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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

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Compartmentalization

- Cellular specialization leads to compartmentalizatio els
  - Tissue level
  - Organ level
  - Organ
- There are
- Properties/c among different compartments

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

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Compartmentalization

- Cellular specialization leads to compartmentalizatio els
  - Tissue level
  - Organ level
  - Organ
- There are
- Properties/c 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

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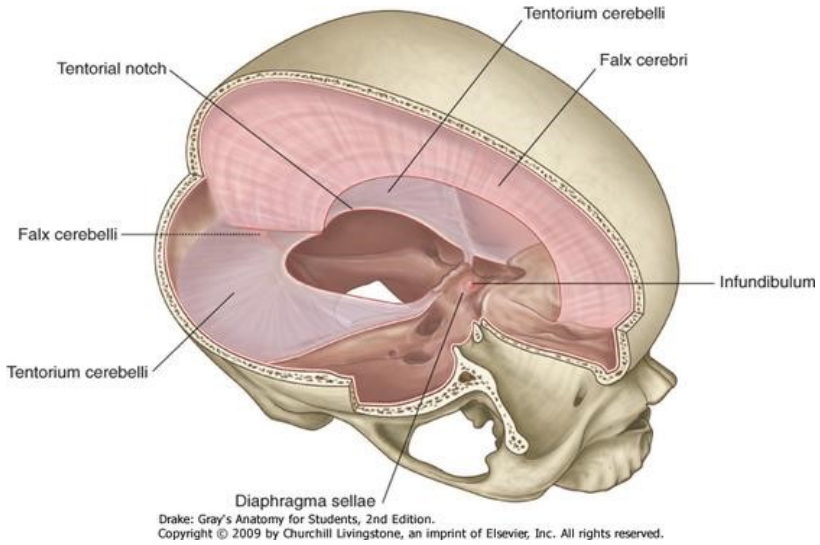
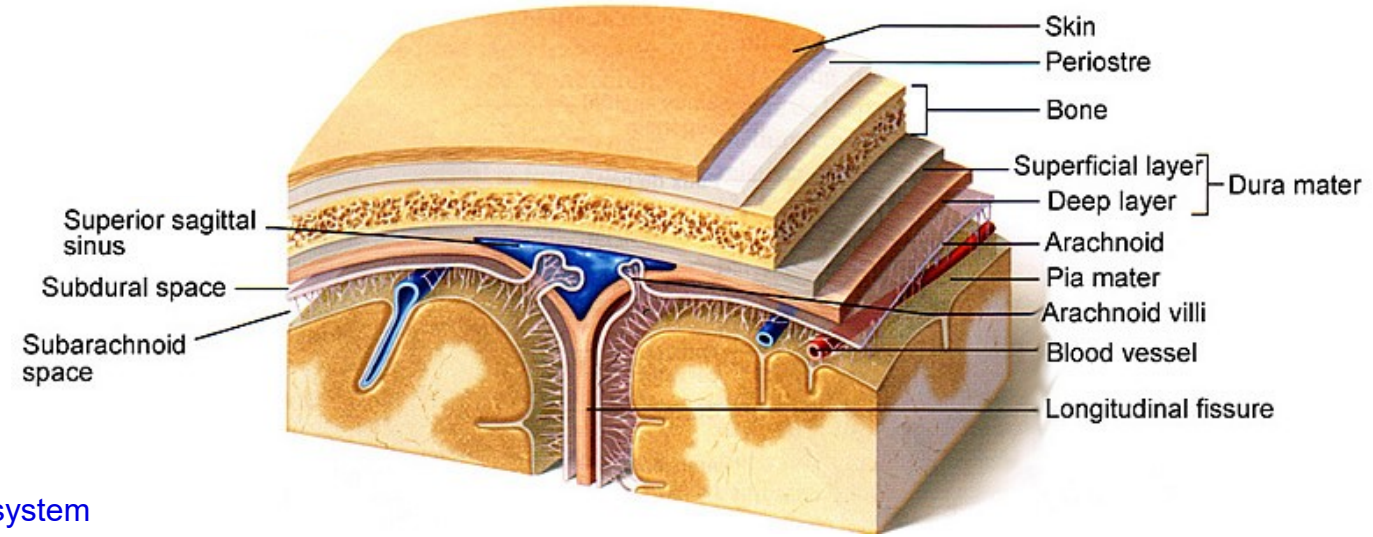
Intracranial compartment

