

**3**

# **Cellular base of nervous system**

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

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  - 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)

# Neuron

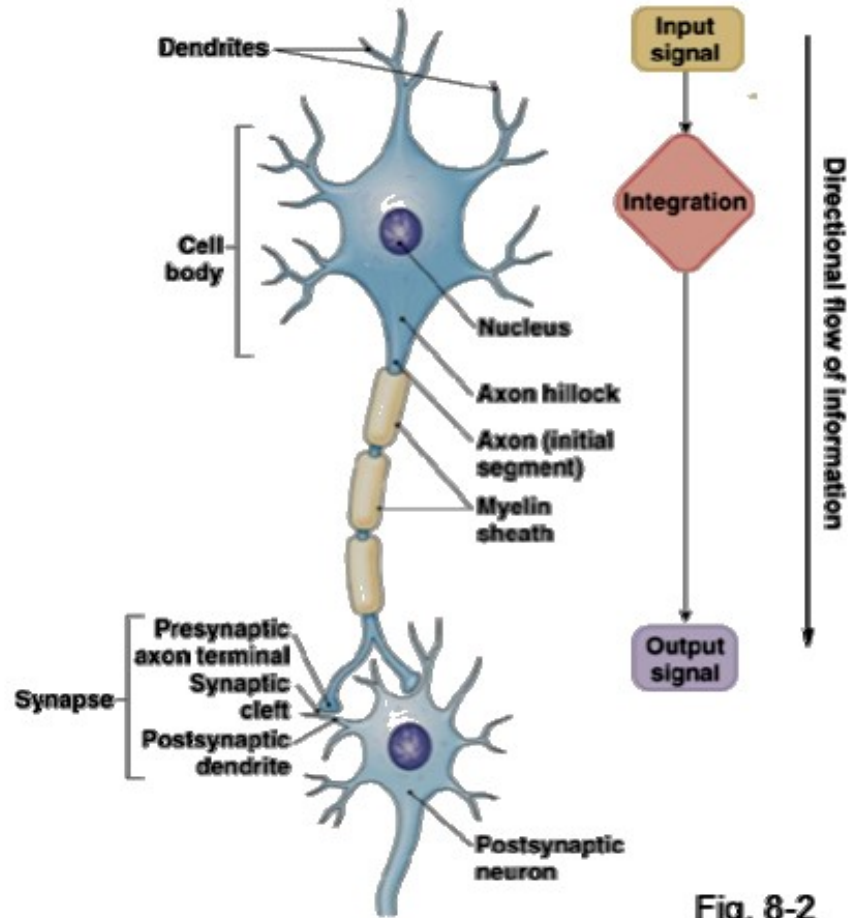


Fig. 8-2

## Main Activity

The inside of the cell

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

# Neuron

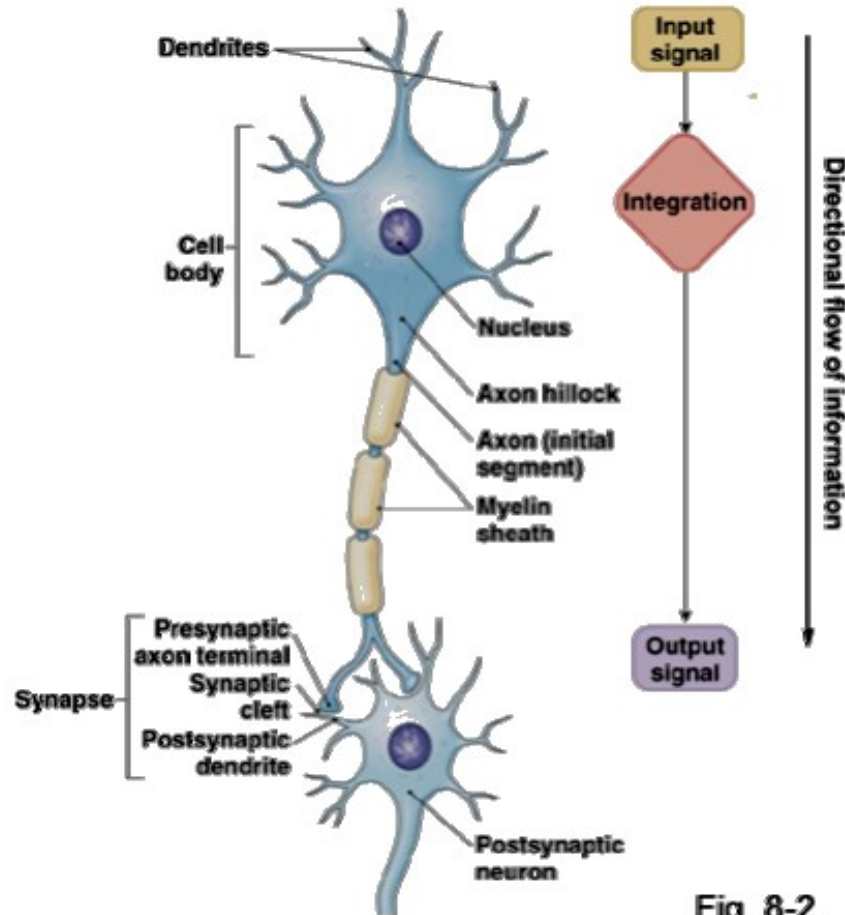


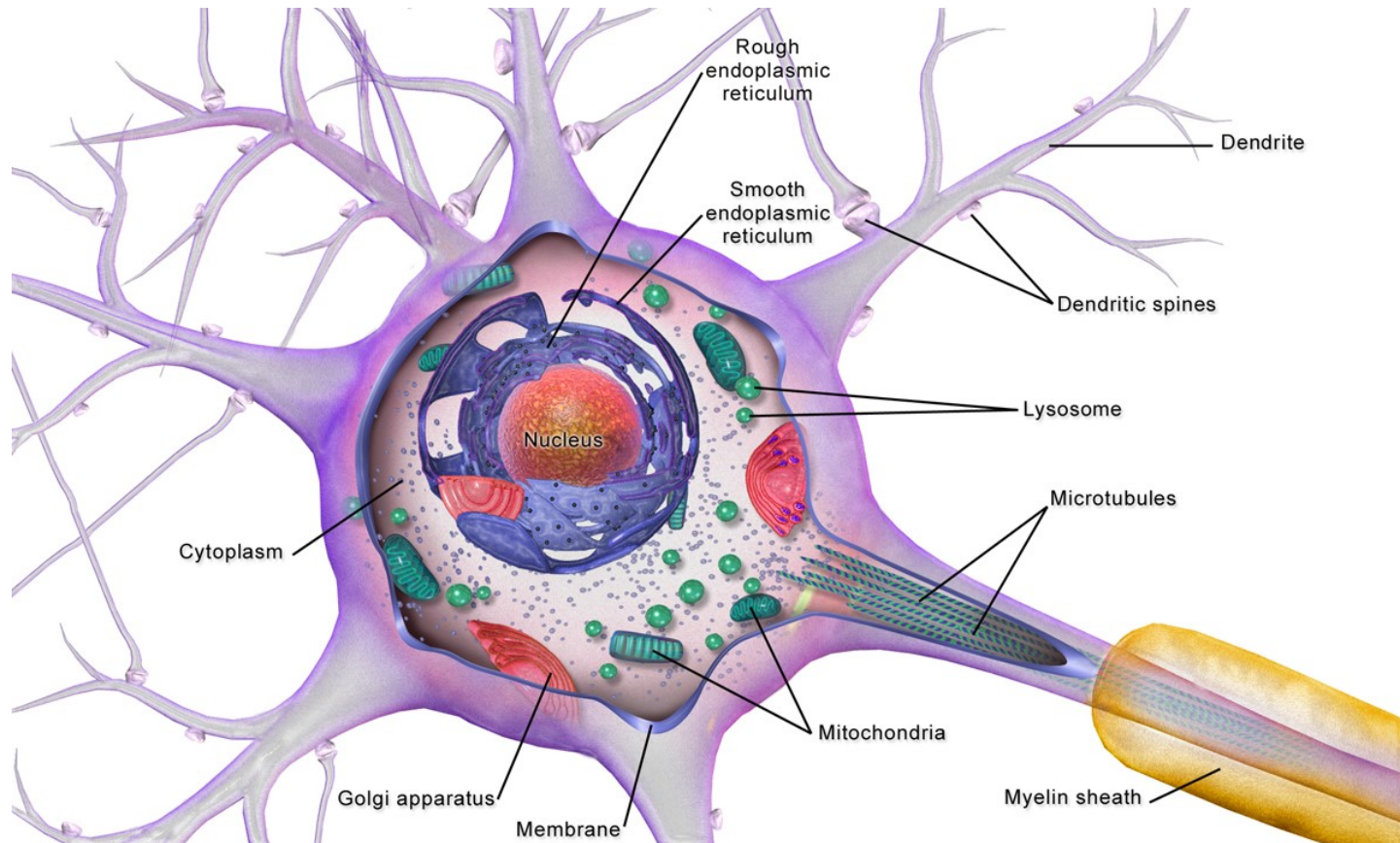
Fig. 8-2

## Information processing and transmission

The membrane

