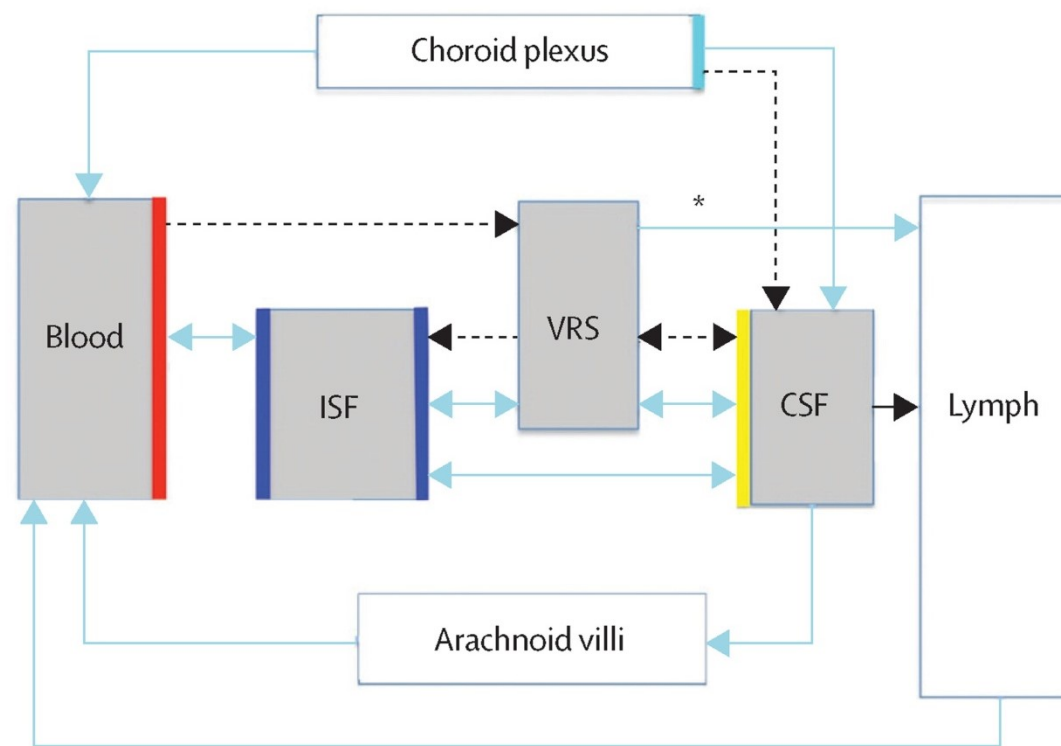


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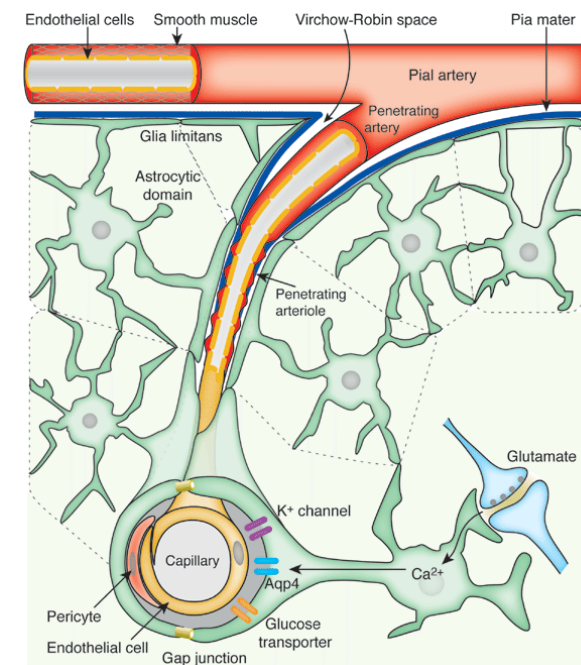
New insight into the production and resorption of CSF

Ducros A, Biousse V. Headache arising from idiopathic changes in CSF pressure. *The Lancet Neurology*. 2015;14:655–668.

- CSF – cerebrospinal fluid
- ISF – interstitial fluid
- VRS – Virchow Robin space (space between the pia mater and an artery or a vein, but not capillaries)



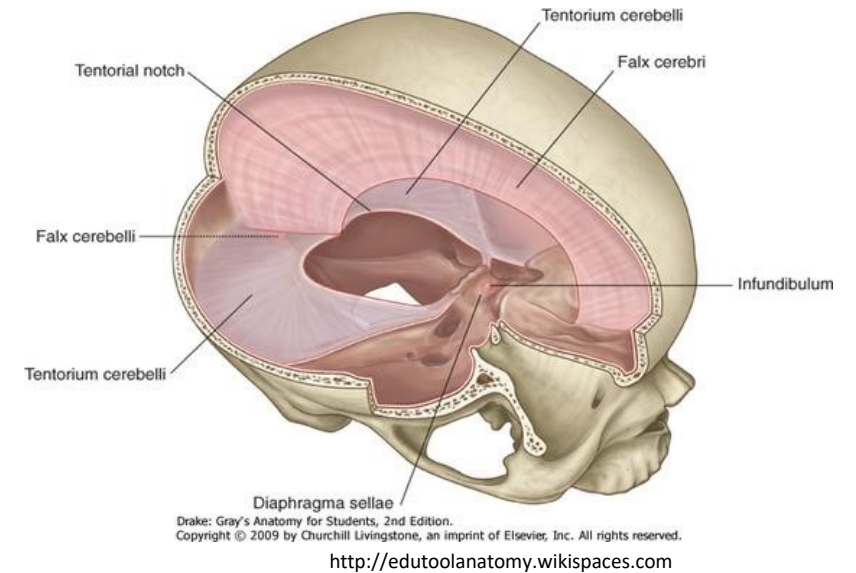
— BBB
 — CP barrier
 — Fluid movements
 — Glia limitans
 — Ependyma/pia mater
 — Cellular movements



<http://visnu528.blogspot.cz/2014/09/glymphatics-and-virchow-robin-space.html>

Intracranial compartment

- Brain
- Cerebrospinal fluid
- Blood (intravascular)
- Intracranial pressure (ICP)
 - Critical determinant of cerebral perfusion
- Cerebral perfusion pressure (CPP)
pressure gradient driving blood
flow intracranially



$$!!! \text{ CPP } = \text{ MAP } - \text{ ICP } !!!$$

Cerebral perfusion pressure | Intracranial pressure
Mean arterial pressure

Cellular base of nervous system

- Neuronal cells
 - Reception, integration and propagation of information
 - Unique, irreplaceable
- Neuroglial cells
 - Support for neuronal cells
 - Easily replaceable