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



http://edutoolanatomy.wikispaces.com



http://www.corpshumain.ca/en/Cerveau3_en.php

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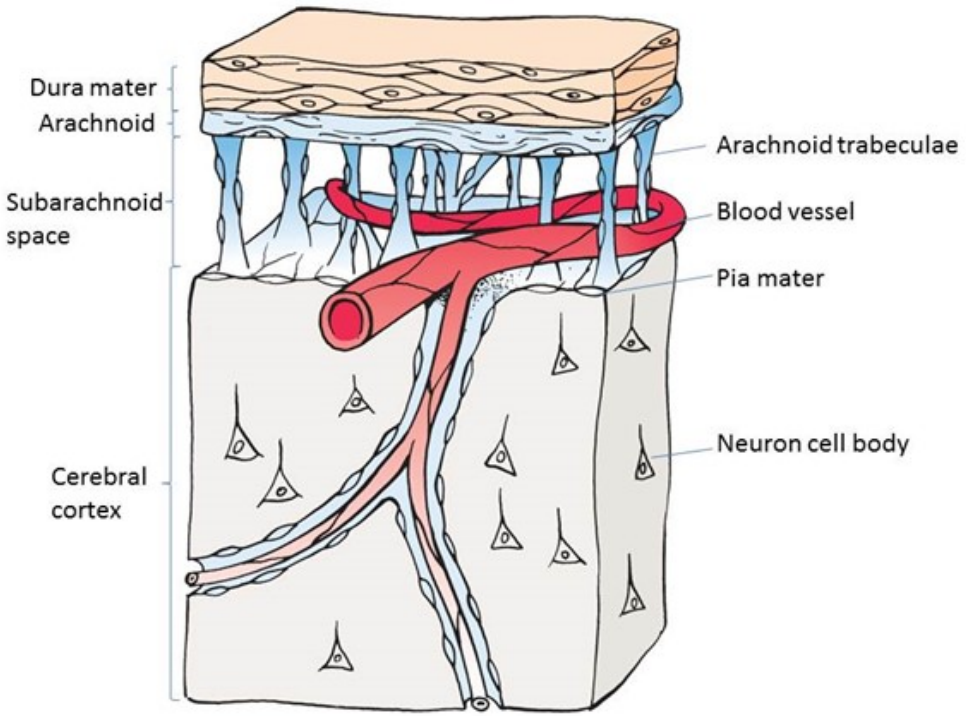
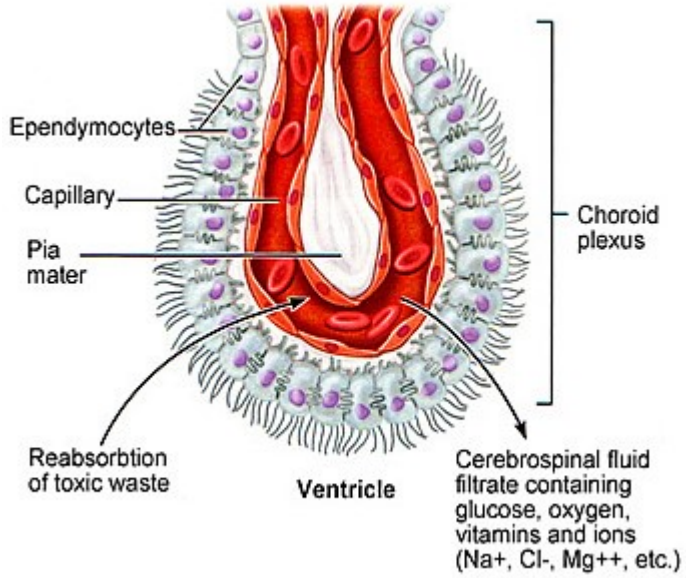
Meningeal and hematoliquor barrier