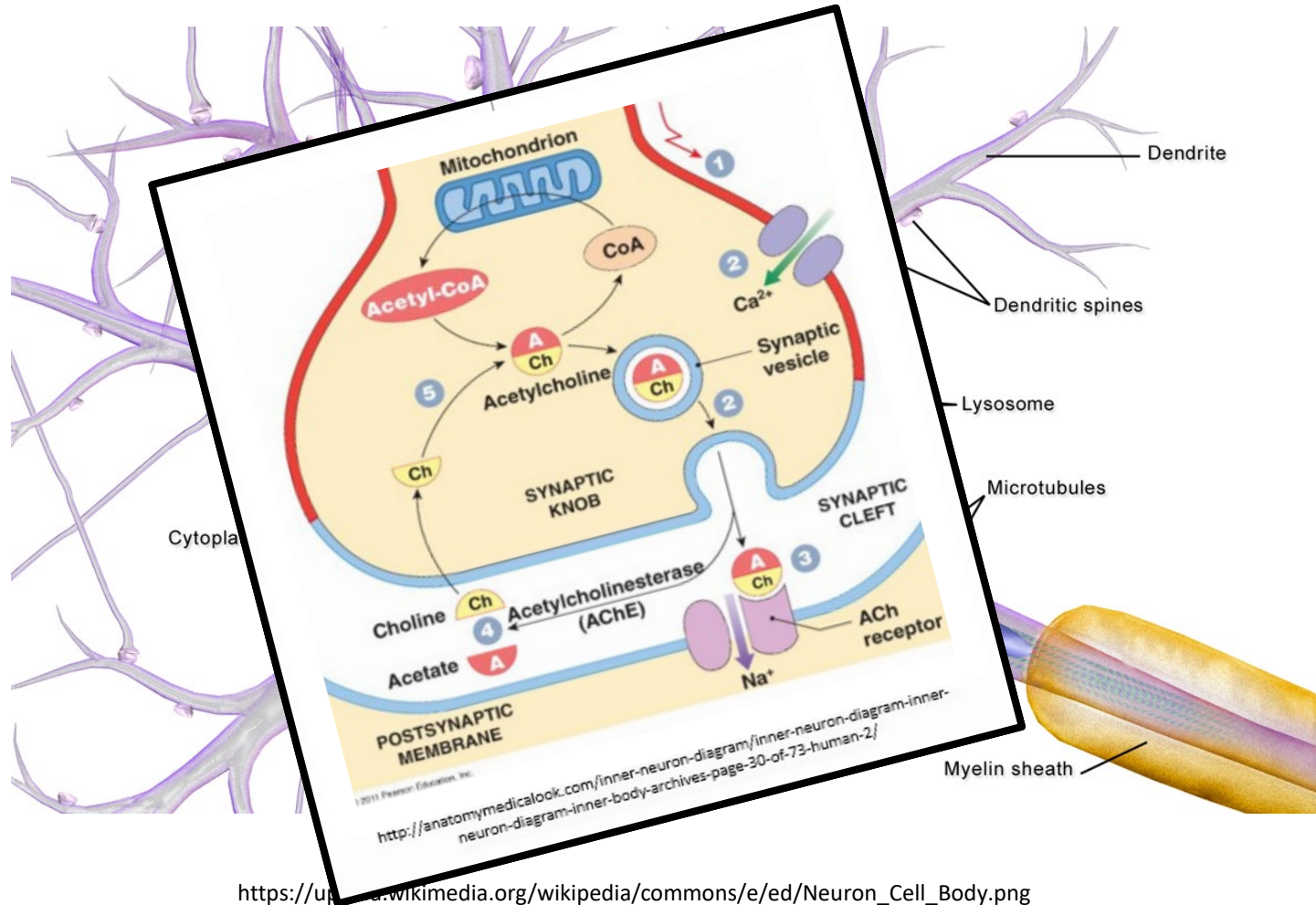
- ✓ Signal reception
- ✓ Signal integration
- ✓ AP generation
- ✓ AP propagation
- ✓ Signal transmission

# Maintain 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)

# Maintain 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)

# Maintain Activity

## Fast axonal transport

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

### Fast axonal transport

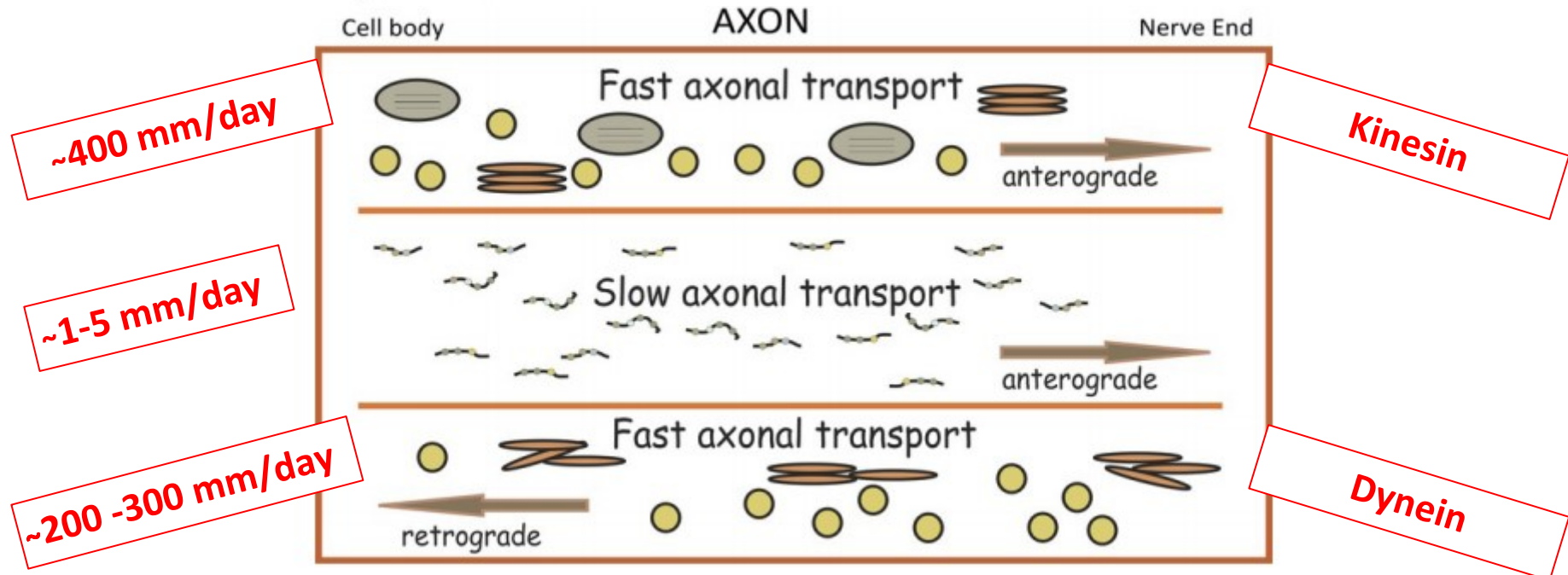
Golgi derived vesicles  
lysosomes, mitochondria  
structural elements of  
endoplasmic reticulum

