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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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- Properties/conditions vary among different compartments

**The brain homeostasis is maintained within a narrow range thanks to hematoencephalic barrier and astrocyte activity**

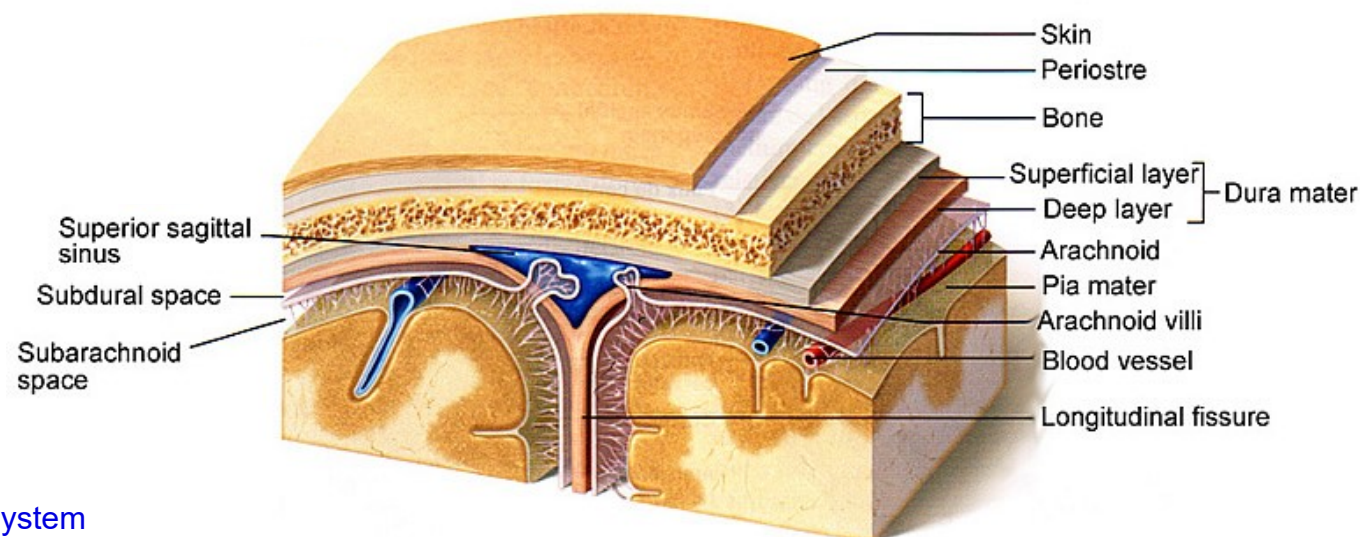
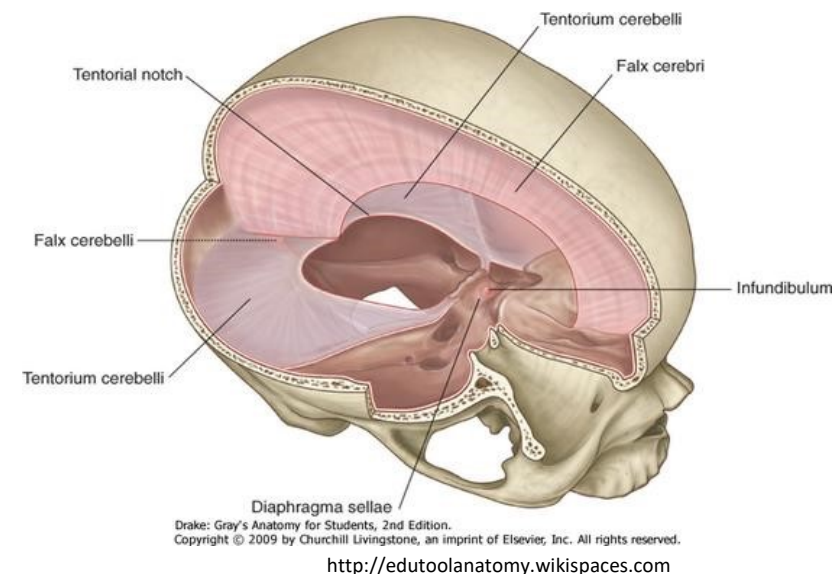
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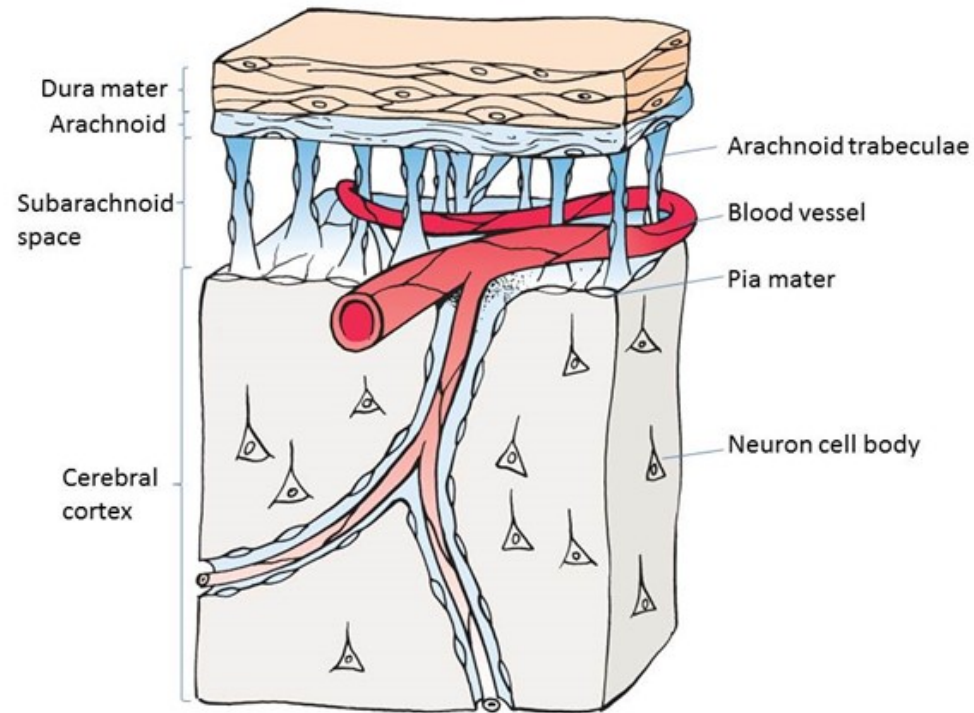
**The brain homeostasis is maintained within a narrow range thanks to hematoencephalic barrier and astrocyte activity**  
**This allows neuronal cells to live for the entire life of the individual**