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

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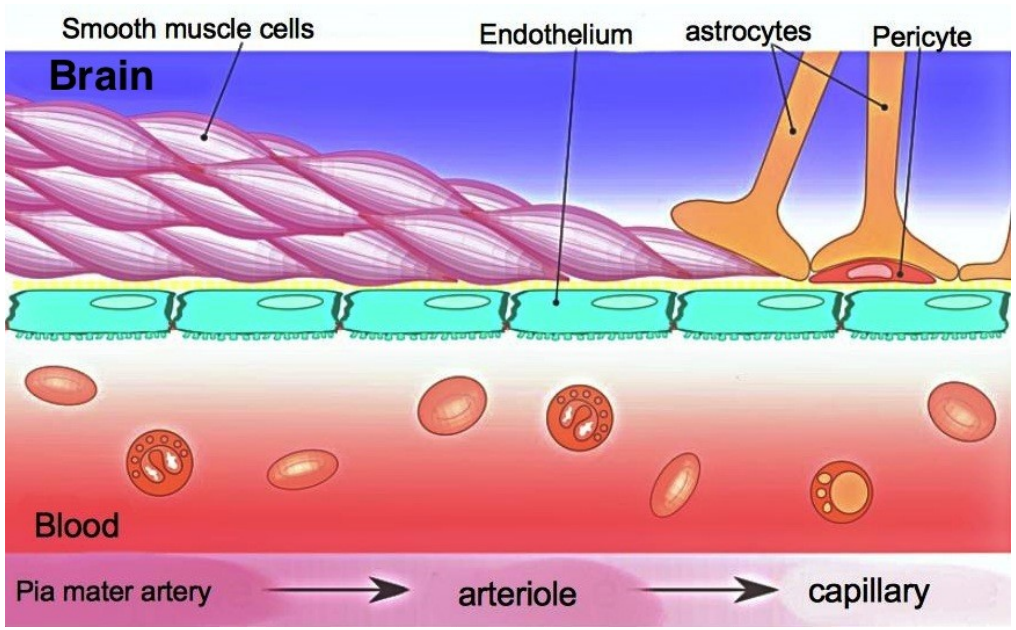
Hematoencephalic barrier