## Slow axonal transport

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

### Slow axonal transport

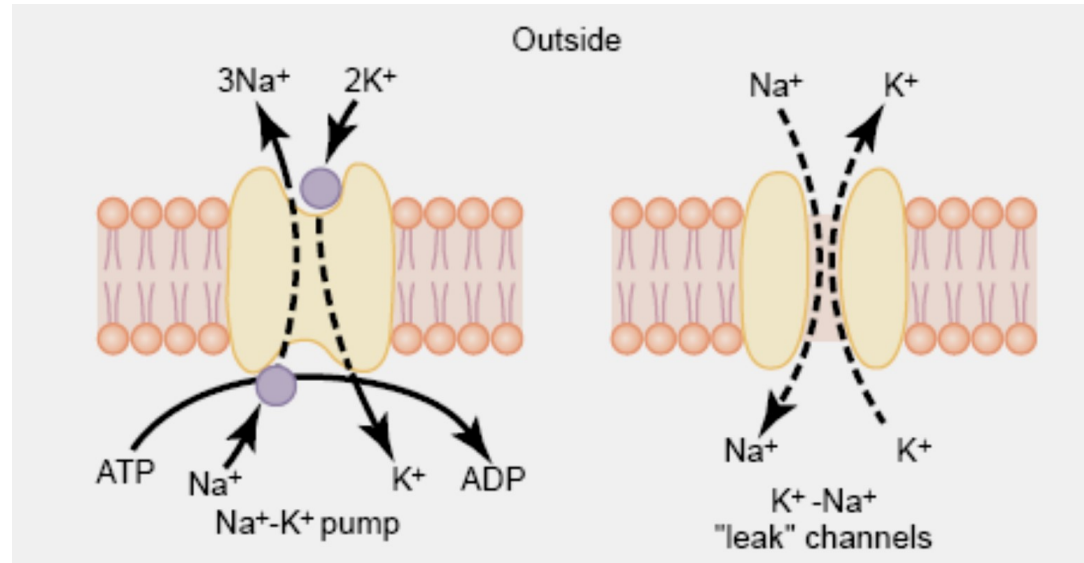
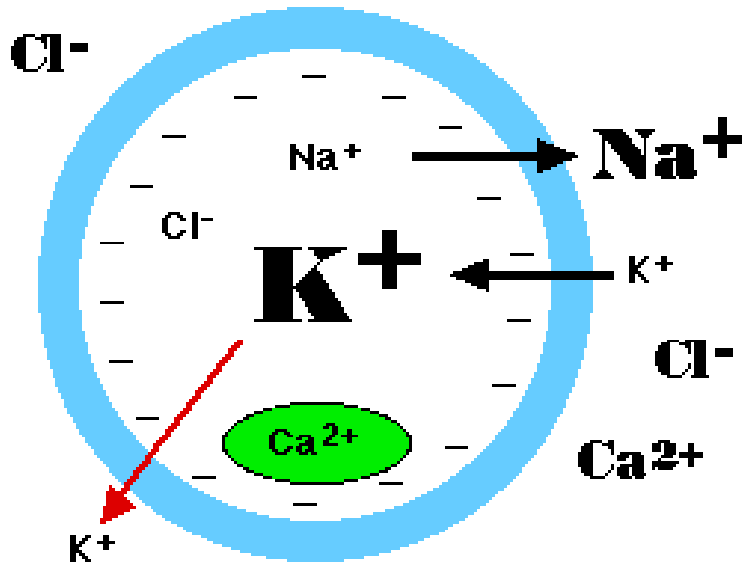
microfilaments, microtubules  
neurofilaments  
cytosolic protein complexes





# Membrane potential

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



# Resting membrane potential of a neuron



<http://assassinscreed.ubi.com>

- Highly instable state of membrane
- Why? – Speed!
- Brain consumption
  - ✓ 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

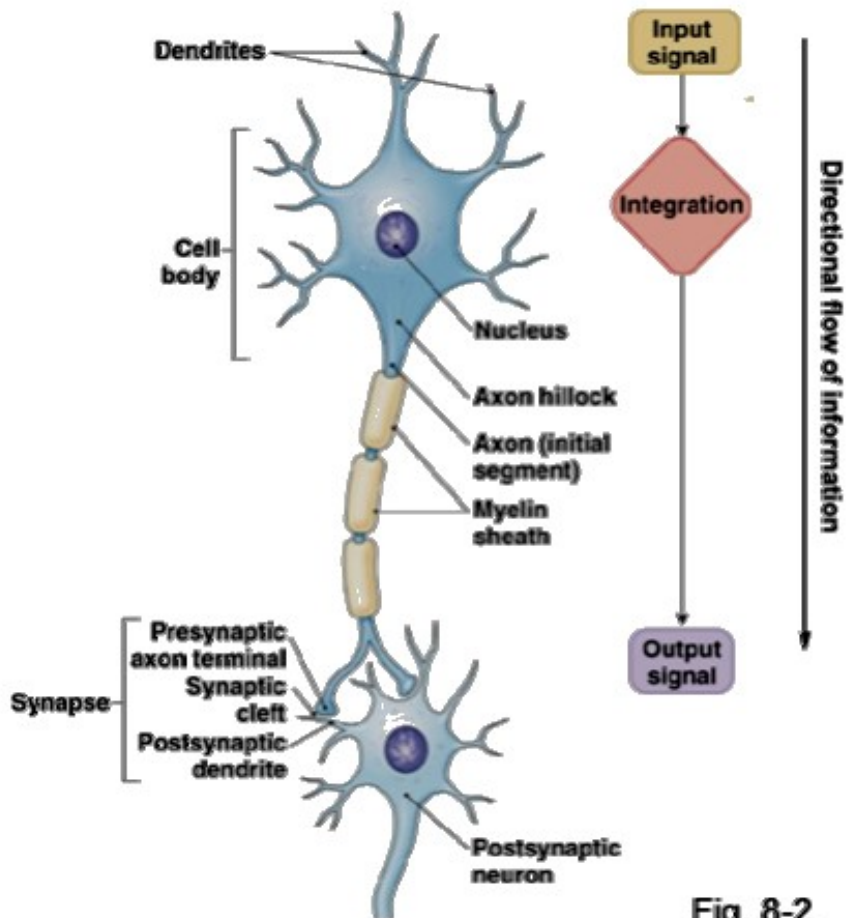
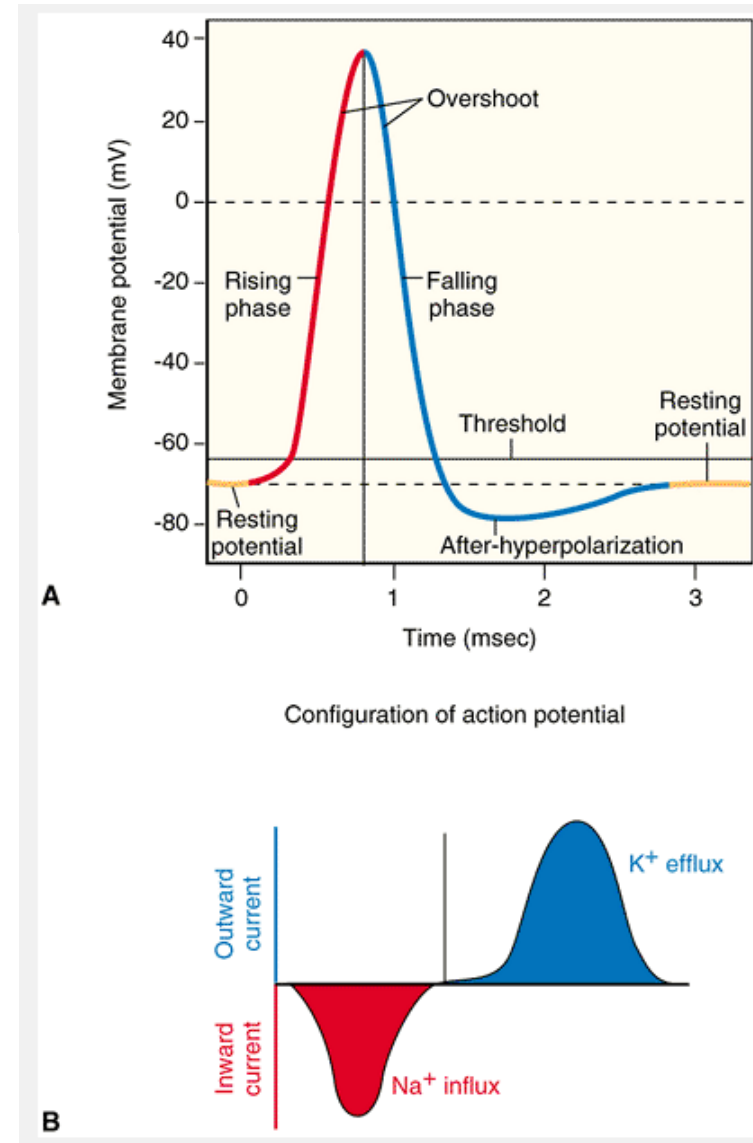
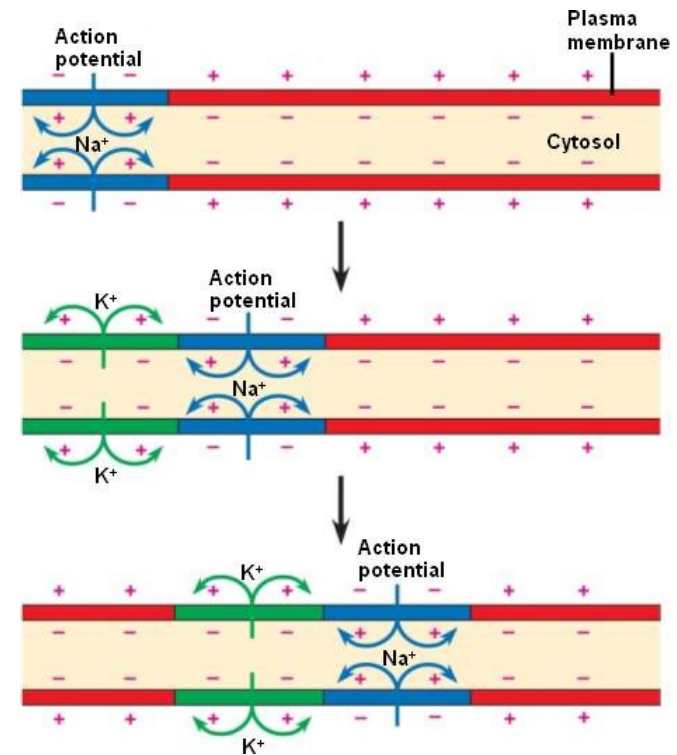
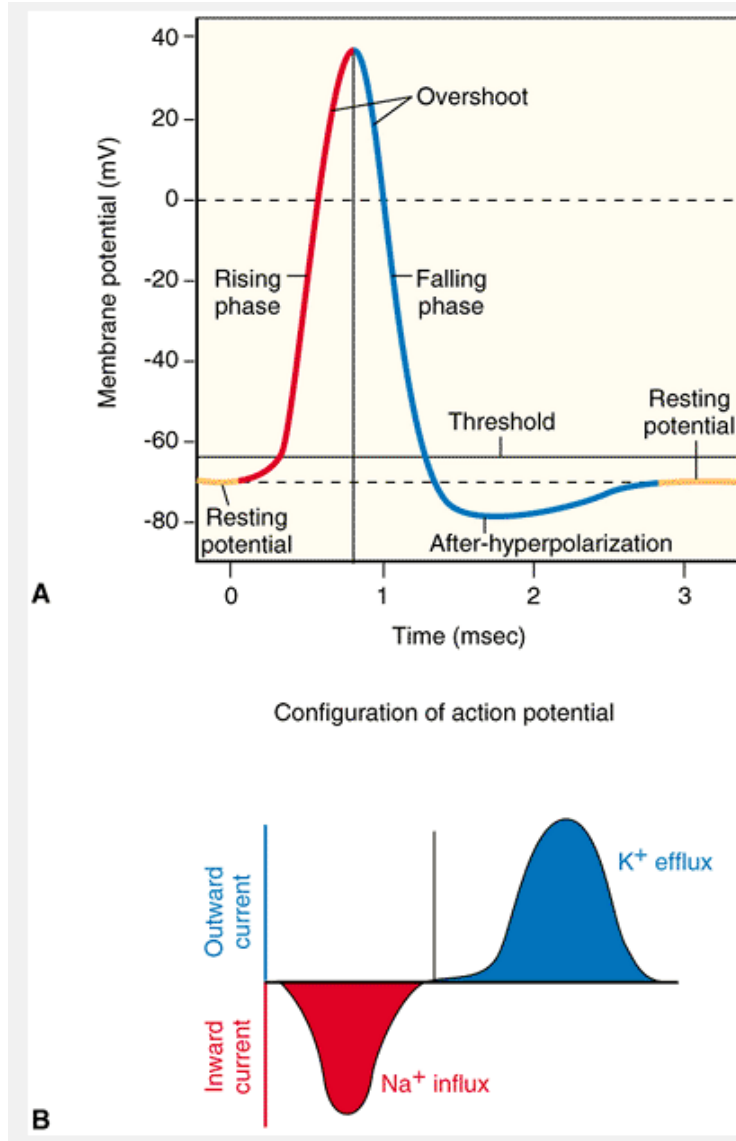