# Intracranial compartment

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

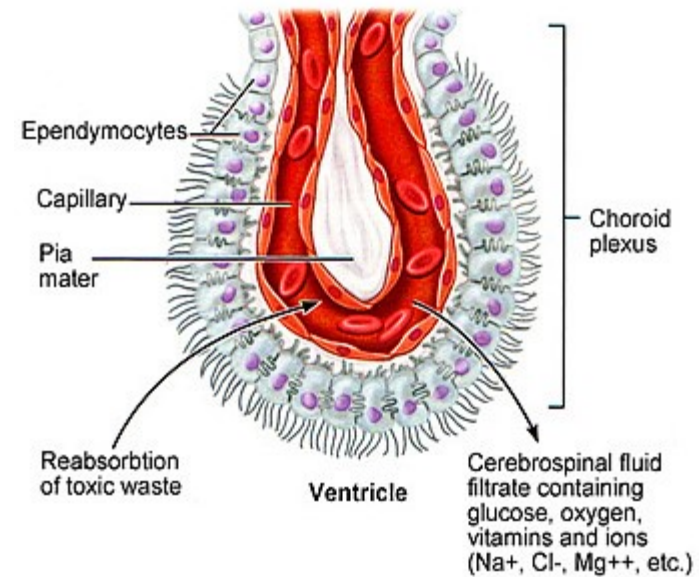


# Meningeal and hematoliquor barrier



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

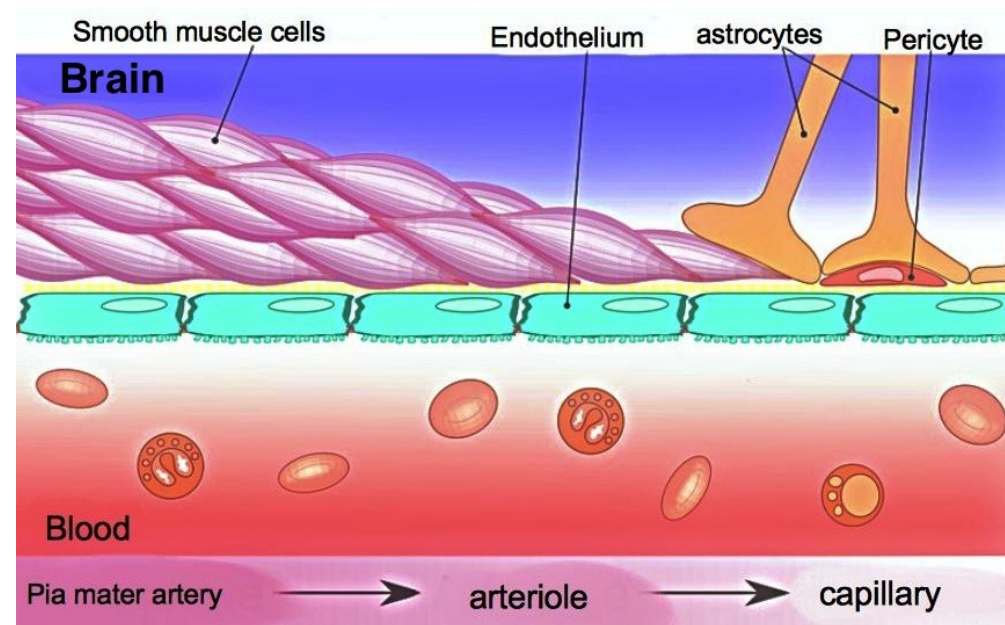
<https://sisu.ut.ee/histology/meninges>



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

# Hematoencephalic barrier

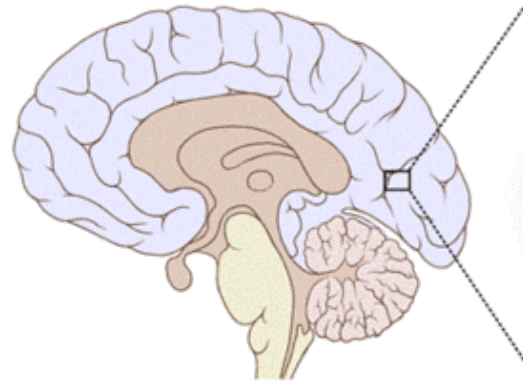
- Highly organised structure
  - Endothelial cells (low permeability thanks to zonula occludens)
  - Basal membrane
  - Astrocytes
  - Pericytes



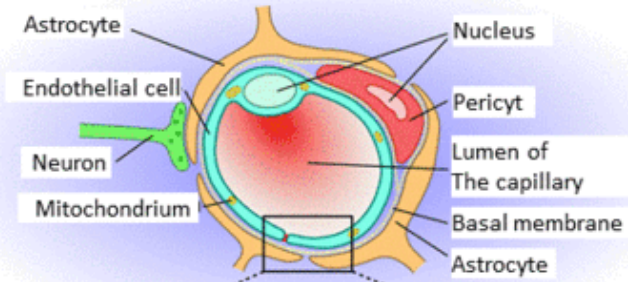
[https://upload.wikimedia.org/wikipedia/commons/1/12/Blood\\_vessels\\_brain\\_english.jpg](https://upload.wikimedia.org/wikipedia/commons/1/12/Blood_vessels_brain_english.jpg)