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



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

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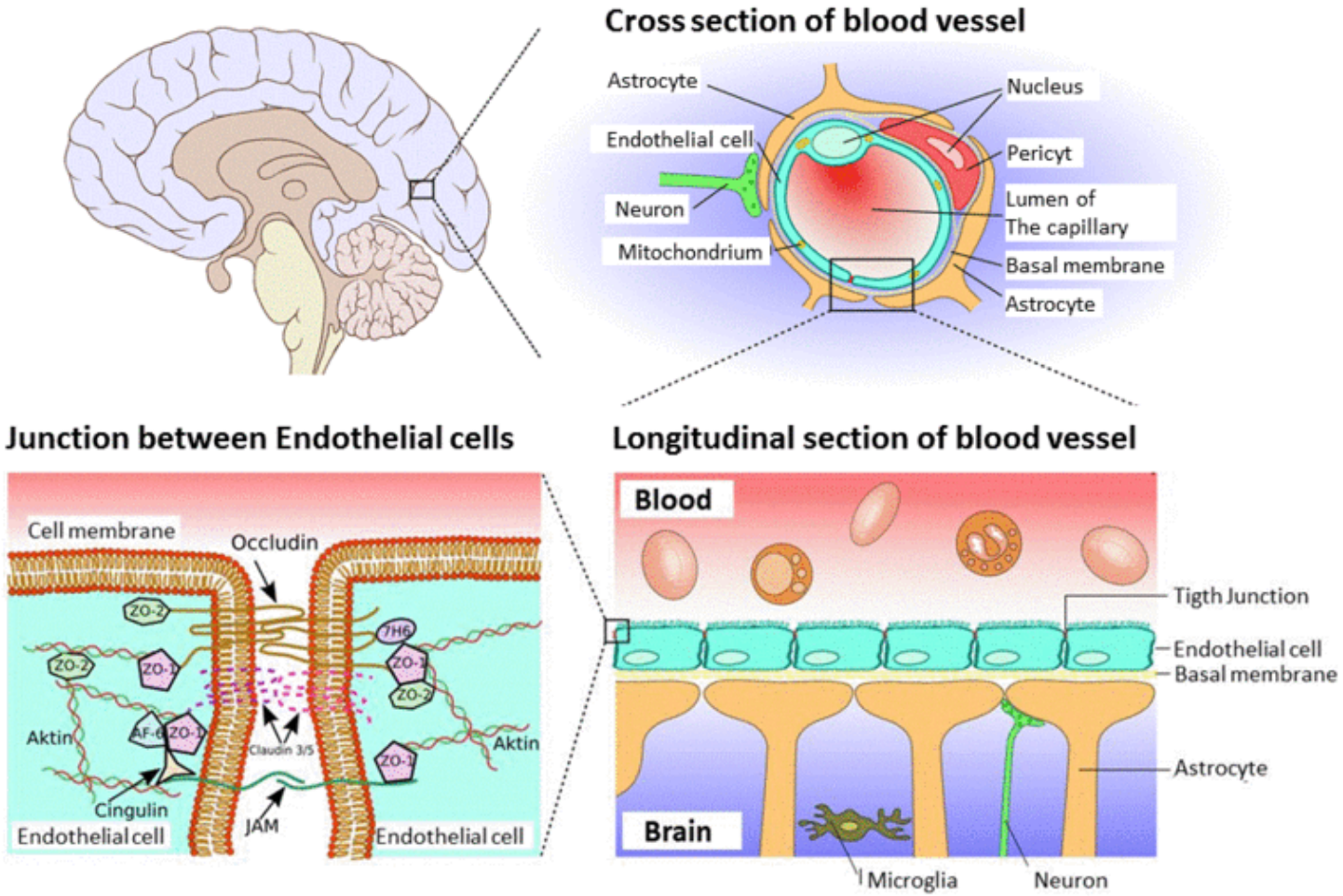
Hematoencephalic barrier



FSM (basic artwork: wikimedia commons)