Fig. 8-2



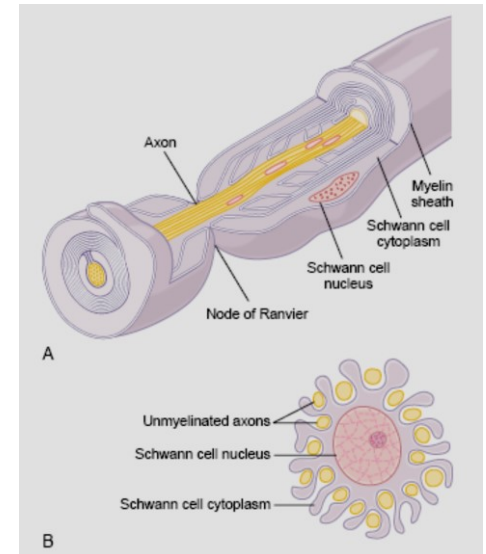
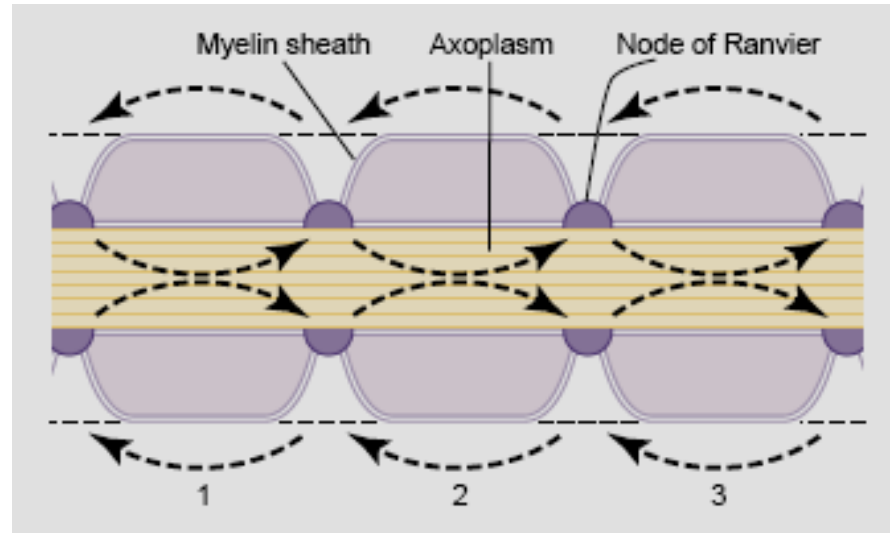
# Action potential spreading



- Local currents
- Anterograde

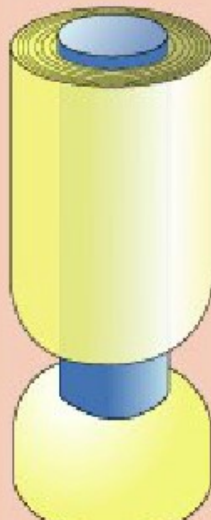



# Saltatory conduction

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

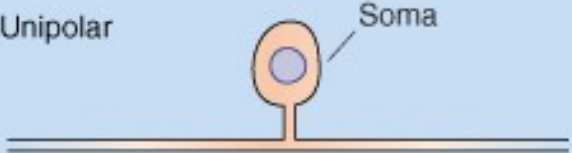

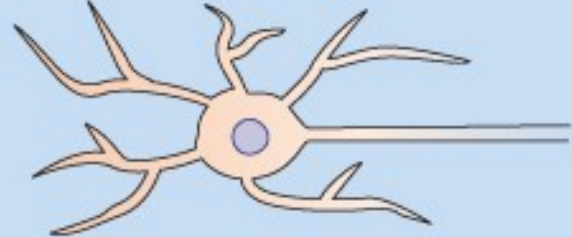


# Classification of nerve fibers

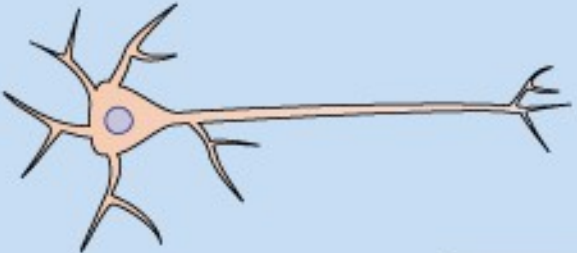
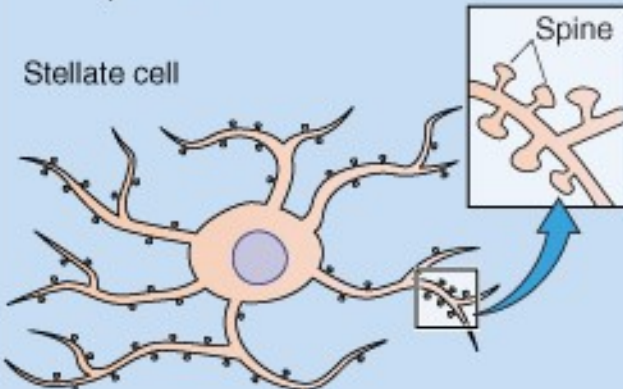
- In humans mostly myelinated
- All fibers are myelinated in CNS
- Non-myelinated are evolutionary old ones