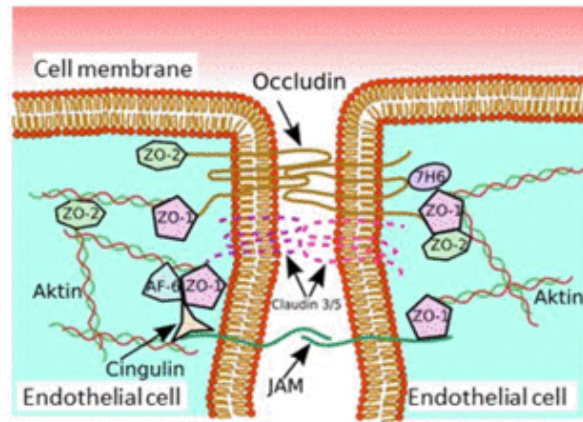
# Hematoencephalic barrier



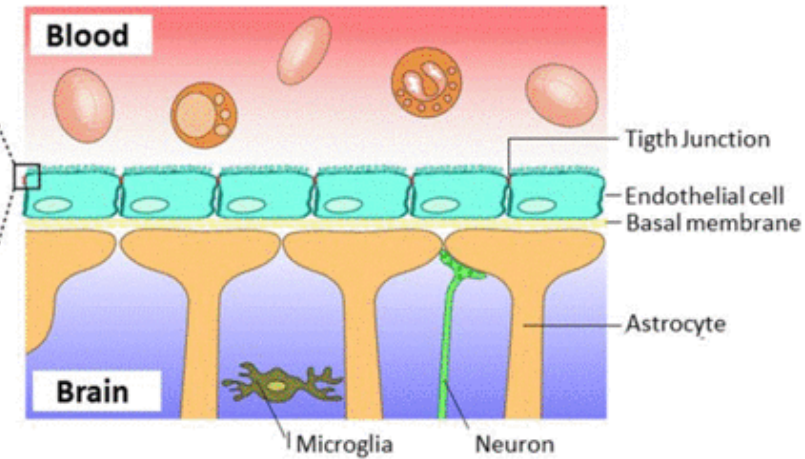
Cross section of blood vessel



Junction between Endothelial cells

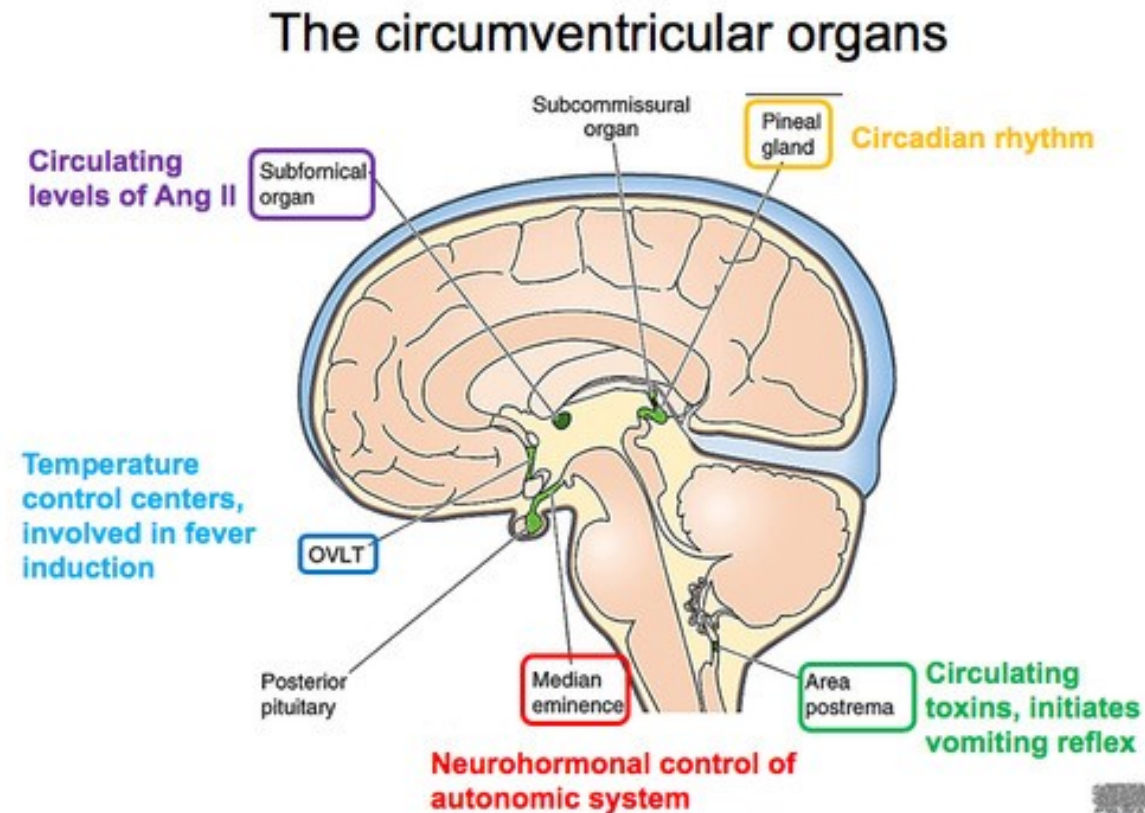


Longitudinal section of blood vessel



# Circumventricular organs

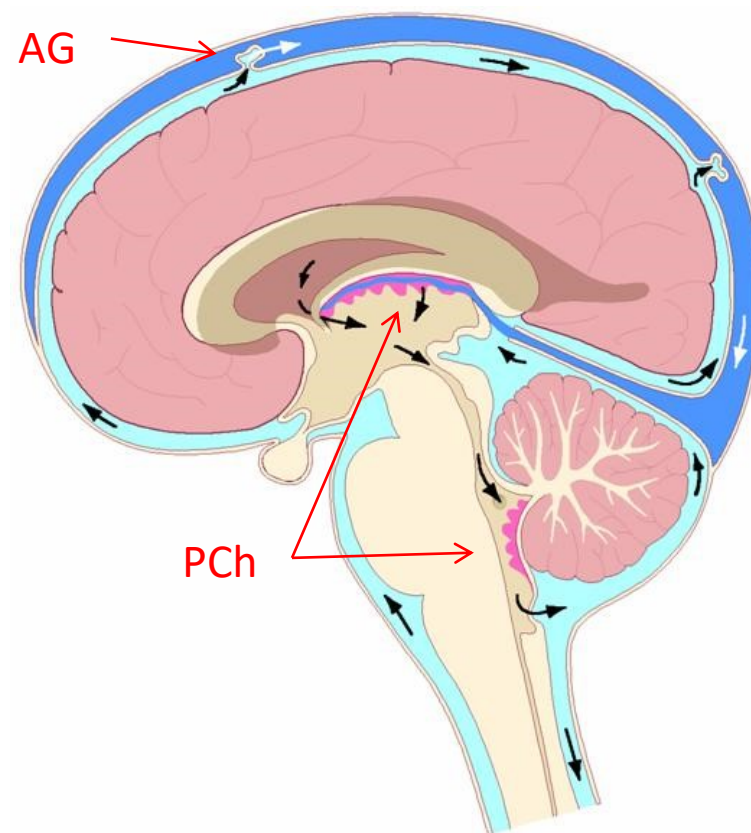
- Rich vascularisation
- Modified hematoencephalic barrier
- Sensors
- Secretion



[http://www.neuros.org/index.php?option=com\\_photos&view=photos&oid=hafizbilal](http://www.neuros.org/index.php?option=com_photos&view=photos&oid=hafizbilal)

# Cerebrospinal fluid

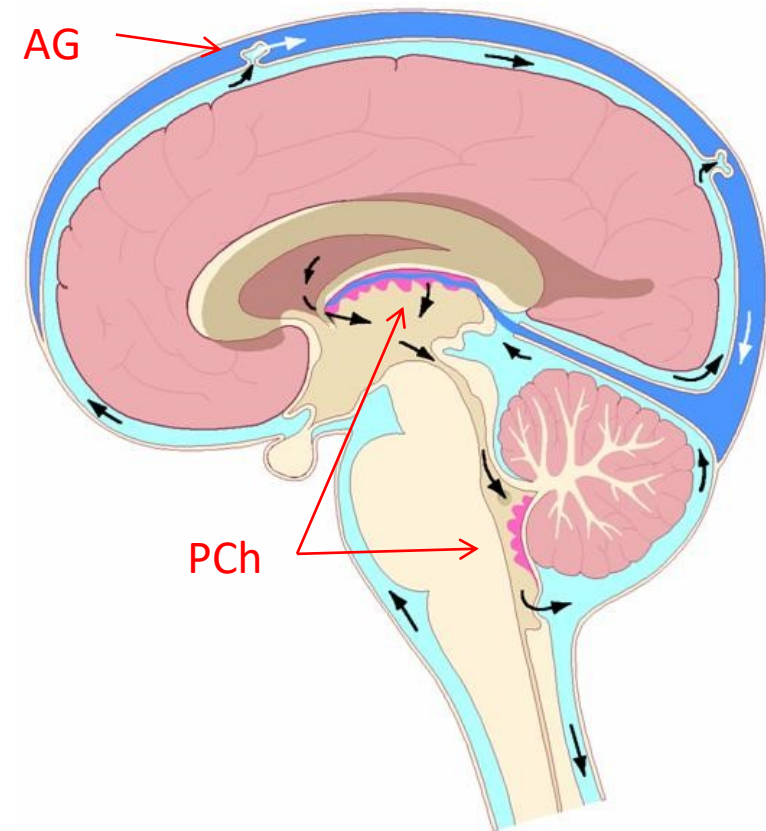
- Content
  - ✓ High levels of  $Mg^{+}$  and  $Na^{+}$
  - ✓ Low levels of  $K^{+}$  and  $Ca^{2+}$
  - ✓ Almost no cells (max 5/ml)
- Function
  - ✓ Protection
  - ✓ Microenvironment of neurons and glia
    - Metabolic function
    - Immunologic function
    - Transport function and so on



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

# Cerebrospinal fluid

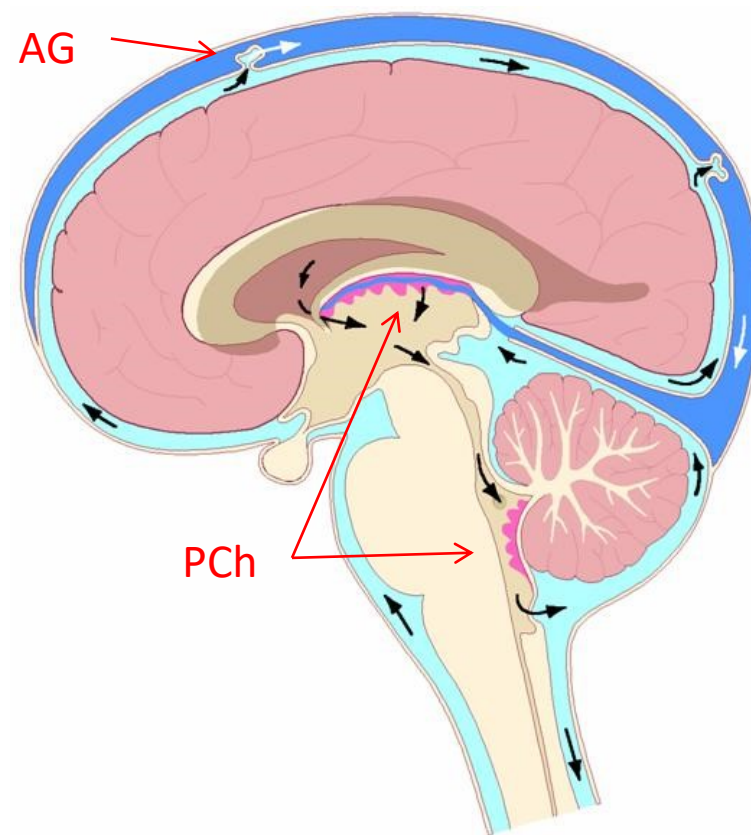
- Clear fluid produced by active secretion
- Liquor space
  - lined by ependymal cells
  - 150-250 ml



<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)