Cellular base of nervous system

- Neuronal cells
 - Reception, integration and propagation of information
 - Unique, irreplaceable
- Neuroglial cells
 - Support for neuronal cells
 - Easily replaceable
- The total amount of neuronal cells - 100 billions (10^{11})
- Neuron/glia ratio
 - 1/10 - 50 (Principles of Neural Science, 4th ed., 2012)
 - 1/2 – 10 (Principles of Neural Science, 5th ed., 2012)
 - 1/1 (Nolte's Human Brain, 7th ed., 2015)

Neuroglial cells

Central nervous system

- Astrocytes
 - Hematoencephalic b.
 - Homeostasis maintaining
 - Metabolism of neurotransmitters
 - Important during brain development

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 - Choroid plexus
 - (hemato-liquor barrier)
 - Ventricular lining
(liquoro-encephalic barrier)

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Peripheral nervous system

- Satellite cells
 - Support functions in PNS

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Peripheral nervous system

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 - Myelin sheat

Neuroglial cells

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 - Metabolism of neurotransmitters
 - Important during brain development

- Oligodendrocytes

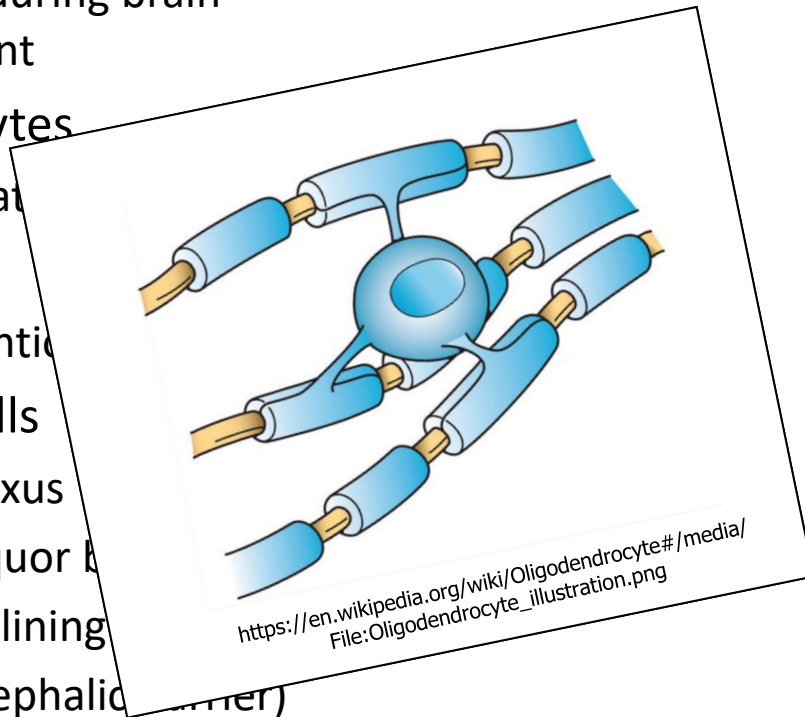
- Myelin sheath

- Microglia

- Immune function

- Ependymal cells

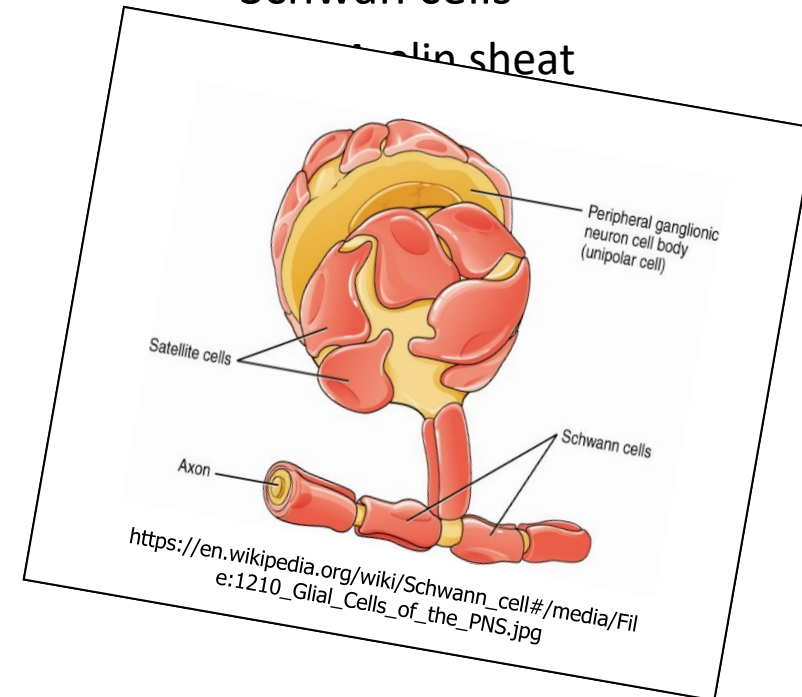
- Choroid plexus
- (hemato-liquor barrier)
- Ventricular lining
- (liquoro-encephalic barrier)