	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

# Neuronal classification

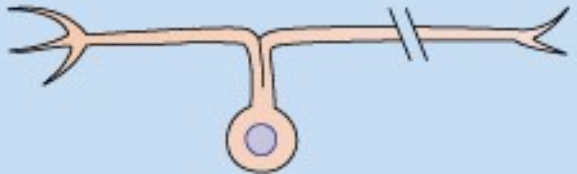

Basis for classification	Example	Functional implication	Structure
<p><b>3. Number of processes</b></p> <p>One process exits the cell body</p> <p>Two processes exit the cell body</p> <p>Many processes exit the cell body</p>	<p>Unipolar neuron (dorsal root ganglion cell)</p> <p>Bipolar neuron (retinal 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>

# Neuronal classification

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



# Neuronal classification

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

# 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

- Satellite cells
  - Support functions in PNS

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## Peripheral nervous system

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

# 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



# Cellular base of nervous system

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

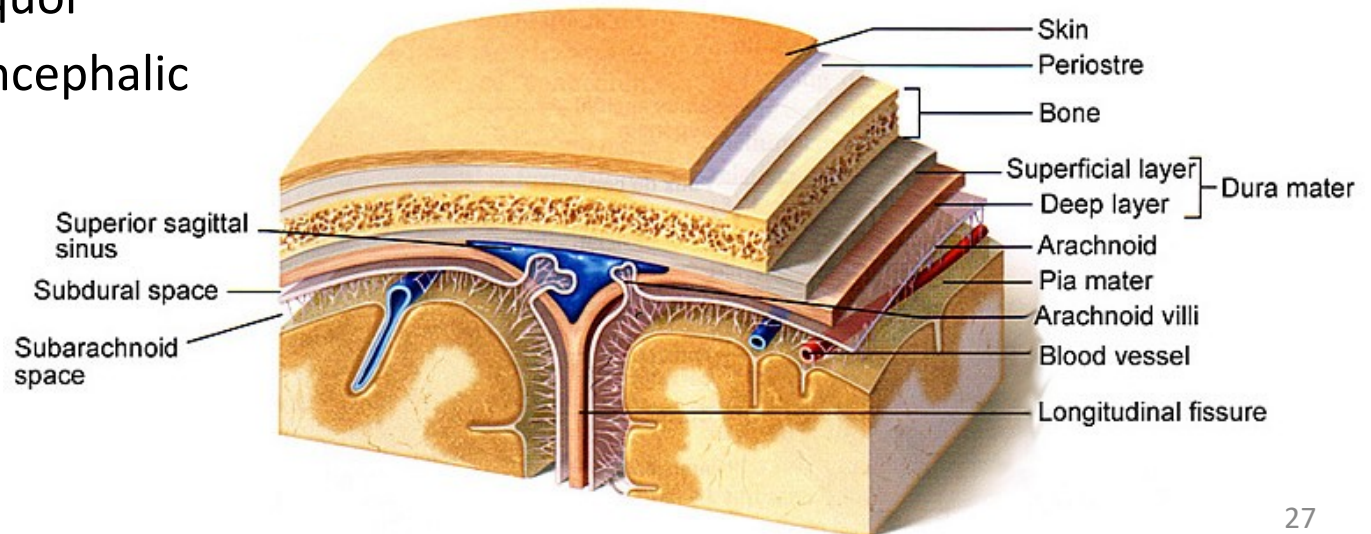
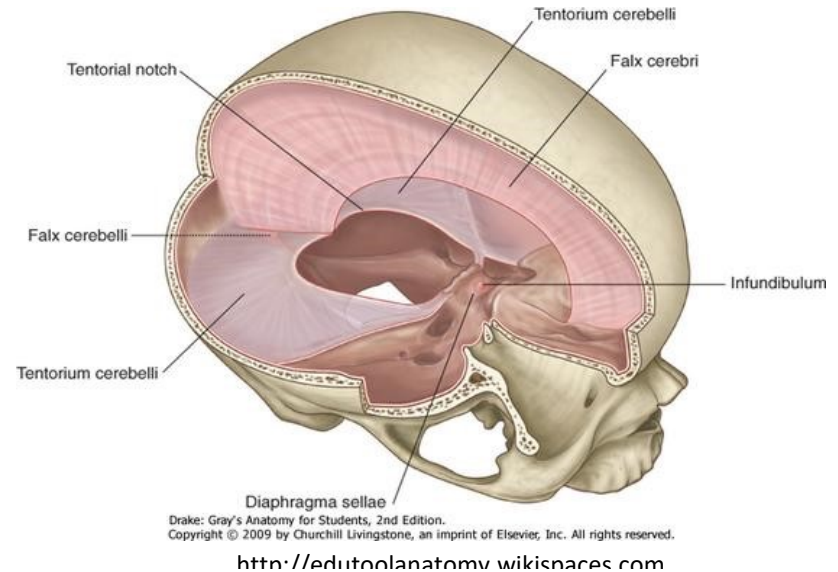
# Cellular base of nervous system

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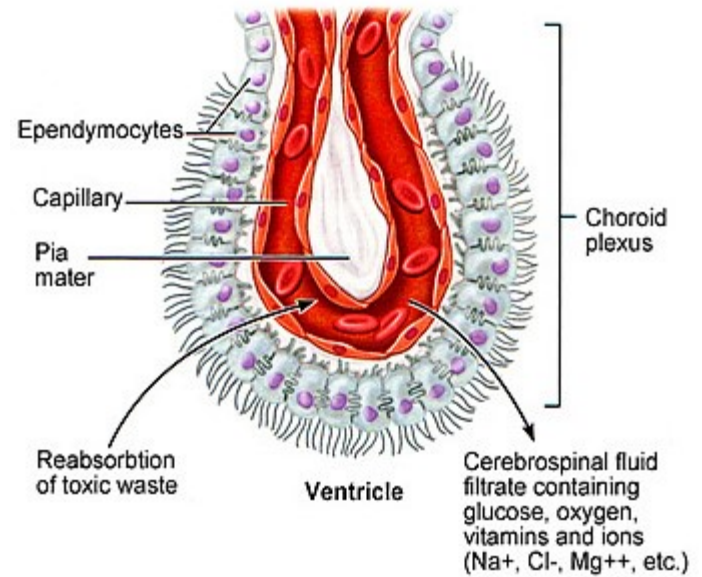
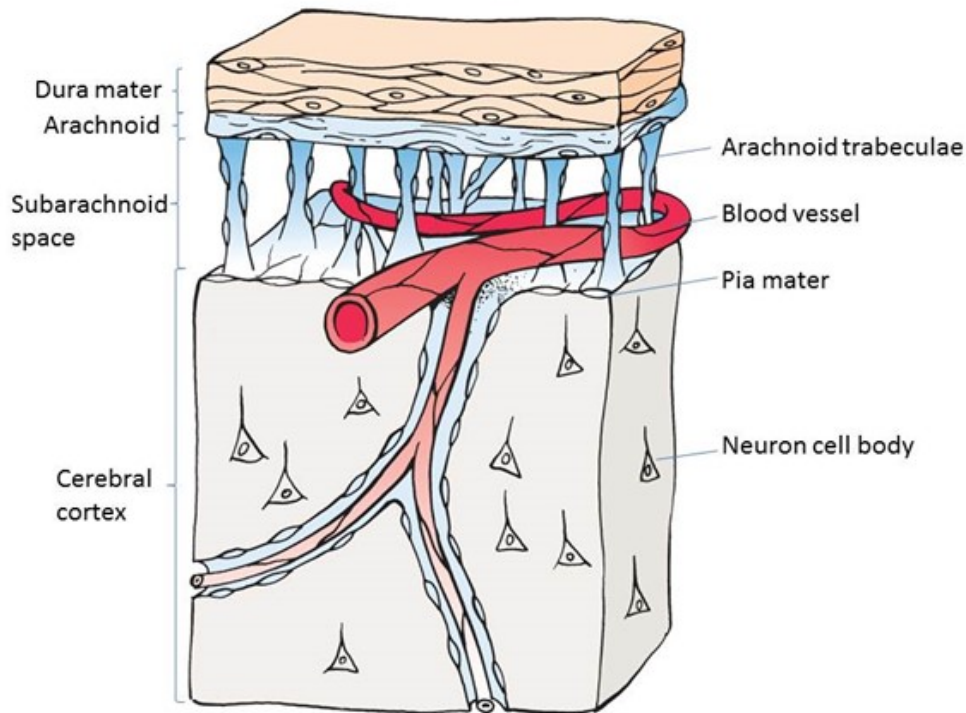
This allows neuronal cells to live for the entire life of the individual