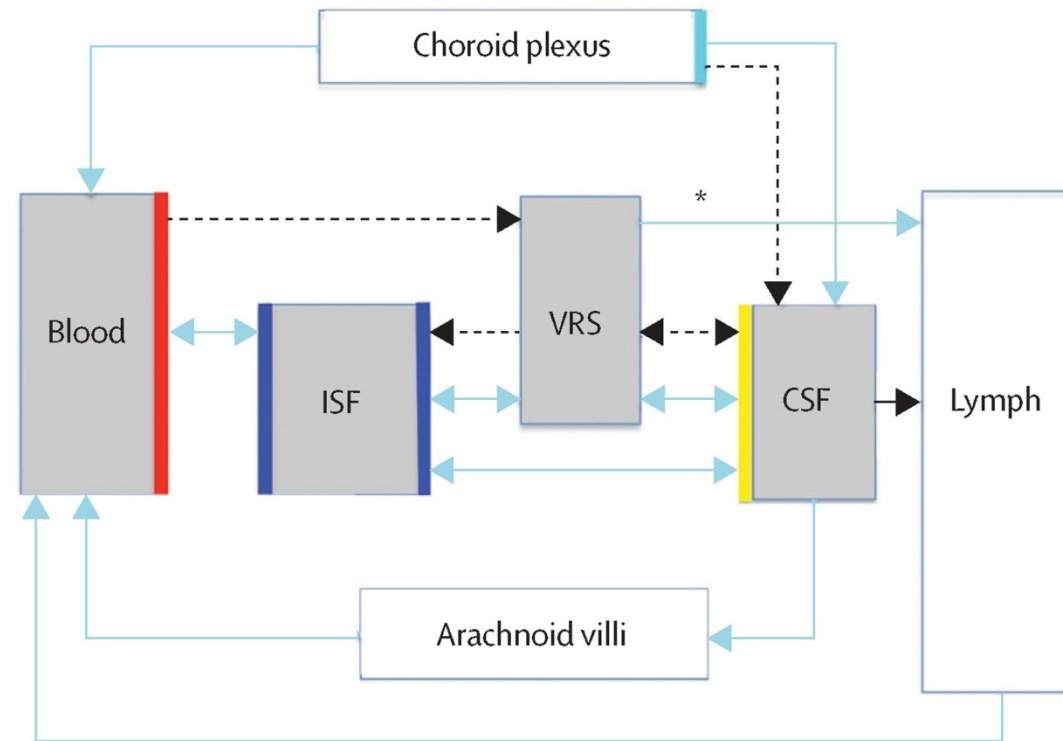


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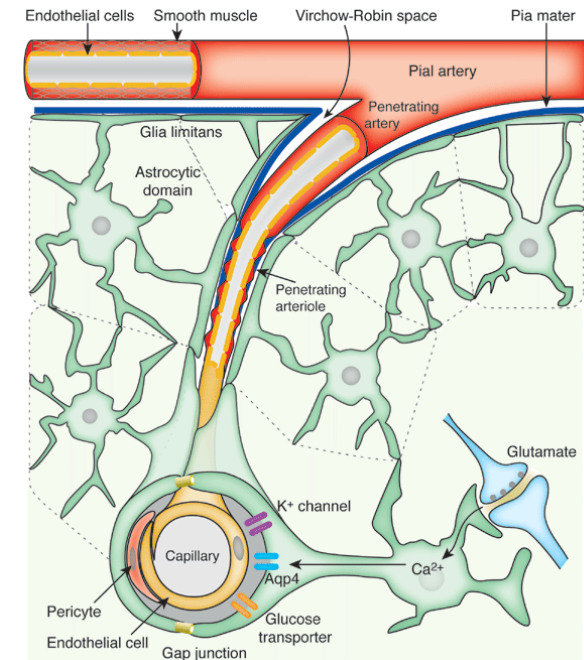
# New insight into the production and resorption of CSF

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)



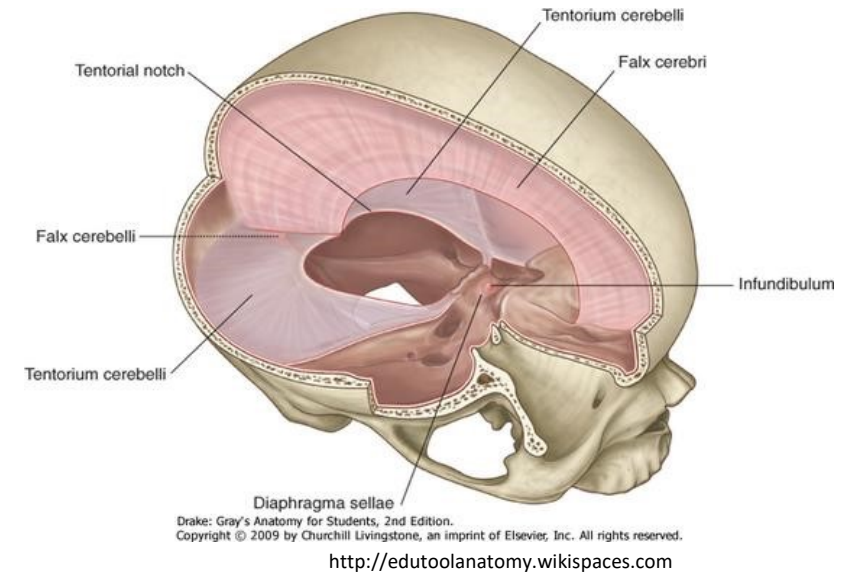
— BBB  
 — Glia limitans  
 — CP barrier  
 — Ependyma/pia mater  
 — Fluid movements  
 - -> Cellular movements



<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



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

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## Peripheral nervous system

- Satelite cells
  - Support functions in PNS

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## Peripheral nervous system

- Satelite cells
  - Support functions in PNS
- Schwan cells
  - Myelin sheat

# Neuroglial cells

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- Oligodendrocytes

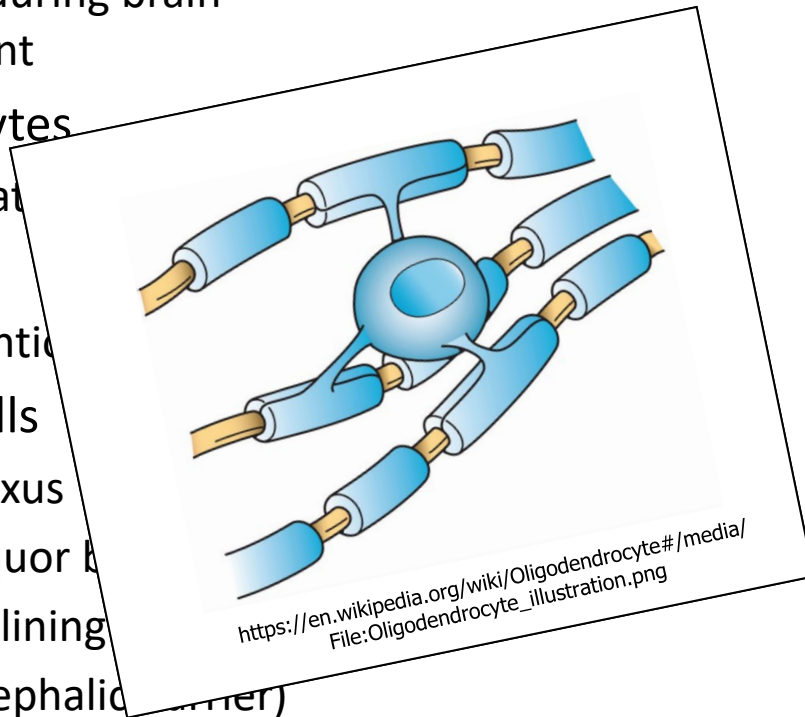
- Myelin sheath

- Microglia

- Immune function

- Ependymal cells

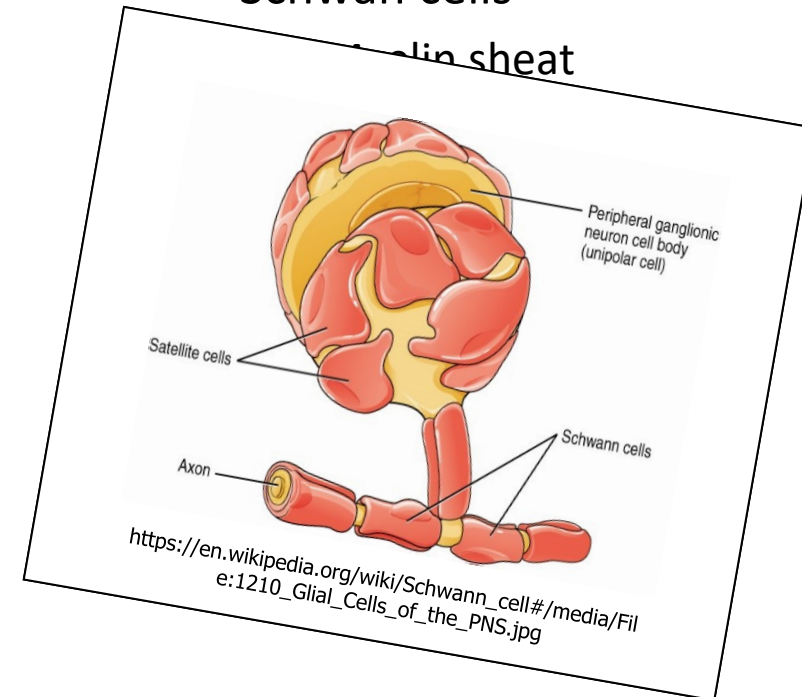
- Choroid plexus
- (hemato-liquor barrier)
- Ventricular lining
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## Peripheral nervous system