Peripheral nervous system

- Satellite cells
 - Support functions in PNS

- Schwann cells



Neuron

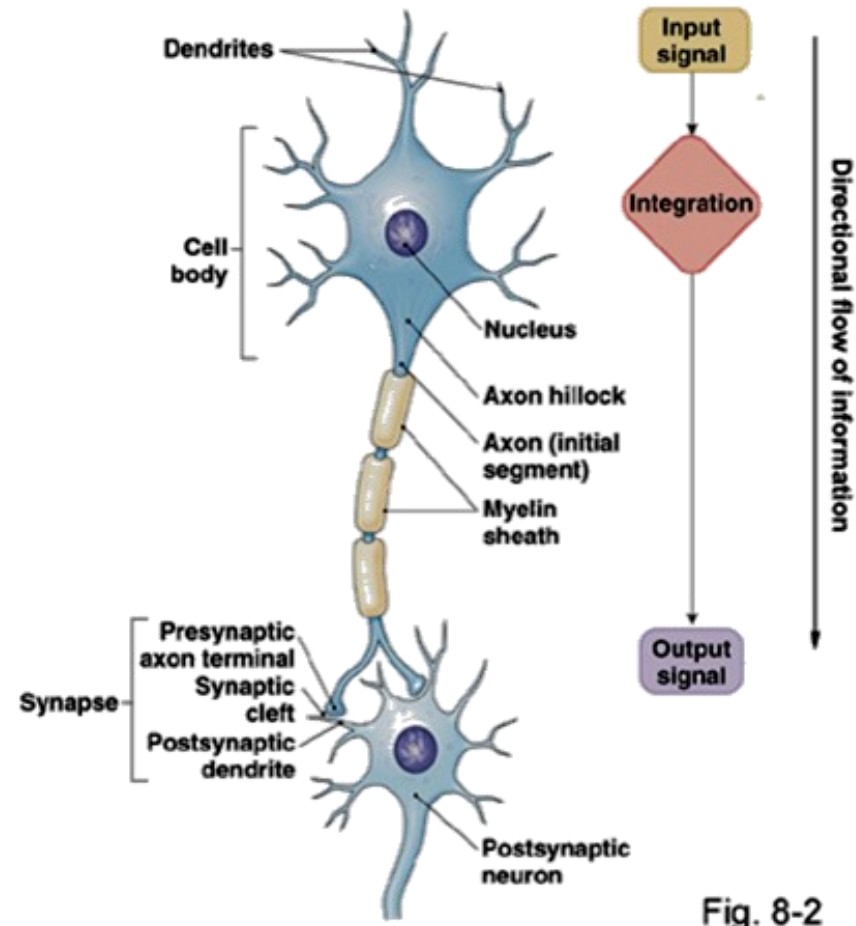


Fig. 8-2

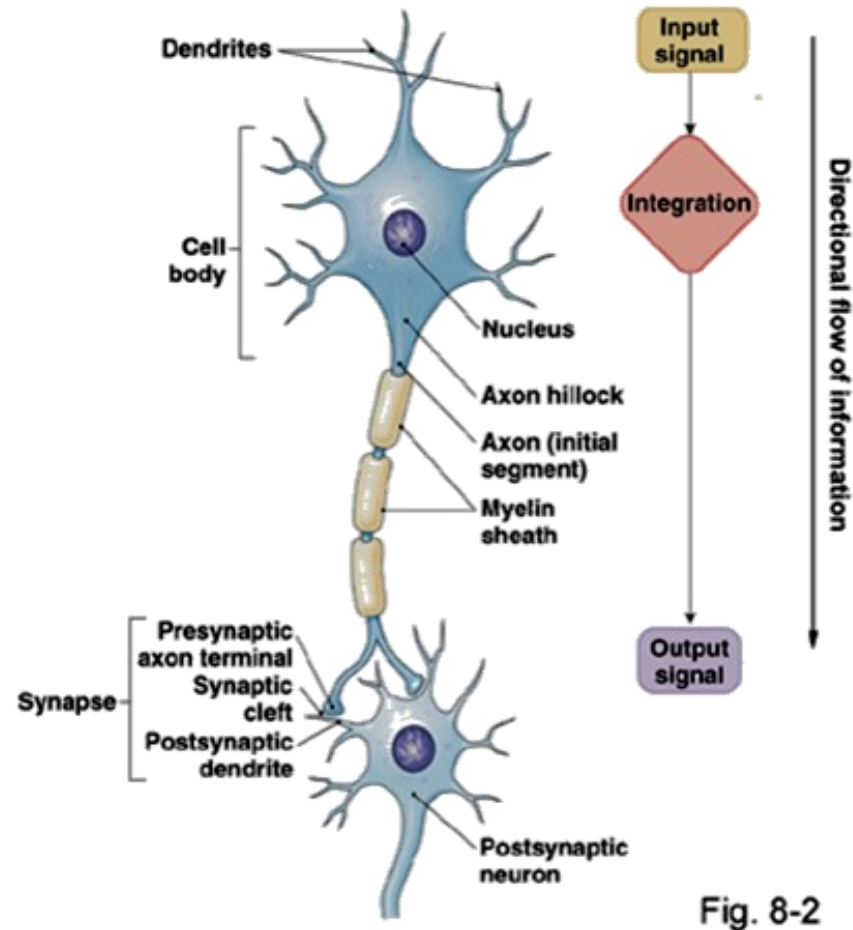
<http://www.slideshare.net/drpsdeb/presentations>

Background Activity

The inside of the cell

- ✓ ...
- ✓ Synthesis
- ✓ Transport
- ✓ ...