# Intracranial compartment

- Brain
- Cerebrospinal fluid
- Blood (intravascular)
- Barriers
  - Meningeal
  - Hematoliquor
  - Hematoencephalic



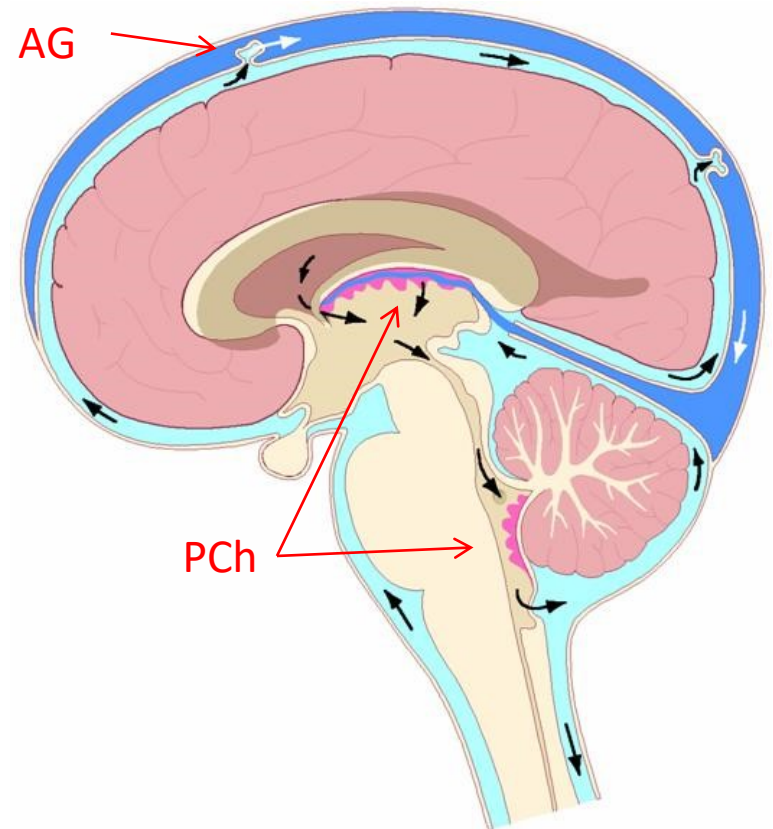
# Meningeal and hematoliquor barrier



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

# Cerebrospinal fluid

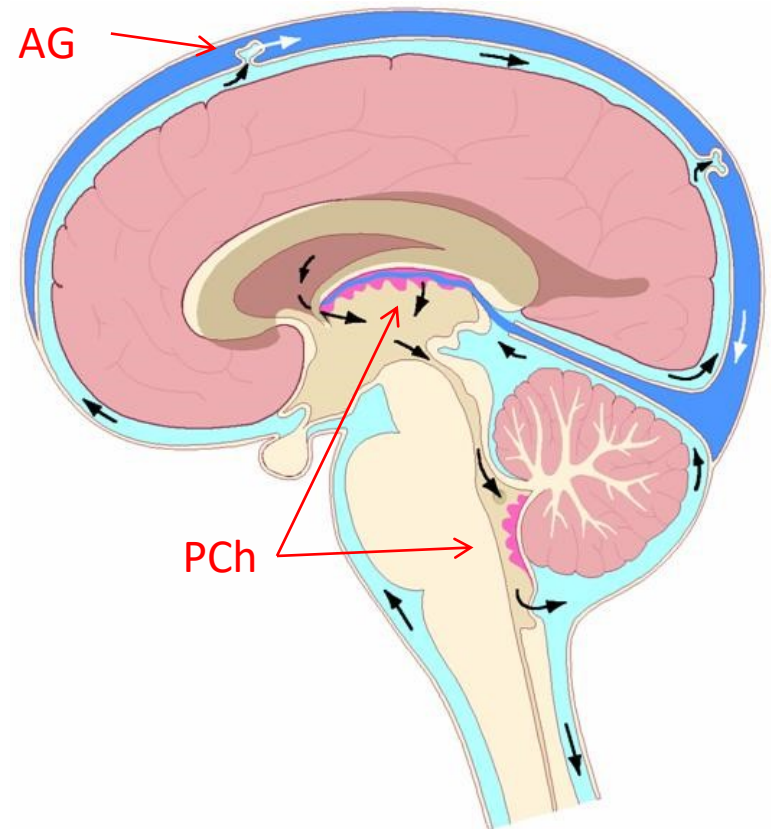
- Clear fluid produced by active secretion
- Liquor space
  - lined by ependymal cells
  - 150-250 ml



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

# Cerebrospinal fluid

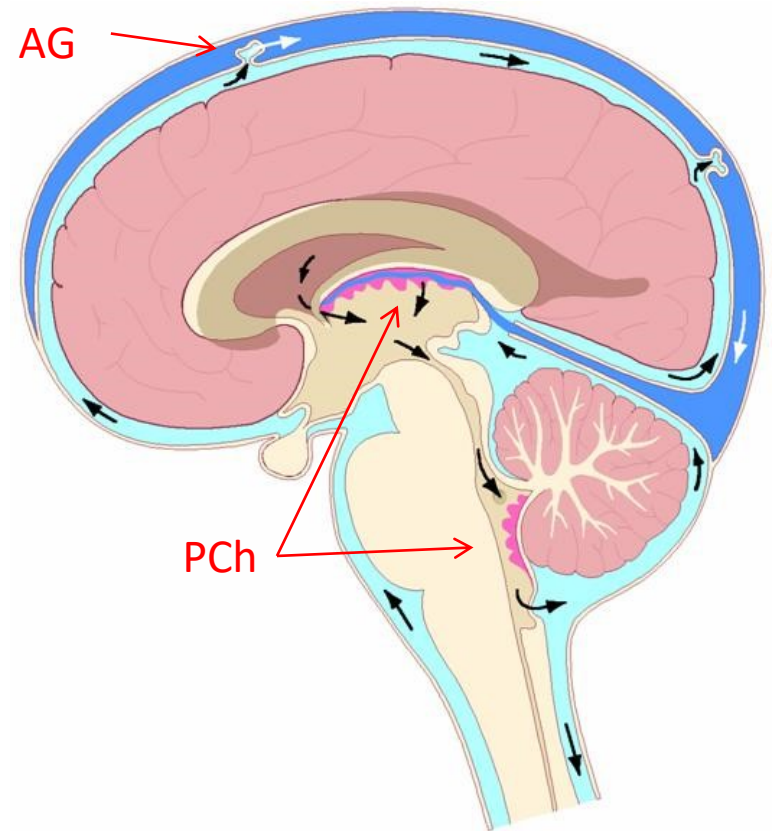
- Clear fluid produced by active secretion
- Liquor space
  - lined by ependymal cells
  - 150-250 ml
- Production
  - ✓ Plexus choroideus (PCh) -70%
  - ✓ Cell metabolism
  - ✓ Capillary filtration
  - 450-750 ml/day
- Resorption
  - ✓ Archnoid granulations (AG)