- Satellite cells
  - Support functions in PNS

- Schwann cells





# Neuron

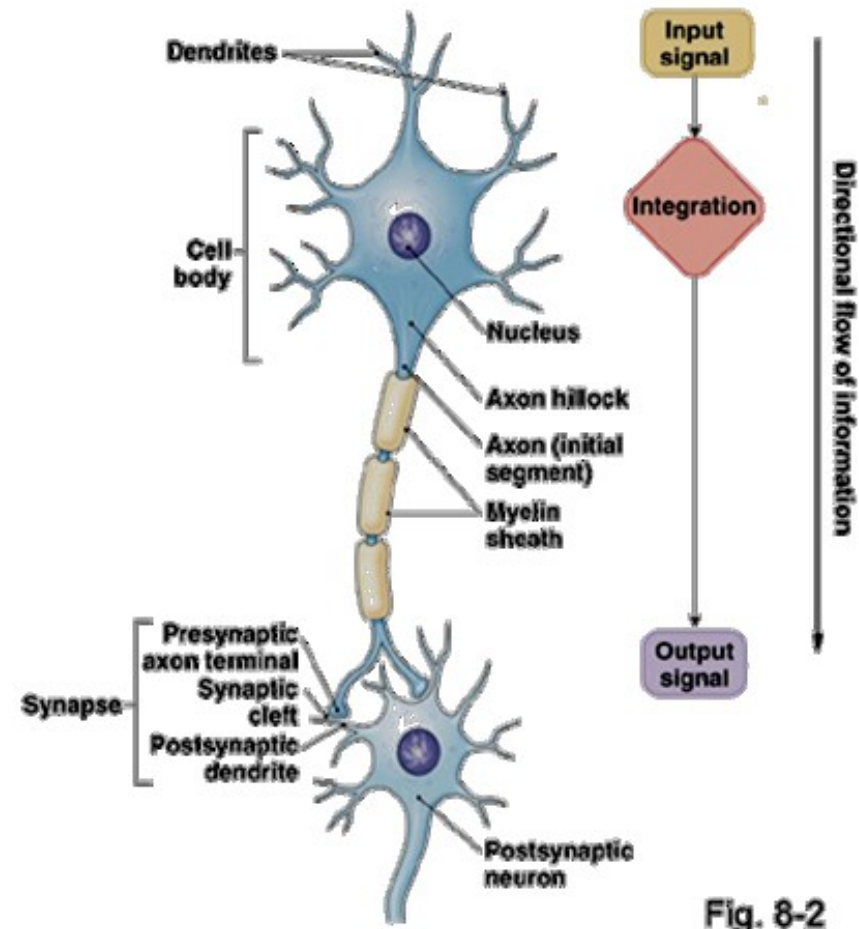


Fig. 8-2

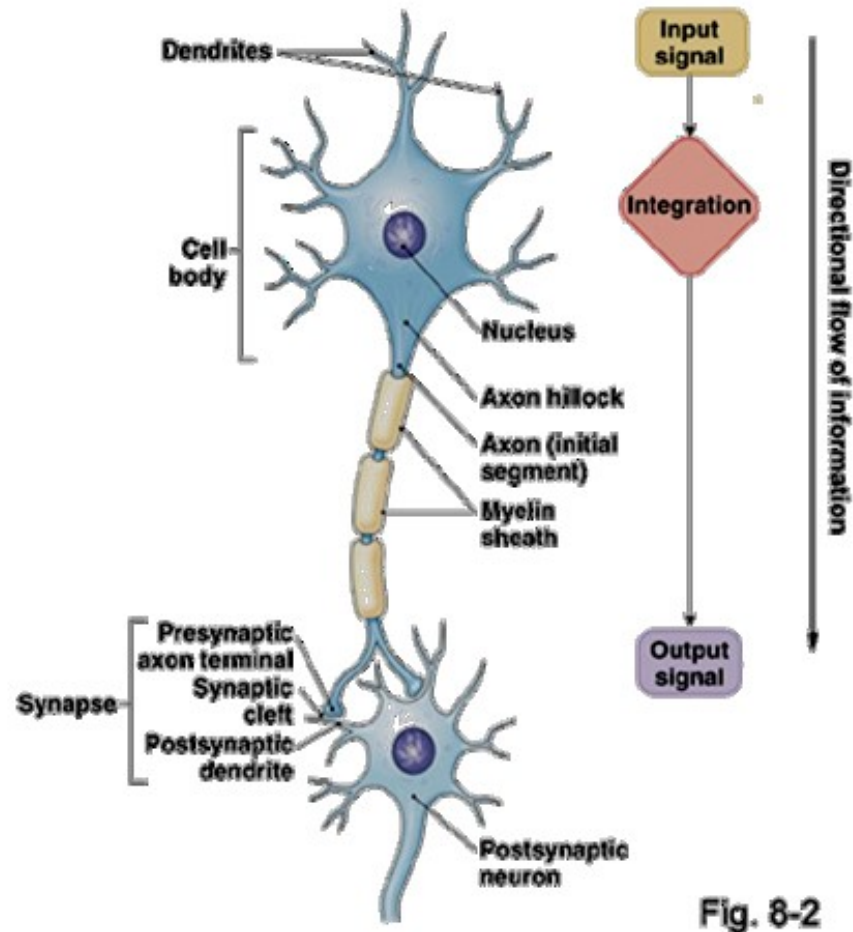
<http://www.slideshare.net/drpsdeb/presentations>

## Background Activity

### The inside of the cell

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

# Neuron



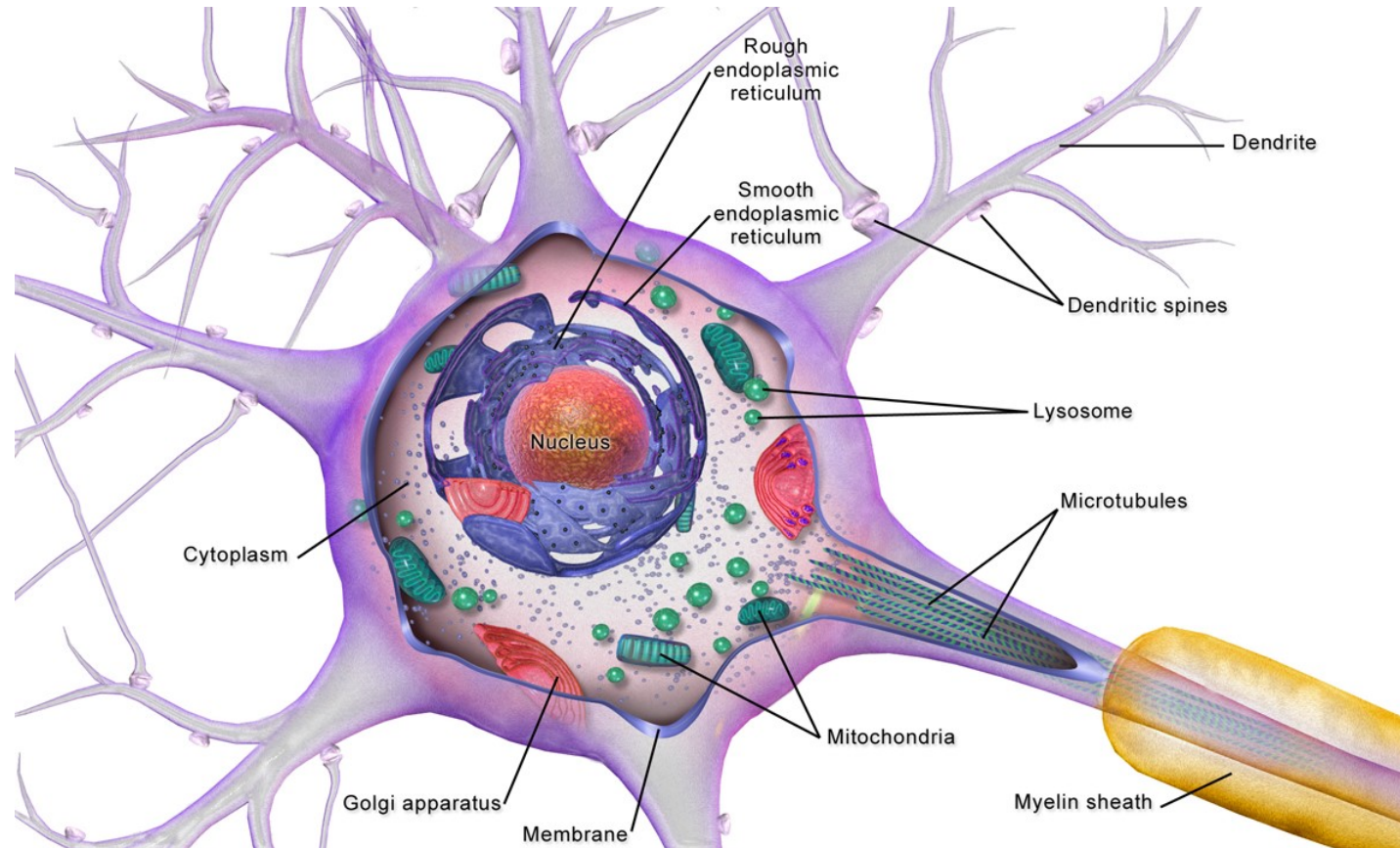
## Information processing and transmission