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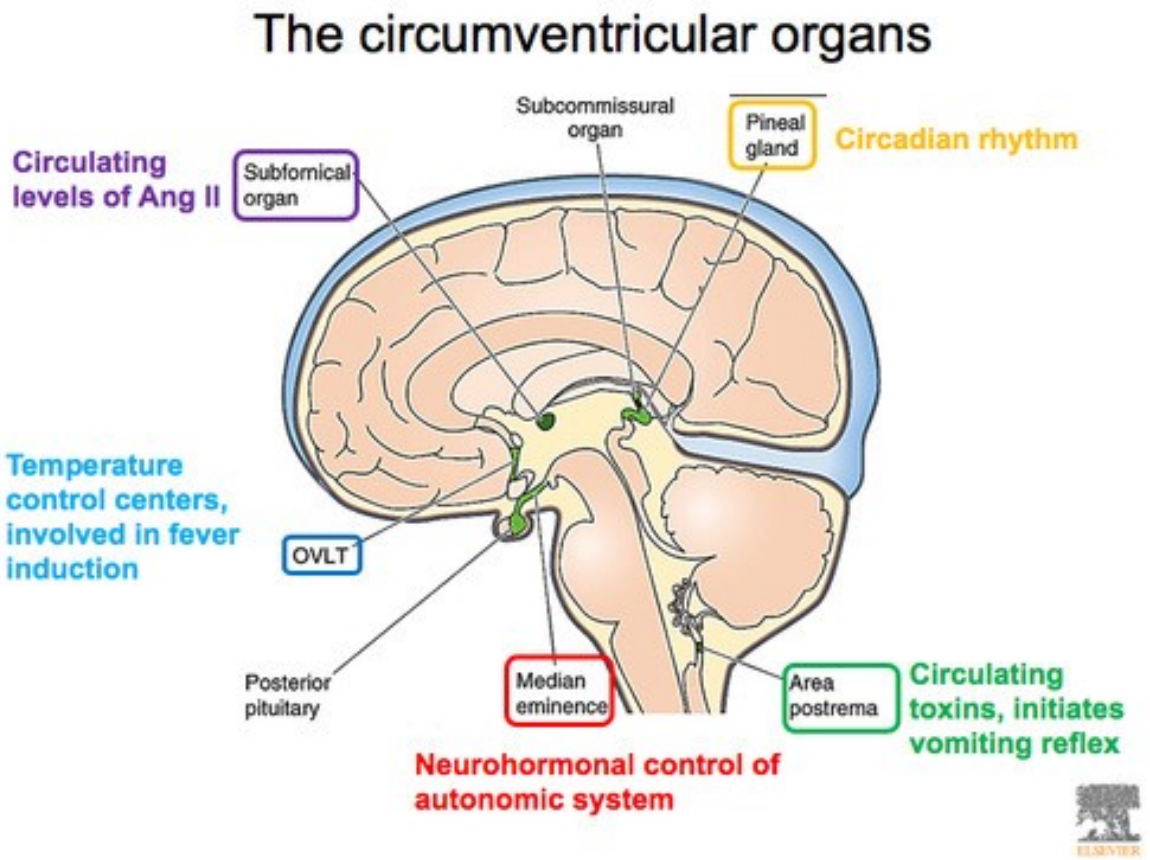
Circumventricular organs

- Rich vascularisation
- Modified hematoencephalic barrier
- Sensors
- Secretion



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

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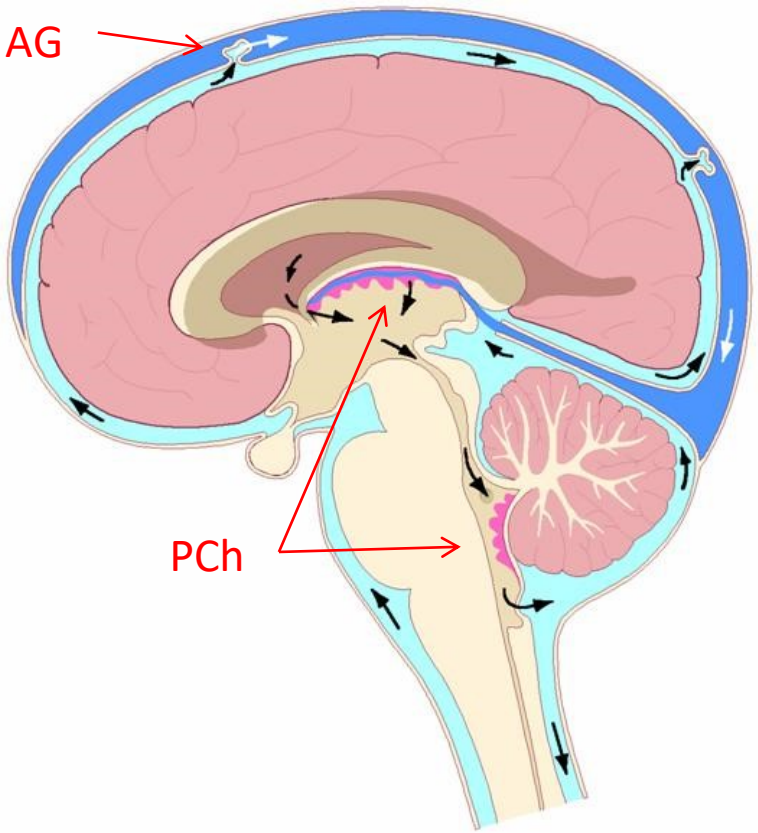
Cerebrospinal fluid