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

# Cerebrospinal fluid

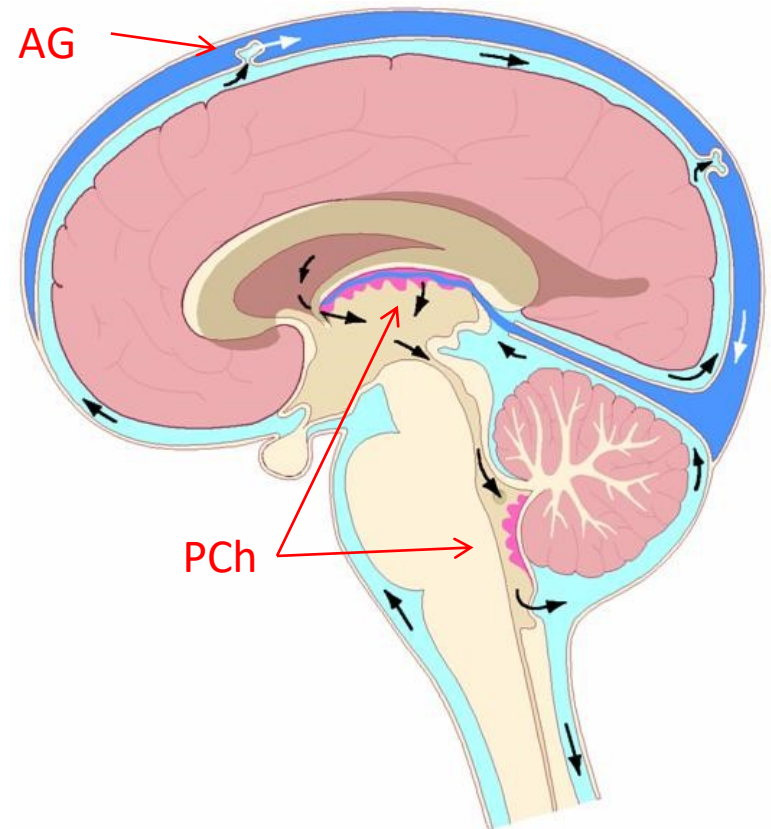
- Content
  - ✓ High levels of  $Mg^{+}$  and  $Na^{+}$
  - ✓ Low levels of  $K^{+}$  and  $Ca^{2+}$
  - ✓ Almost no cells (max 5/ml)



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

# Cerebrospinal fluid

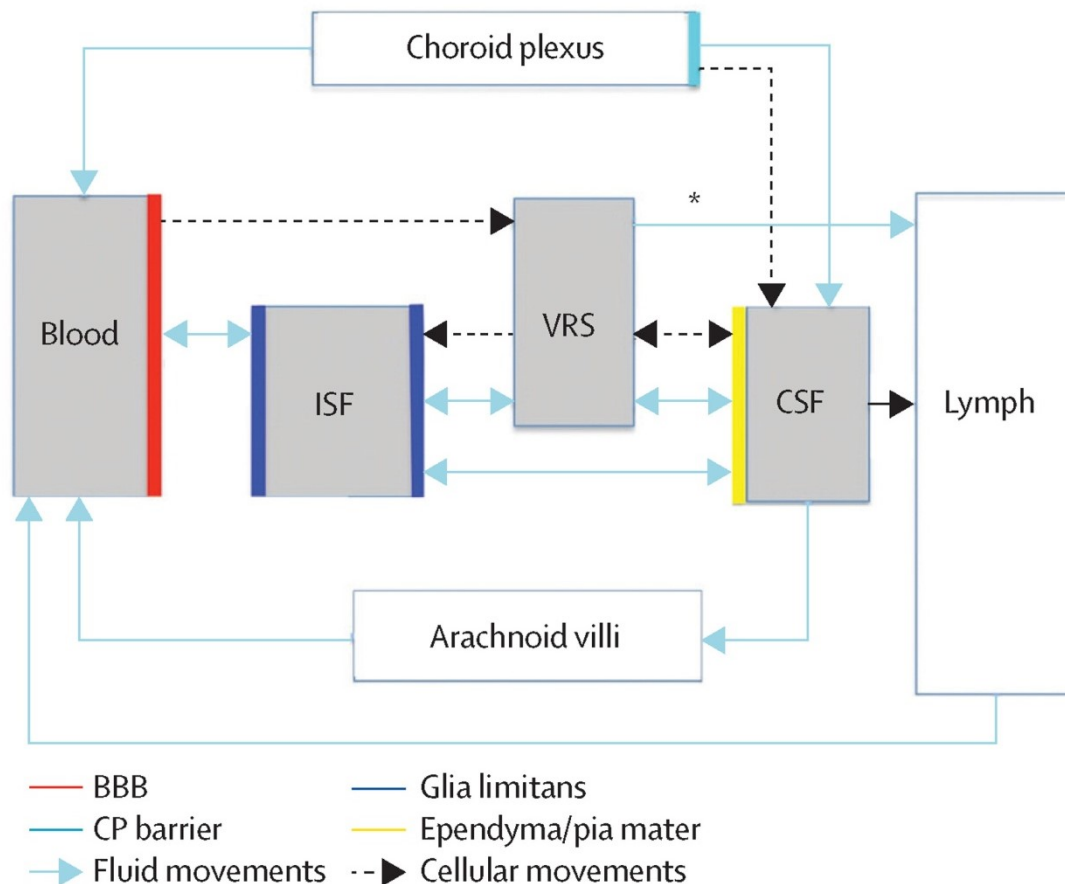
- Content
  - ✓ High levels of  $Mg^{+}$  and  $Na^{+}$
  - ✓ Low levels of  $K^{+}$  and  $Ca^{2+}$
  - ✓ Almost no cells (max 5/ml)
- Function
  - ✓ Protection
  - ✓ Microenvironment of neurons and glia
    - Metabolic function
    - Immunologic function
    - Transport function and so on



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



# New insight into the production and resorption of CSF

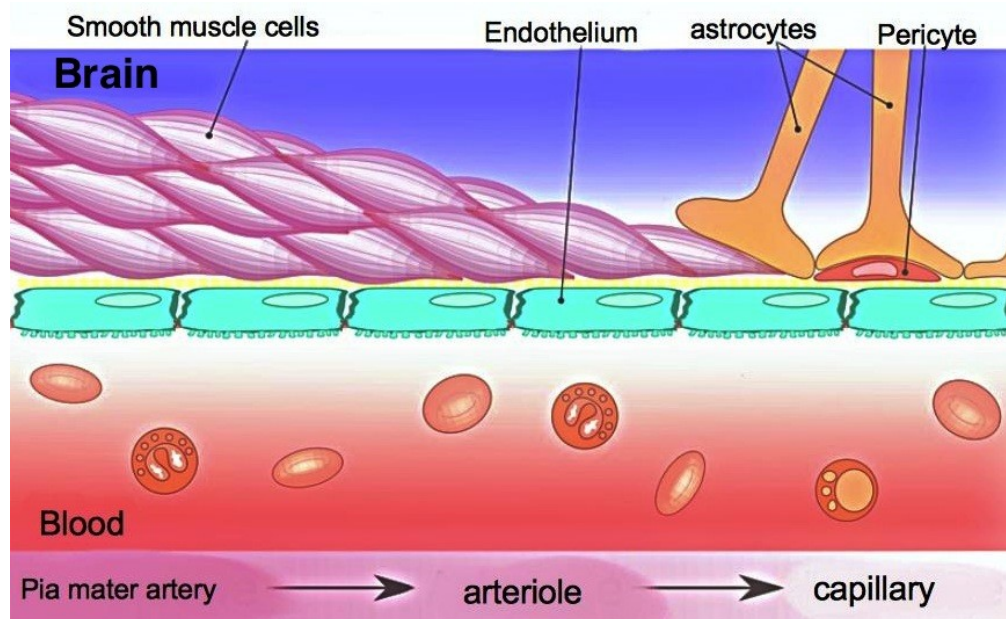


- CSF – cerebrospinal fluid
- ISF – interstitial fluid
- VRS – Virchow Robin space (space between the pia mater and an artery or a vein, but not capillaries)

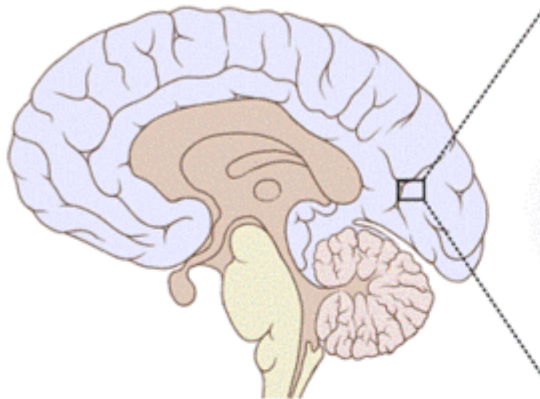
Ducros A, Biousse V. Headache arising from idiopathic changes in CSF pressure. *The Neurology*. 2015;14:655–668.