Neuron



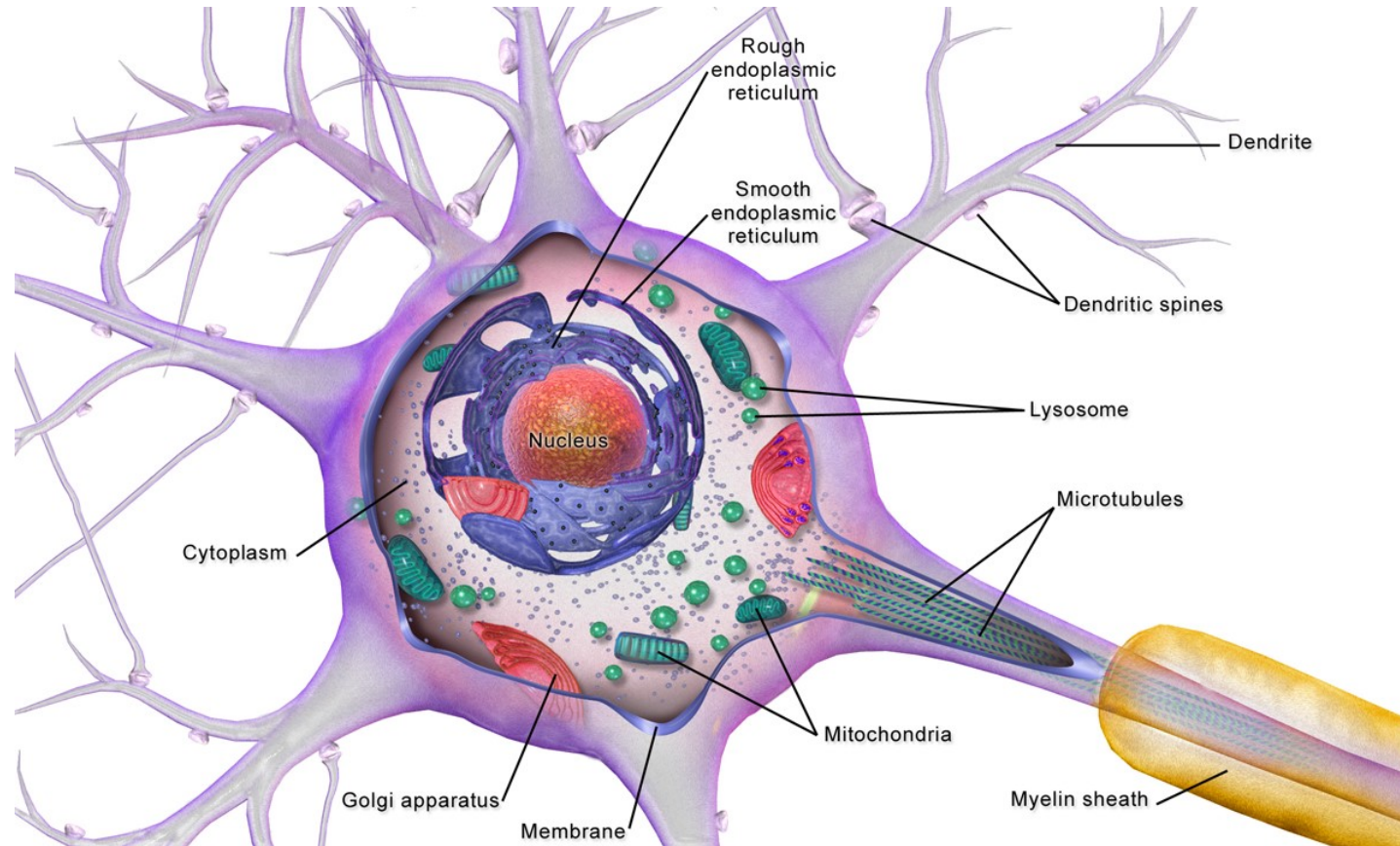
Information processing and transmission

The membrane

- ✓ Signal reception
- ✓ Signal integration
- ✓ AP generation
- ✓ AP propagation
- ✓ Signal transmission

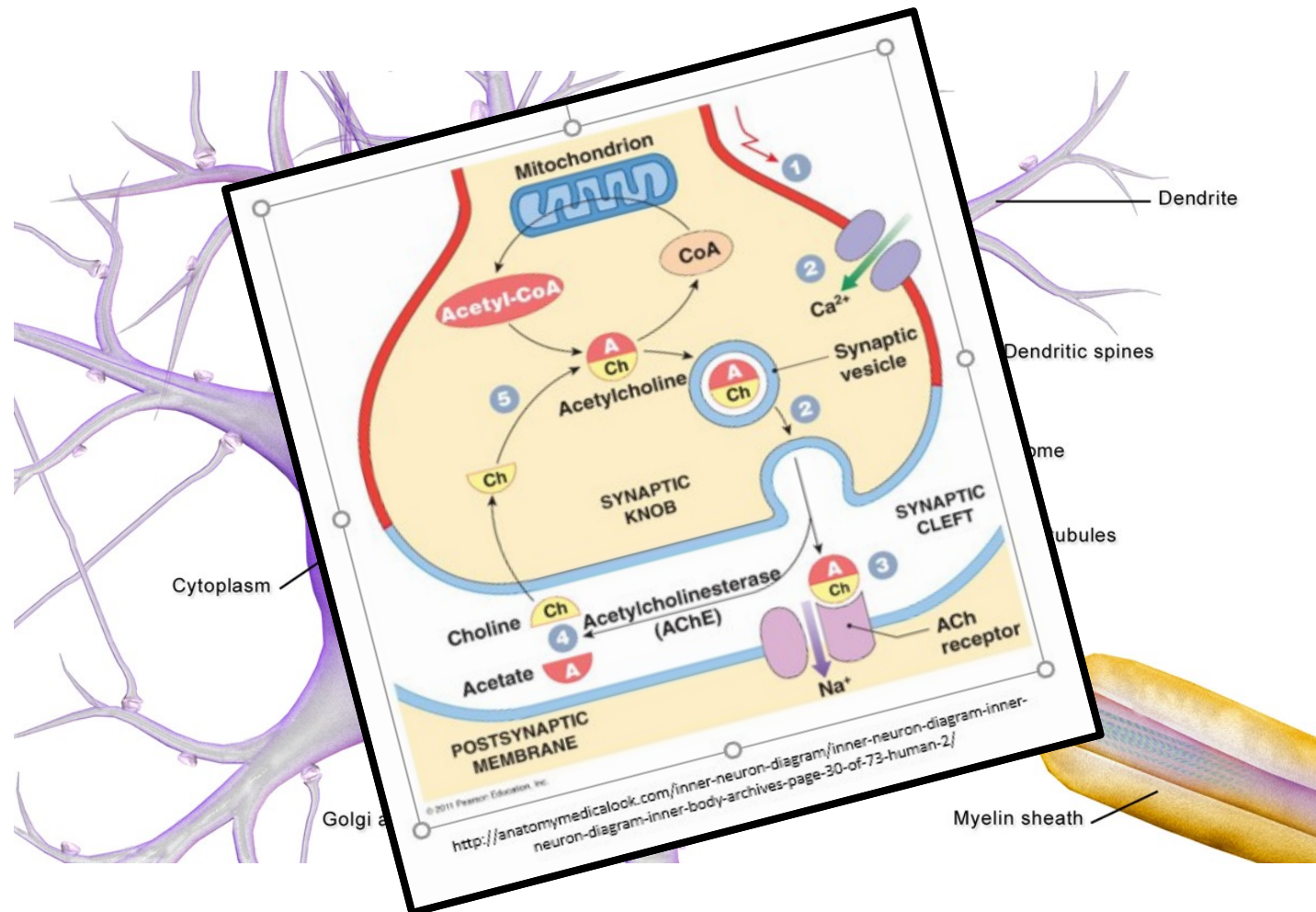
<http://www.slideshare.net/drpsdeb/presentations>

Background Activity



https://upload.wikimedia.org/wikipedia/commons/e/ed/Neuron_Cell_Body.png

Background Activity



https://upload.wikimedia.org/wikipedia/commons/e/ed/Neuron_Cell_Body.png

Background Activity

Fast axonal transport

- bidirectional
- ATP dependant
- associated with microtubules: dynein and kinesin