- 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

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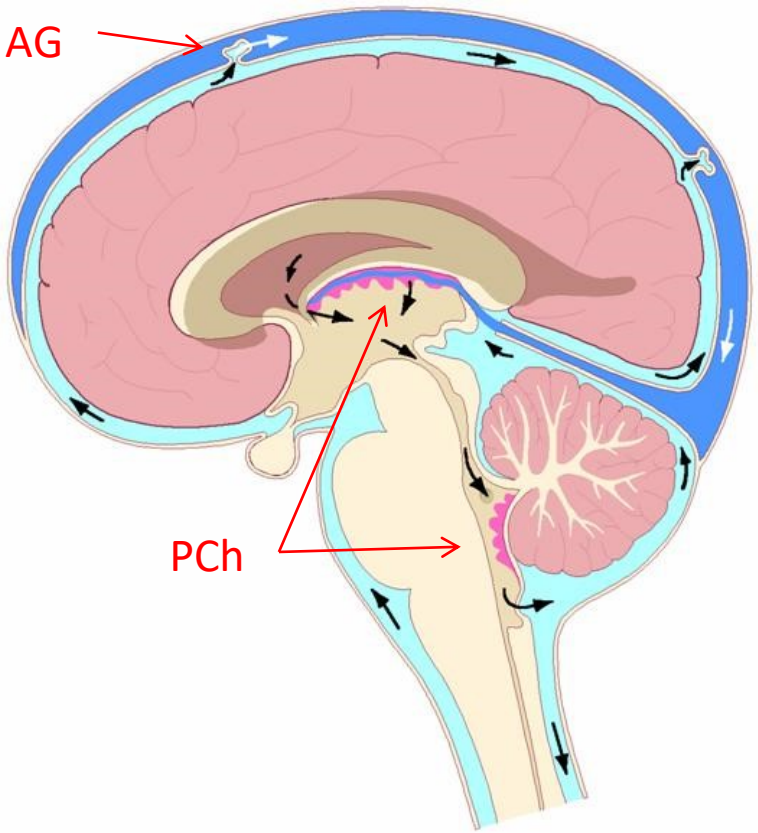
Cerebrospinal fluid

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



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

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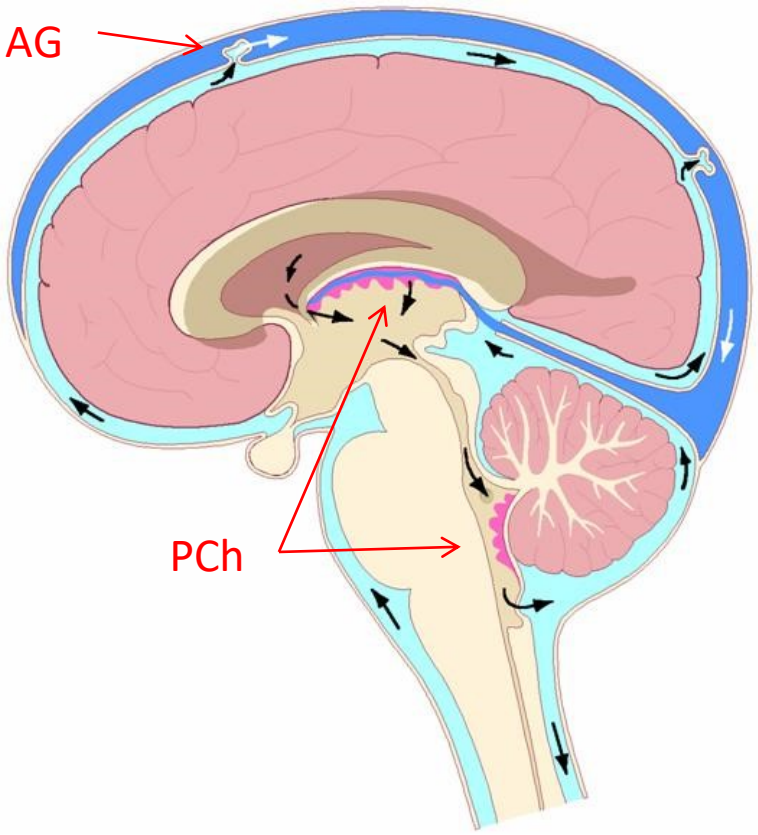
Cerebrospinal fluid