### The membrane

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

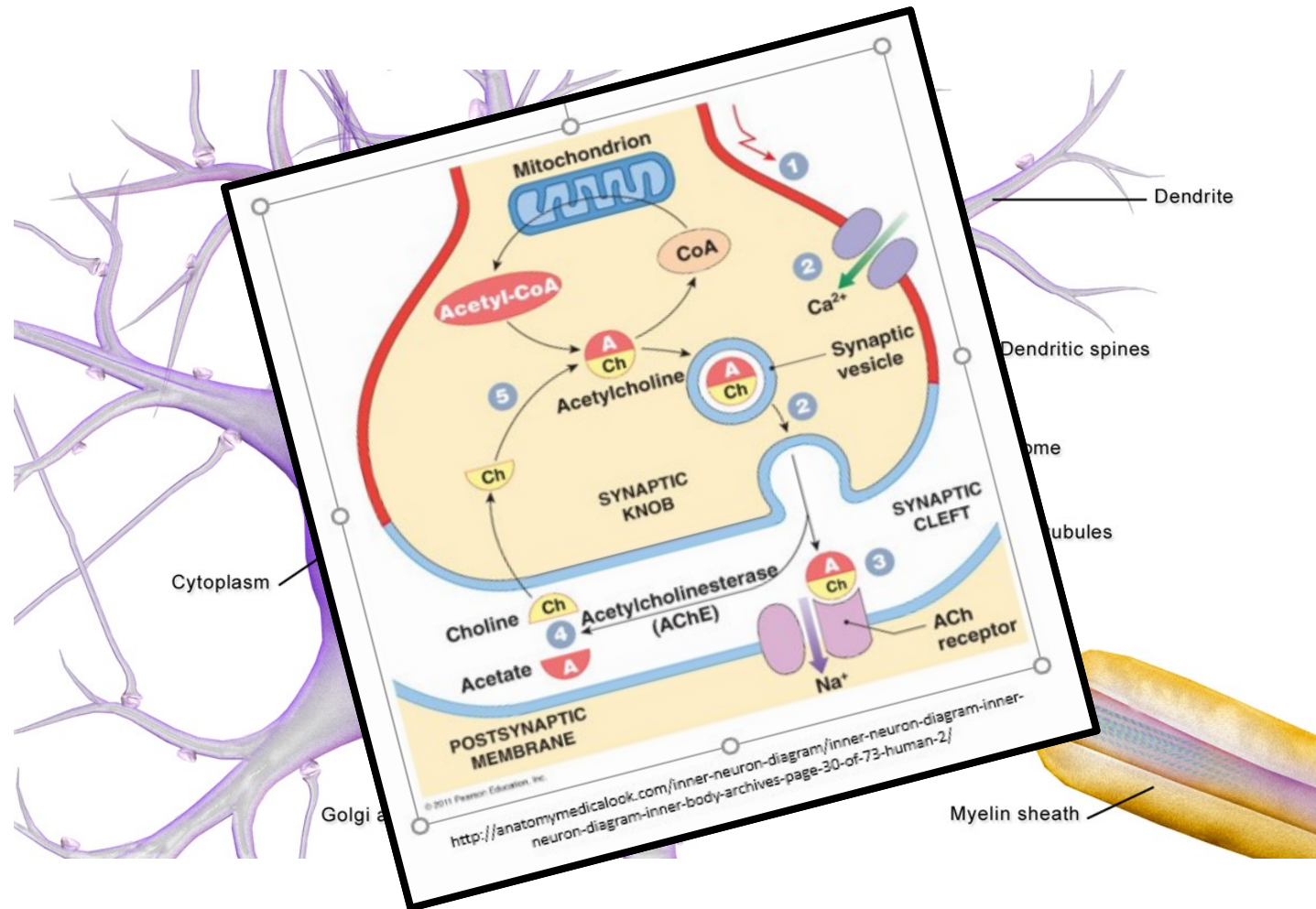
<http://www.slideshare.net/drpsdeb/presentations>

# Background Activity



[https://upload.wikimedia.org/wikipedia/commons/e/ed/Neuron\\_Cell\\_Body.png](https://upload.wikimedia.org/wikipedia/commons/e/ed/Neuron_Cell_Body.png)

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[https://upload.wikimedia.org/wikipedia/commons/e/ed/Neuron\\_Cell\\_Body.png](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

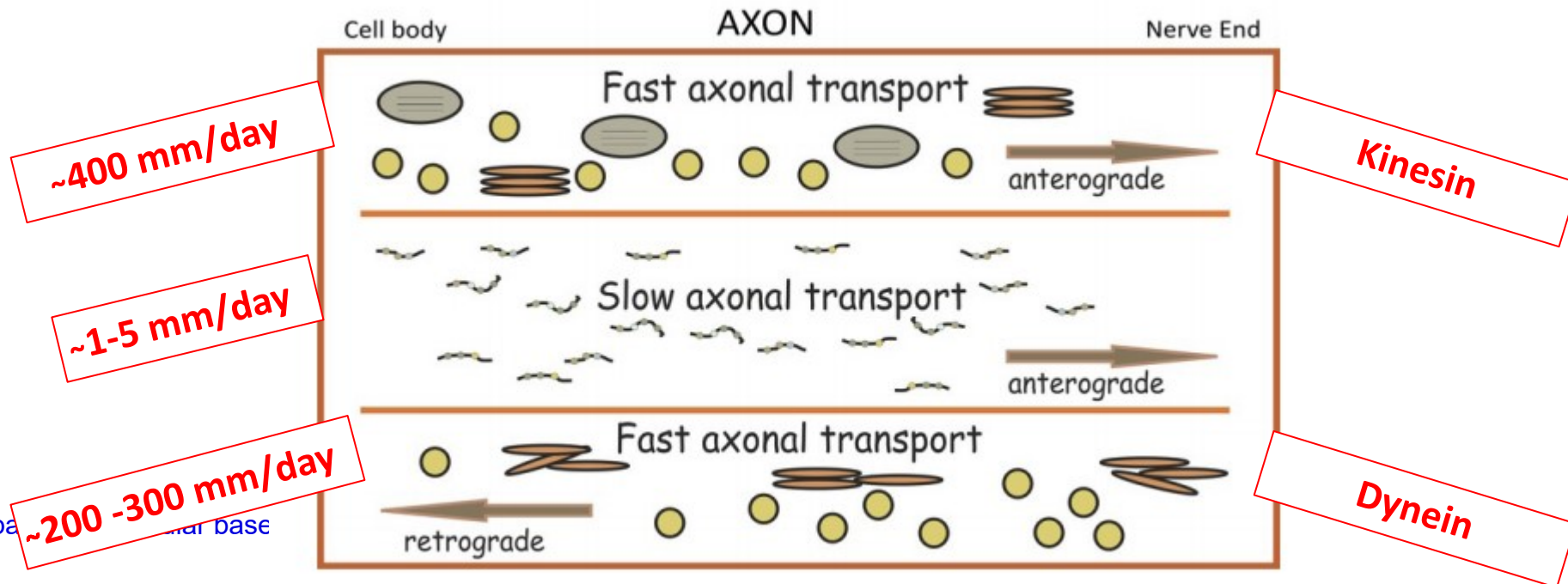
Golgi derived vesicles  
lysosomes, mitochondria  
structural elements of  
endoplasmic reticulum