Fast axonal transport

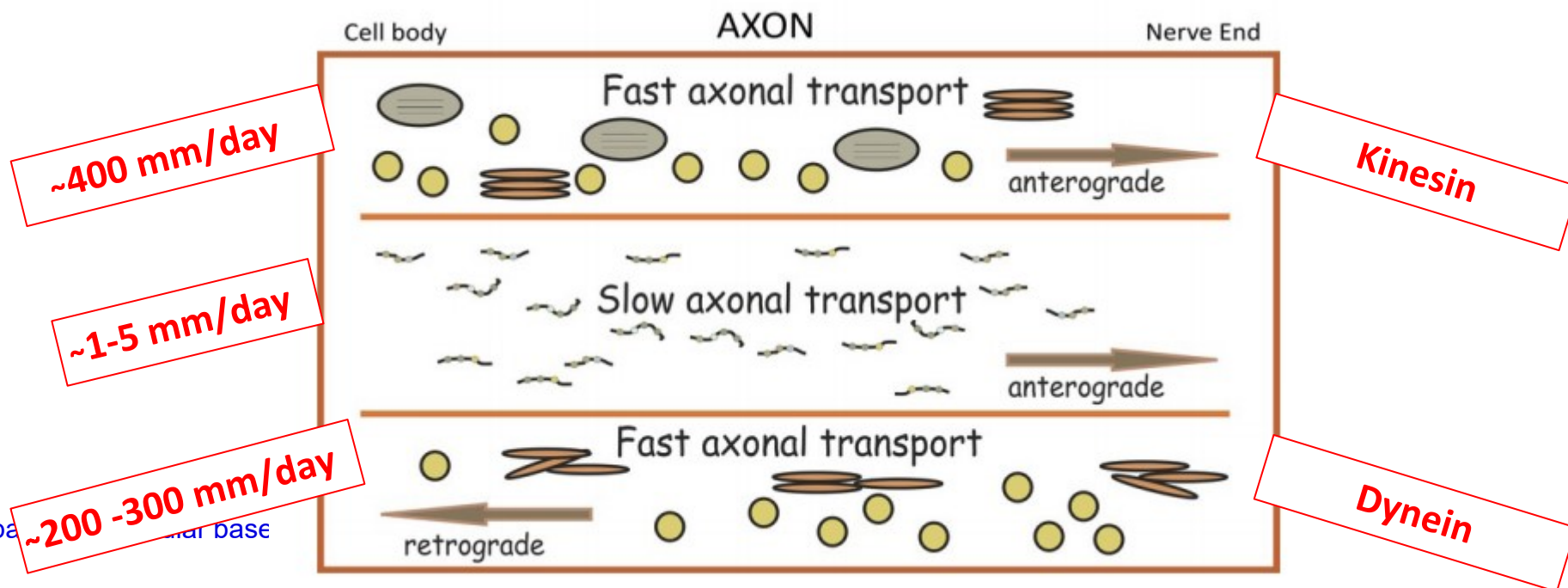
Golgi derived vesicles
lysosomes, mitochondria
structural elements of
endoplasmic reticulum

Slow axonal transport

- unidirectional,
- ATP independant
- conducted by sliding, polymerizing and protein interacting

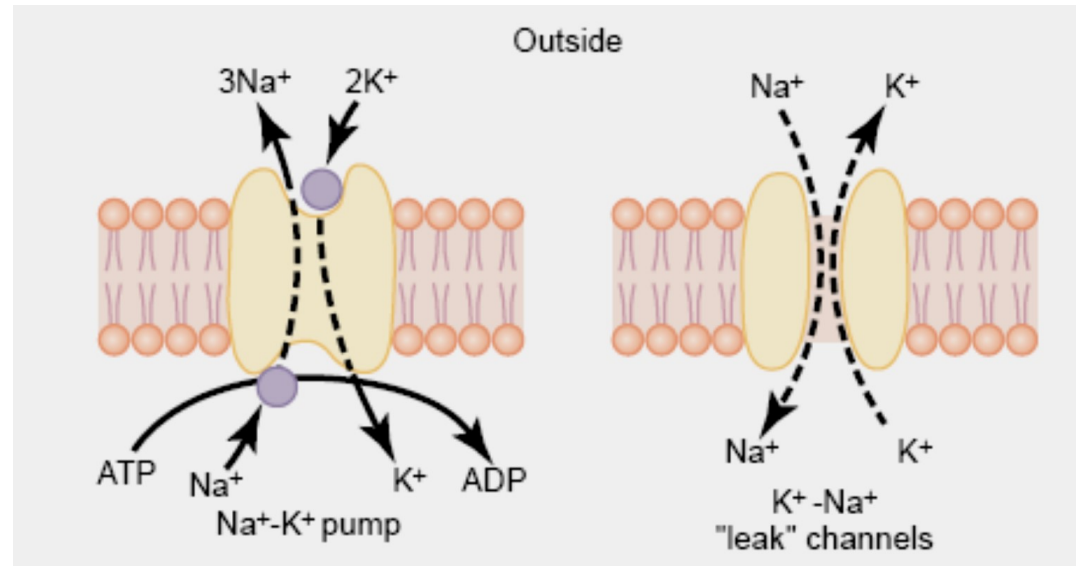
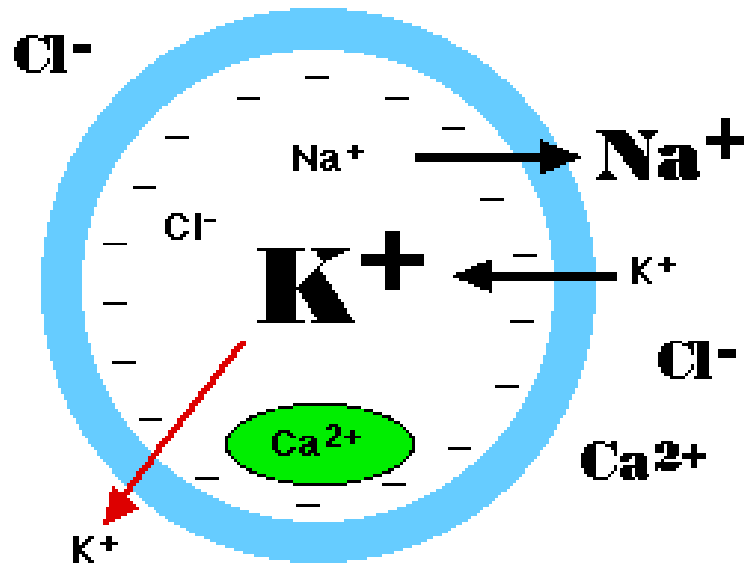
Slow axonal transport

microfilaments, microtubules
neurofilaments
cytosolic protein complexes



Membrane potential

- Due to differences in the concentrations of ions on opposite sides of a cellular membrane