# Hematoencephalic barrier

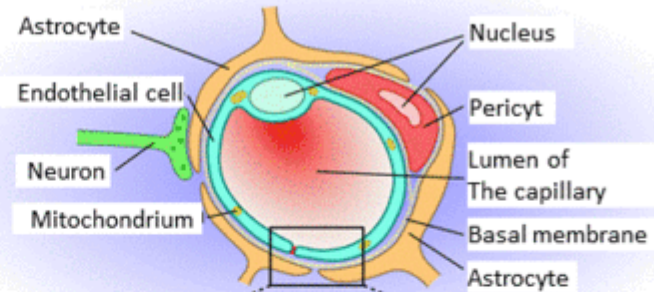
- Highly organised structure
  - Endothelial cells (low permeability thanks to zonula occludens)
  - Lamina basalis
  - Astrocytes



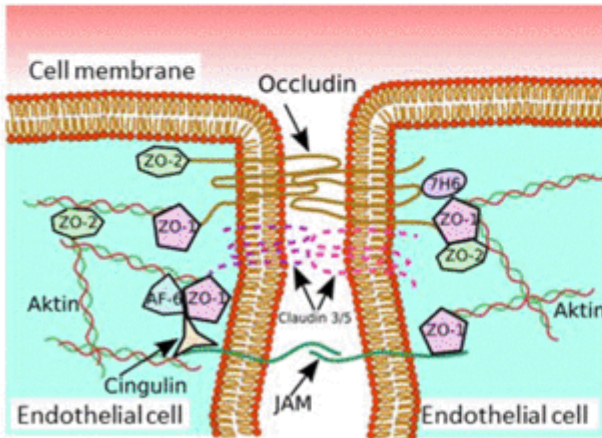
# Hematoencephalic barrier



## Cross section of blood vessel

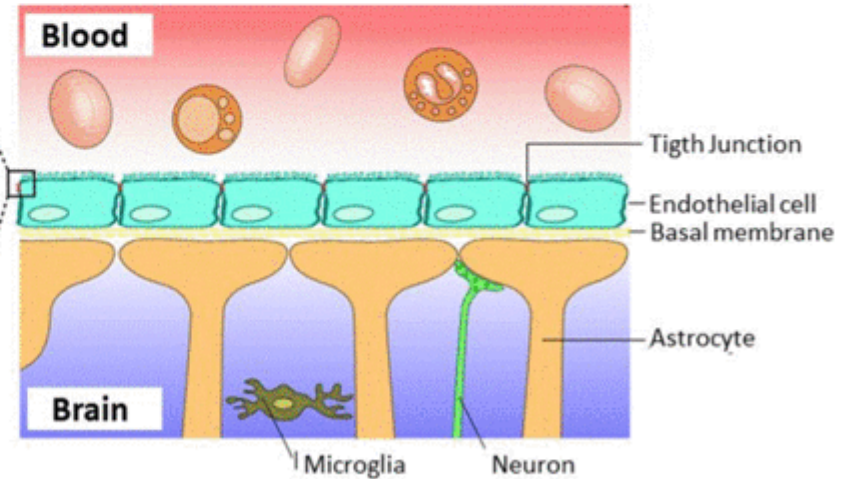


## Junction between Endothelial cells



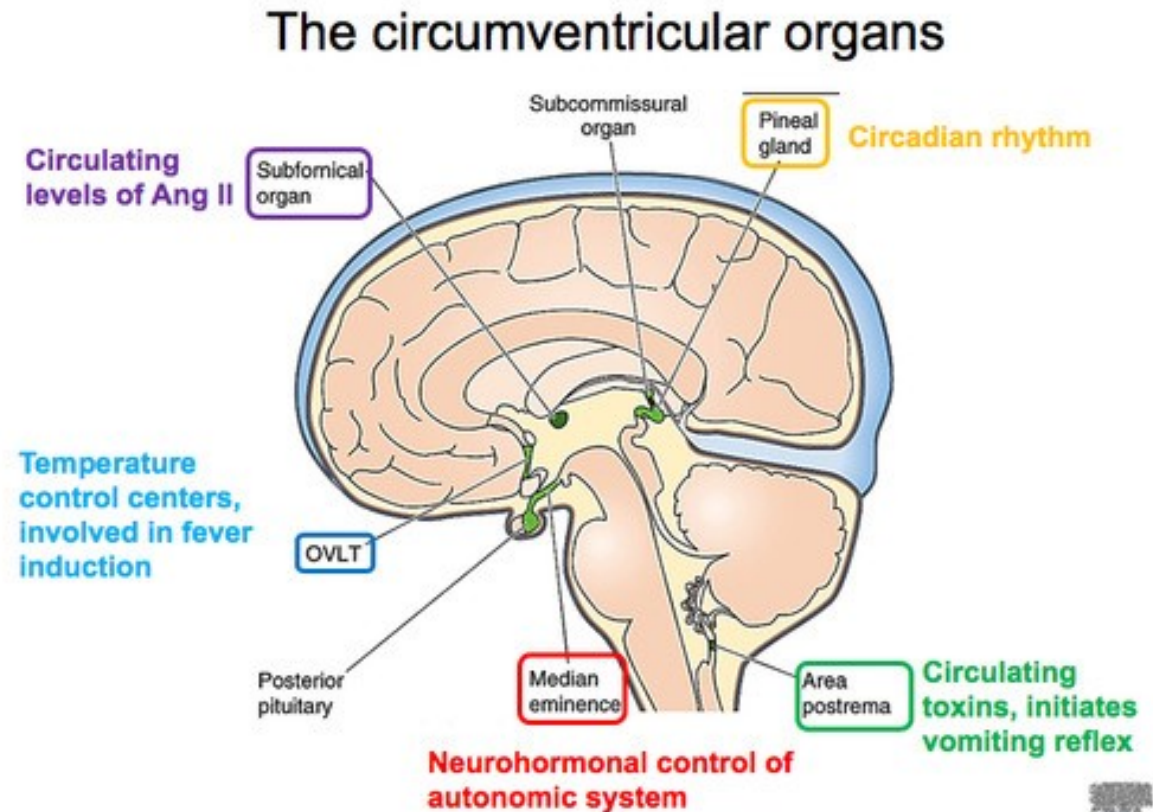
FSM (basic artwork: wikimedia commons)

## Longitudinal section of blood vessel



# Circumventricular organs

- Rich vascularisation
- Modified hematoencephalic barrier
- Sensors
- Secretion

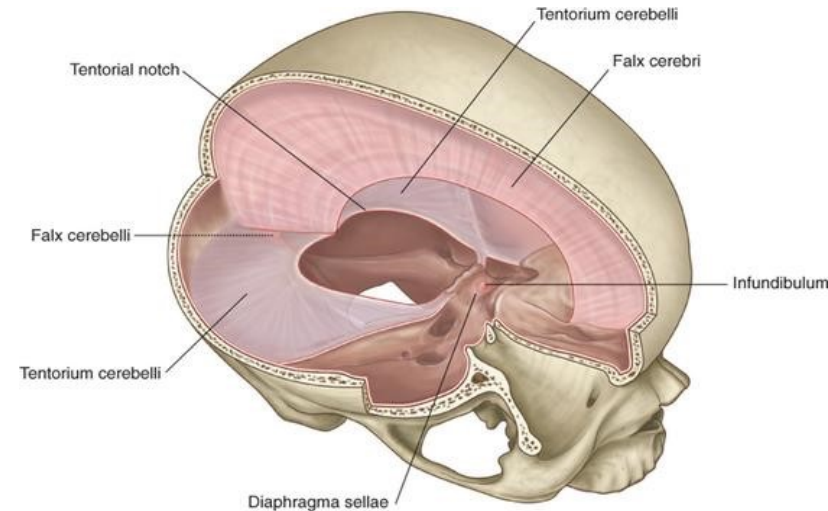


[http://www.neuros.org/index.php?option=com\\_photos&view=photos&oid=hafizbilal](http://www.neuros.org/index.php?option=com_photos&view=photos&oid=hafizbilal)



# Intracranial compartment

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



Drake: Gray's Anatomy for Students, 2nd Edition.  
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<http://edutoolanatomy.wikispaces.com>

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

Cerebral perfusion pressure

Intracranial pressure

Mean arterial pressure