## Slow axonal transport

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

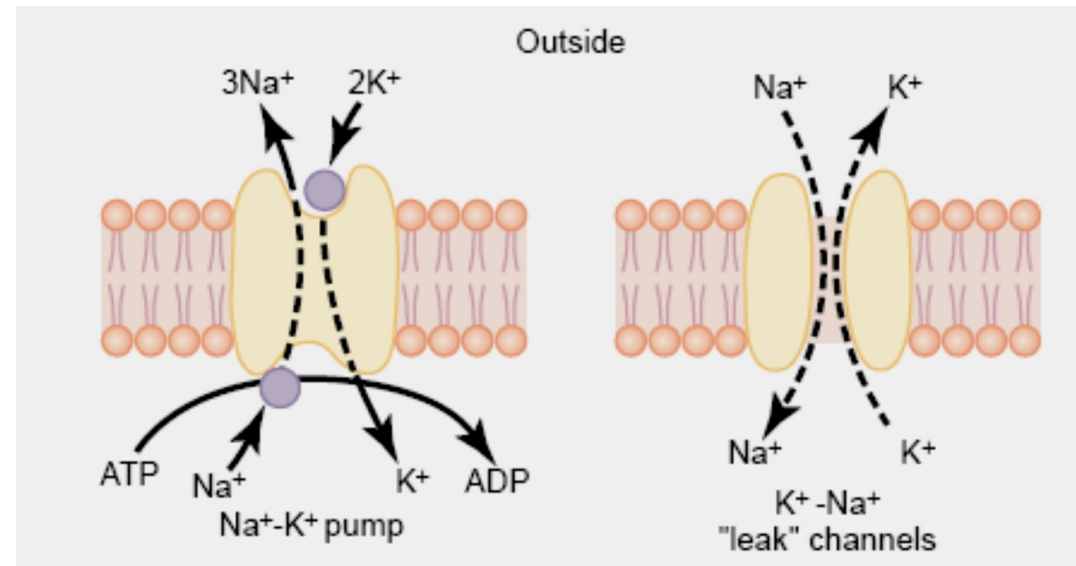
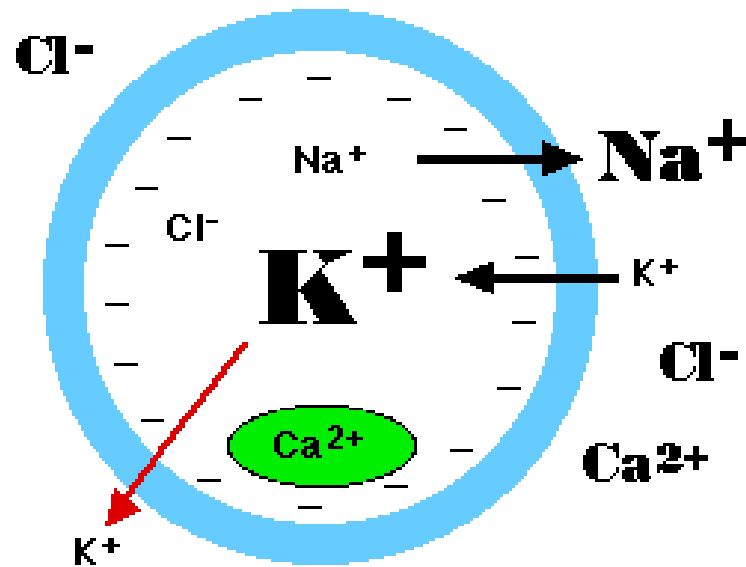
## Slow axonal transport

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



<http://assassinscreed.ubi.com>

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**

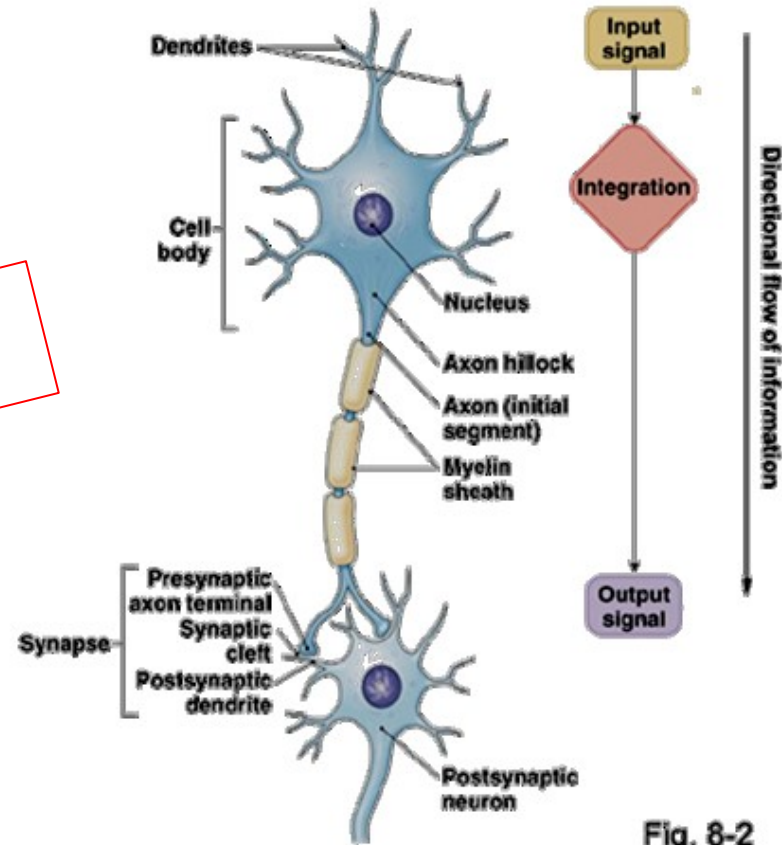
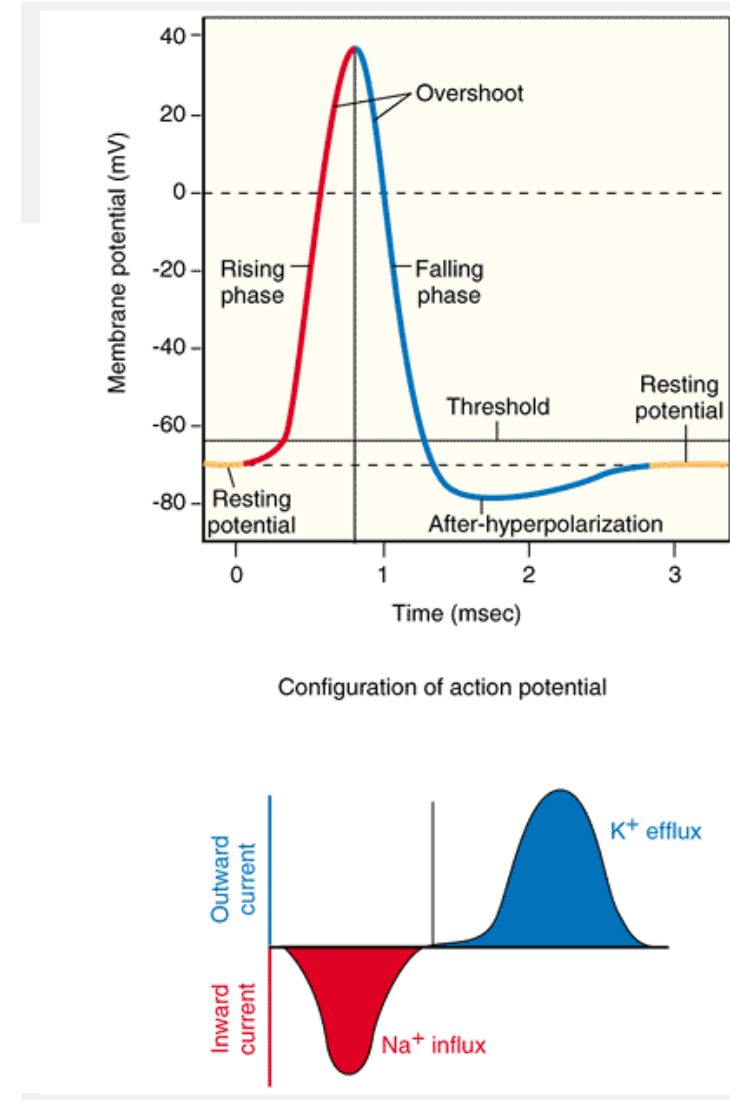
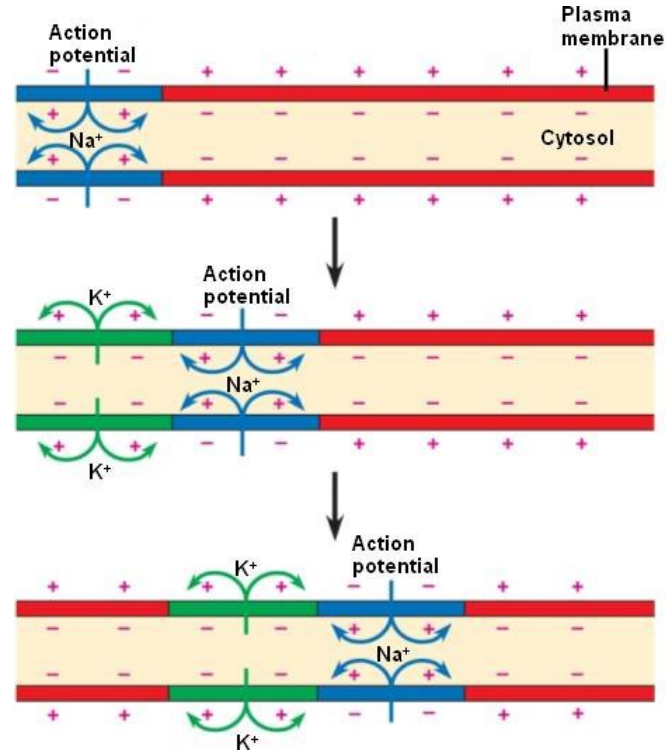
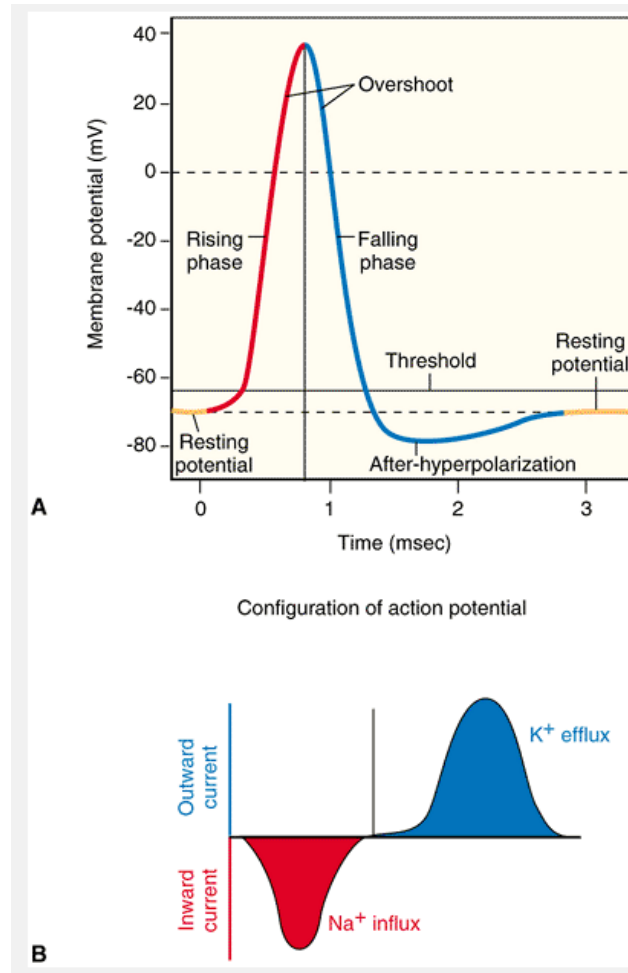