<http://www.slideshare.net/drpsdeb/presentations>

Resting membrane potential of a neuron



Resting potential
around -70 mV

- Highly instable state of membrane
- Why? – Speed!
- High energetical demands
 - ✓ Oxygen - 20% of total body consumption
 - ✓ Glucose – 25% of total body consumption

Action potential

- Quick voltage change on the membrane
- Spreads along the axon
- All or nothing principle

Threshold potential around -55 mV

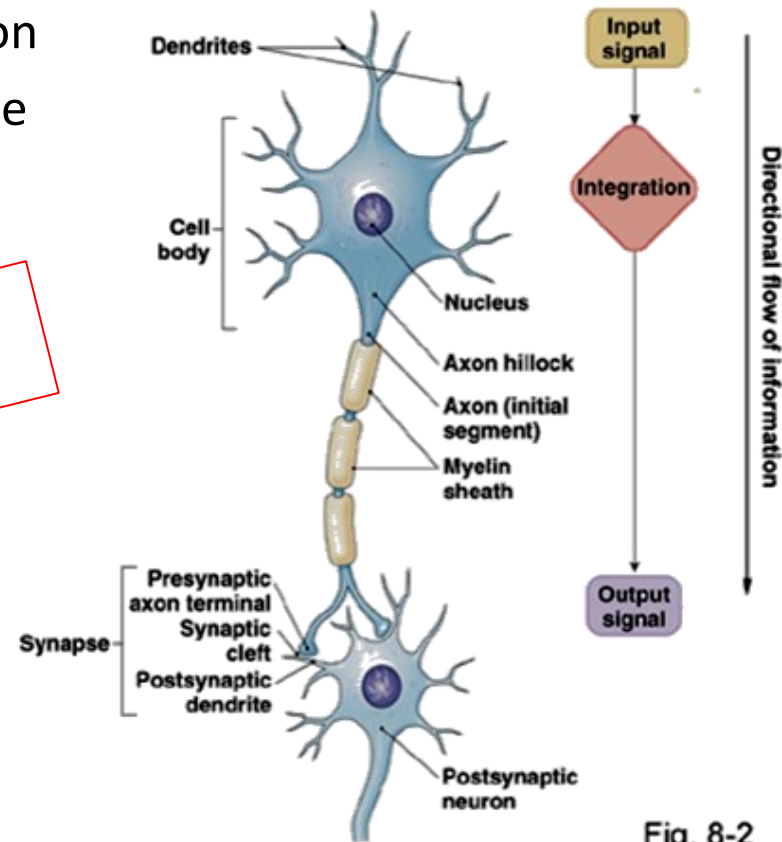
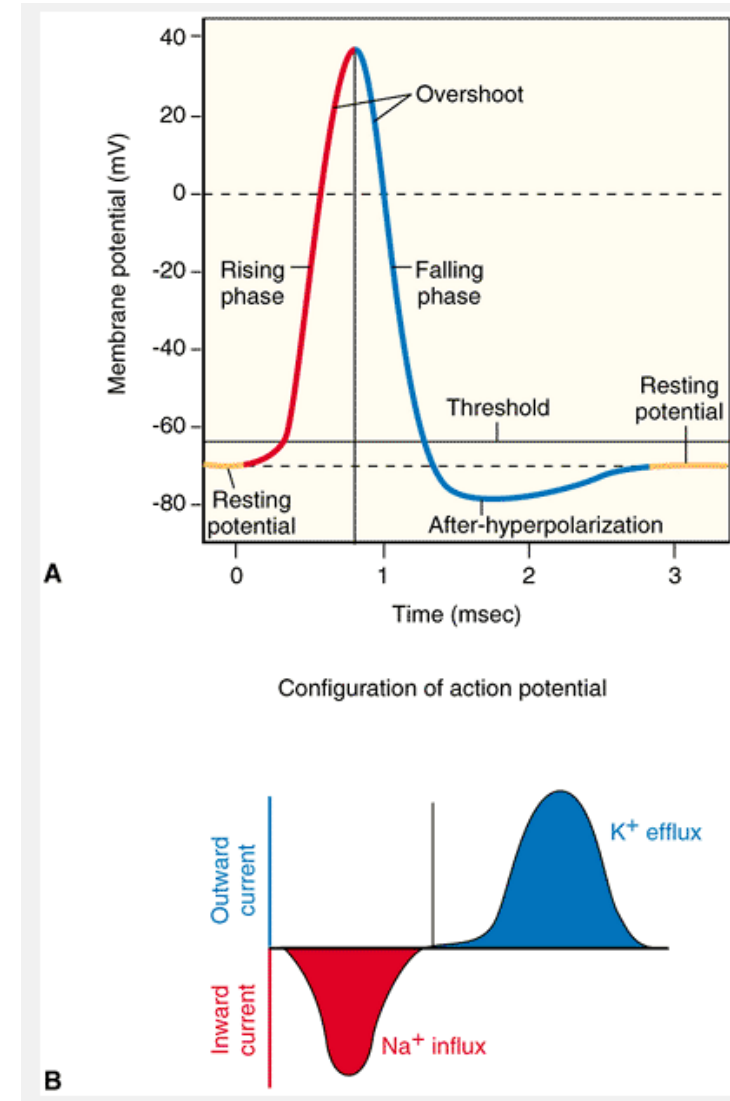
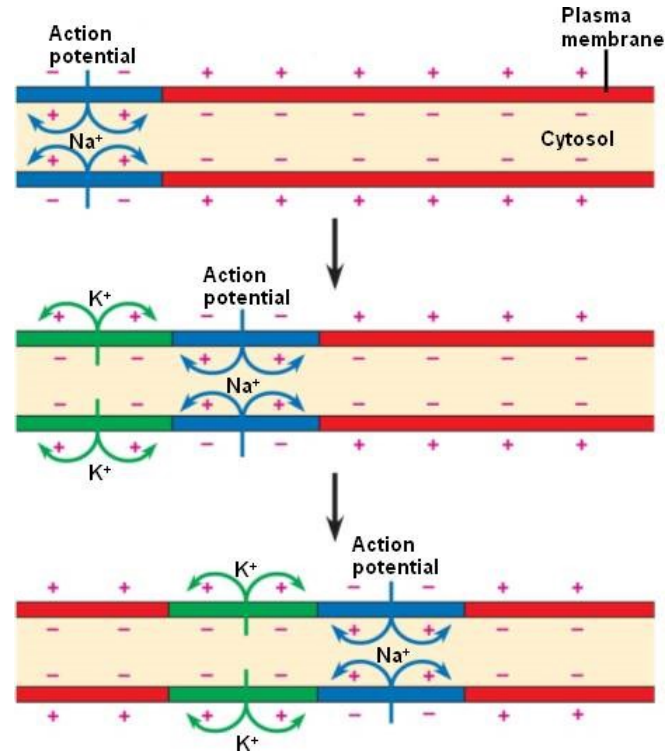
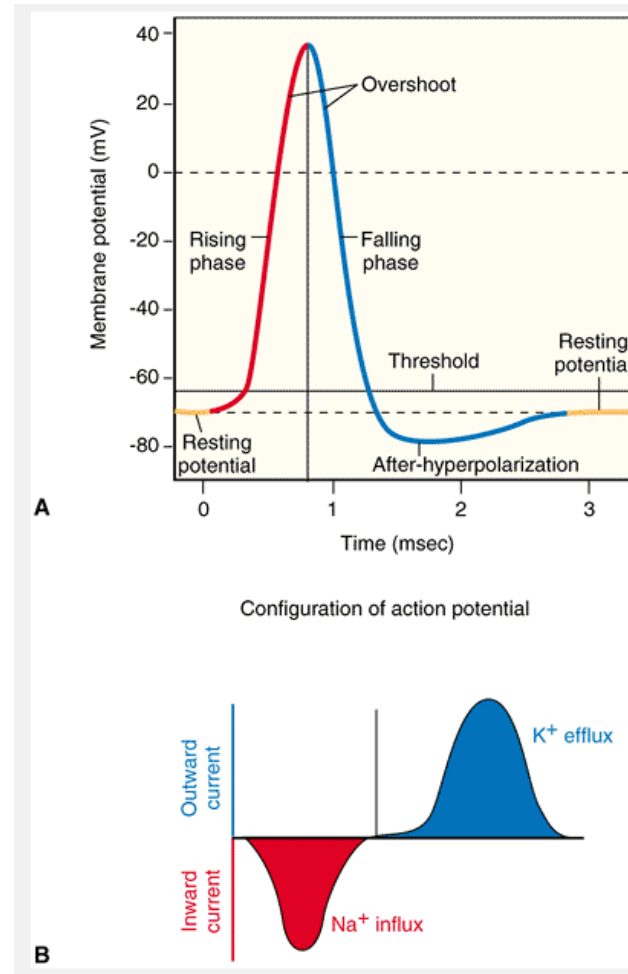


Fig. 8-2



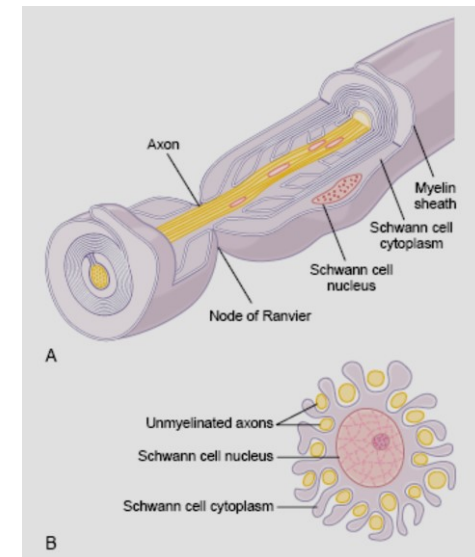
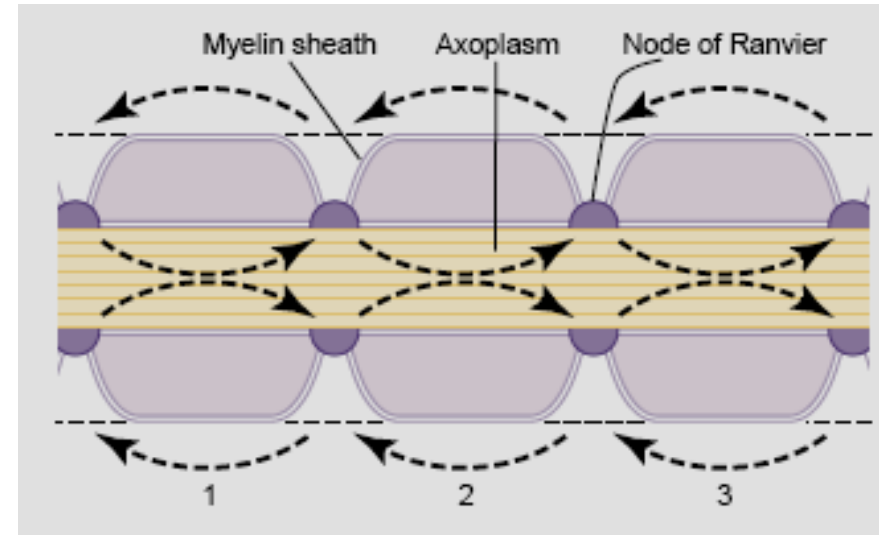
Action potential spreading



- Local currents
- Anterograde

Saltatory conduction

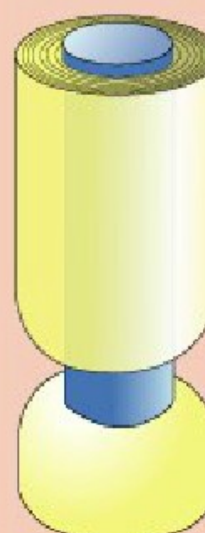
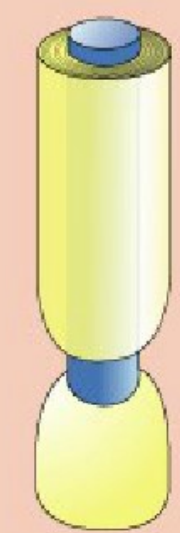


- Myelin sheath
- Nodes of Ranvier
- Economy
- Speed of conduction
- Speed of conduction also dependent of nerve fibre diameter
 - the electrical resistance is inversely proportional to area of cross-section