Fig. 8-2





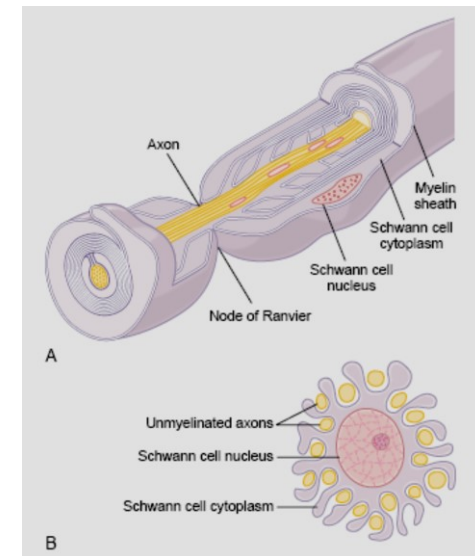
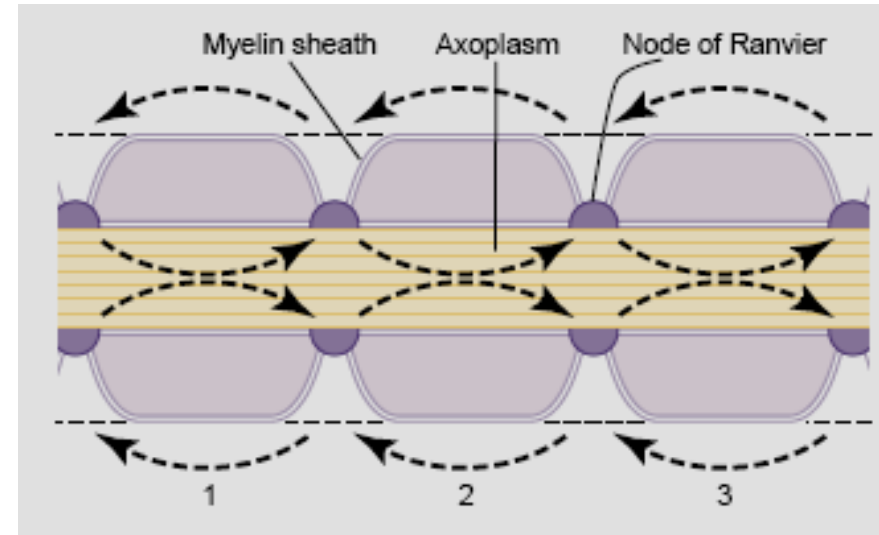
# Action potential spreading



- Local currents
- Anterograde

# Saltatory conduction

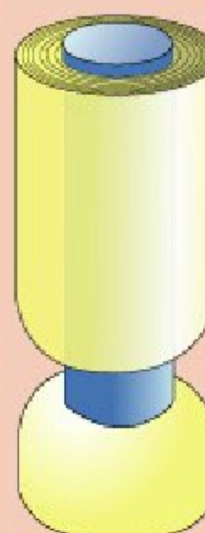
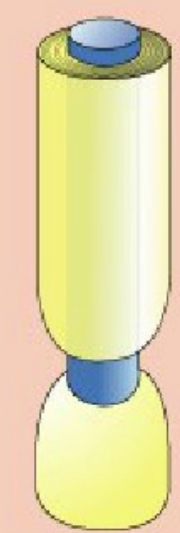


- Myelin sheath
- Nodes of Ranvier
- Economy
- Speed of conduction
- Speed of conduction also dependent of nerve fibre diameter
  - the electrical resistance is inversely proportional to area of cross-section



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

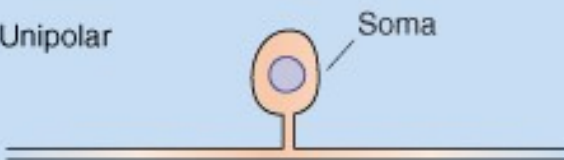

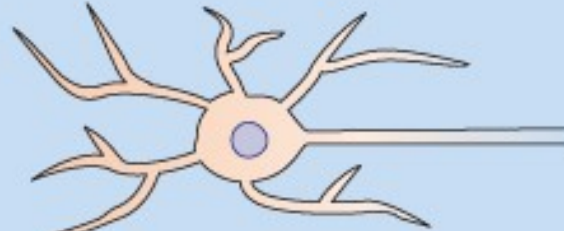
# Classification of nerve fibers

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

	A $\alpha$	A $\beta$	A $\delta$	C
1 <sup>o</sup> Axon to skin				
1 <sup>o</sup> 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

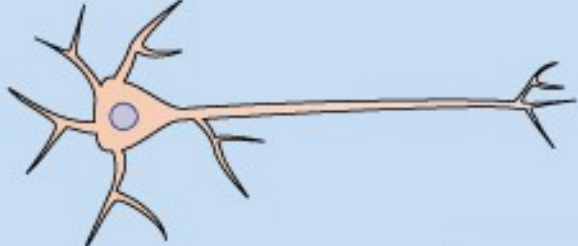
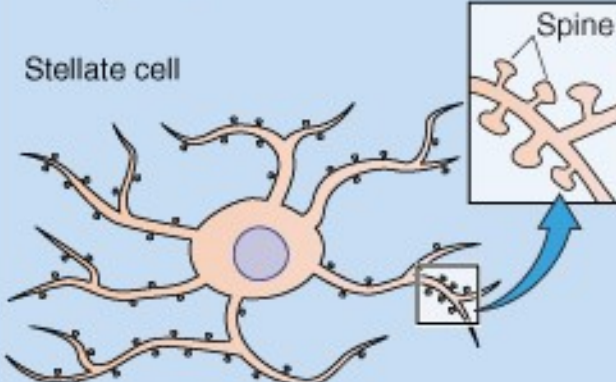
<http://neuroscience.uth.tmc.edu/s2/chapter04.html>

# Neuronal classification

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

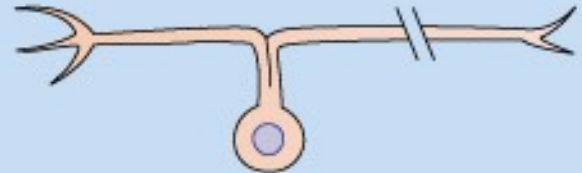

<http://www.slideshare.net/CsillaEgri/presentations>

# Neuronal classification

Basis for classification	Example	Functional implication	Structure
<p><b>2. Dendritic pattern</b></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
<b>1. Axonal projection</b>  Goes to a distant brain area    Stays in a local brain area	Projection neuron or Principal neuron or Golgi type I cell (cortical motor neuron)	Affects different brain areas	Dorsal root ganglion cell  
	Intrinsic neuron or Interneuron or Golgi type II cell (cortical inhibitory neuron)	Affects only nearby neurons	Retinal bipolar cell  

<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

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