<http://www.slideshare.net/drpsdeb/presentations>

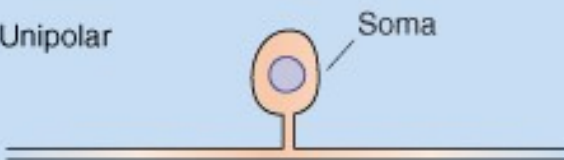

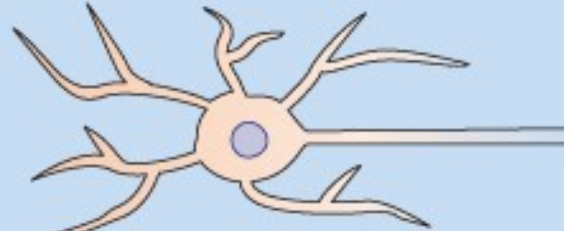
Classification of nerve fibers

- In humans mostly myelinated
- All fibers are myelinated in CNS
- Non-myelinated are evolutionary old ones

	A α	A β	A δ	C
1 ^o Axon to skin				
1 ^o Axon to muscle				
	Group I	Group II	Group III	Group IV
				
Diameter (um)	12-20	6-12	1-6	0.2-1.5
Speed(m/sec)	70-170	30-70	5-30	0.5-2
Sensory receptors	Proprioceptors of skeletal muscle	Mechanoreceptors of skin	Pain, temperature	Temp, pain, itch

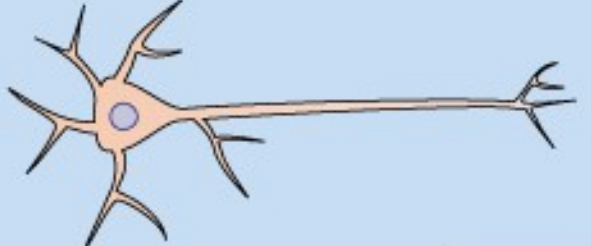
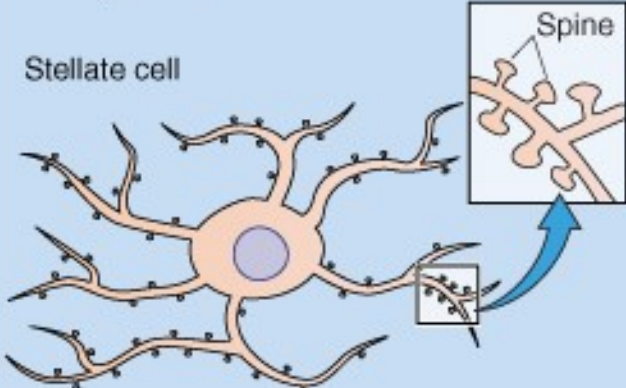
<http://neuroscience.uth.tmc.edu/s2/chapter04.html>

Neuronal classification

Basis for classification	Example	Functional implication	Structure
<p>3. Number of processes</p> <p>One process exits the cell body</p>	<p>Unipolar neuron (dorsal root ganglion cell)</p>	<p>Small area for receiving synaptic input: highly specialized function</p>	<p>Unipolar</p>  <p>Soma</p>
<p>Two processes exit the cell body</p>	<p>Bipolar neuron (retinal bipolar cell)</p>	<p>Small area for receiving synaptic input: highly specialized function</p>	<p>Bipolar</p> 
<p>Many processes exit the cell body</p>	<p>Multipolar neuron (spinal motor neuron)</p>	<p>Large area for receiving synaptic input; determines the pattern of incoming axons that can interact with the cell</p>	<p>Multipolar</p> 

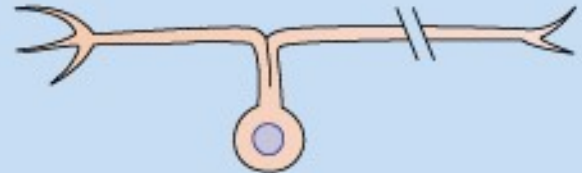

<http://www.slideshare.net/CsillaEgri/presentations>

Neuronal classification

Basis for classification	Example	Functional implication	Structure
<p>2. Dendritic pattern</p> <p>Pyramid-shaped spread of dendrites</p>	<p>Pyramidal cell (hippocampal pyramidal neuron)</p>	<p>Large area for receiving synaptic input; determines the pattern of incoming axons that can interact with the cell (i.e., pyramid-shaped)</p>	<p>Pyramidal cell</p> 
<p>Radial-shaped spread of dendrites</p>	<p>Stellate cell (cortical stellate cell)</p>	<p>Large area for receiving synaptic input; determines pattern of incoming axons that can interact with the cell (i.e., star-shaped)</p>	<p>Stellate cell</p> 

<http://www.slideshare.net/CsillaEgri/presentations>

Neuronal classification

Basis for classification	Example	Functional implication	Structure
<p>1. Axonal projection</p> <p>Goes to a distant brain area</p>	Projection neuron or Principal neuron or Golgi type I cell (cortical motor neuron)	Affects different brain areas	<p>Dorsal root ganglion cell</p> 
<p>Stays in a local brain area</p>	Intrinsic neuron or Interneuron or Golgi type II cell (cortical inhibitory neuron)	Affects only nearby neurons	<p>Retinal bipolar cell</p> 

<http://www.slideshare.net/CsillaEgri/presentations>

68. Cellular base of nervous system

- ✓ Neuroglial cells
 - Classification and functional overview
- ✓ Neuronal cells
 - Characterization, classification, anatomy
 - Functions of neurons
 - Background activity (cytoplasm)
 - Synthesis (soma)
 - Transport (categorization, characterization)
 - Information processing and transmission (membrane)
 - Main points of question No. 70

69. Intracranial compartment, intracranial pressure

- ✓ Content of intracranial compartment (brain, blood, CSF)
- ✓ Barriers among compartments (meningeal, hematoencephalic, hematoliquor)
 - HEB description
 - Circumventricular organs
- ✓ CSF
 - Function
 - Production, circulation, absorption
- ✓ Intracranial pressure
 - Definition, equation, implications

70. Membrane voltage, action potential – generation and propagation through nerve fibers

- ✓ Membrane potentials
 - General characteristics and ionic mechanisms description
- ✓ Resting potential in neuron (characteristics)
- ✓ Action potential
 - Characteristics
 - Ionic mechanisms
 - Signal conduction
 - Role of myelin, saltatory conduction
- ✓ Classification of nerve fibres

M U N I

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