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



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

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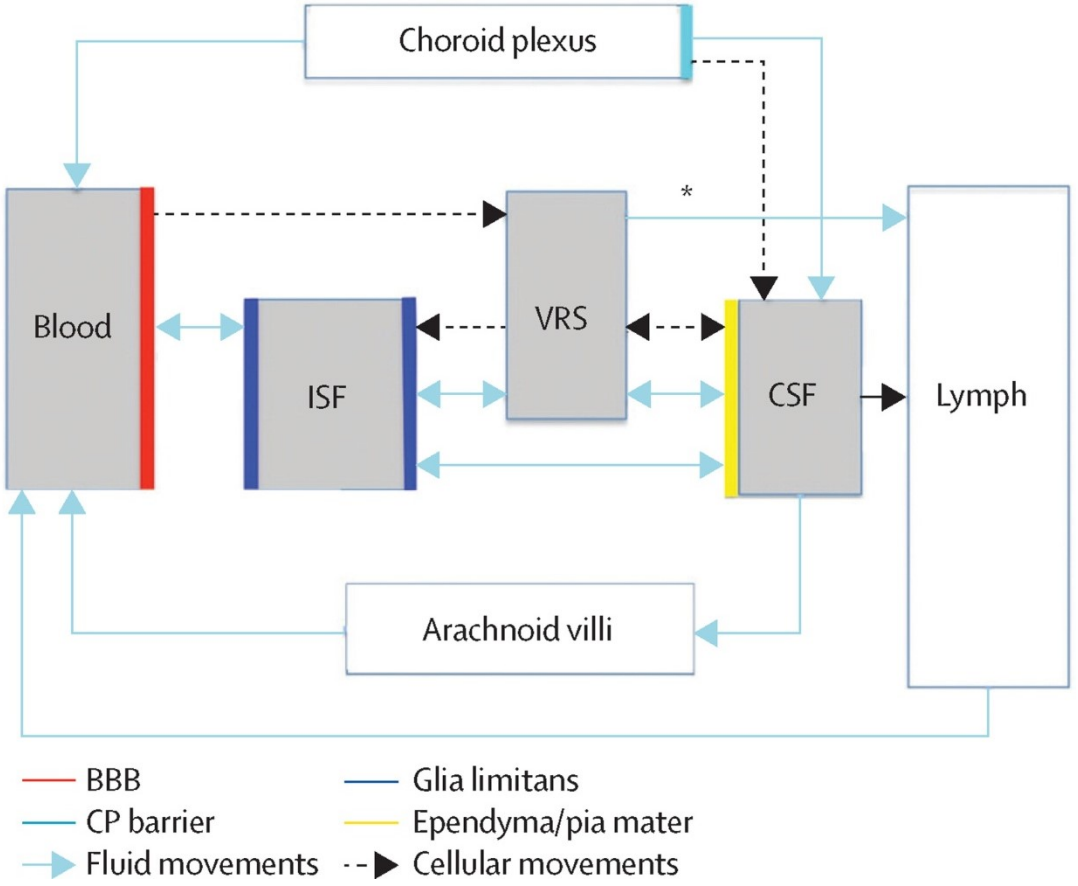
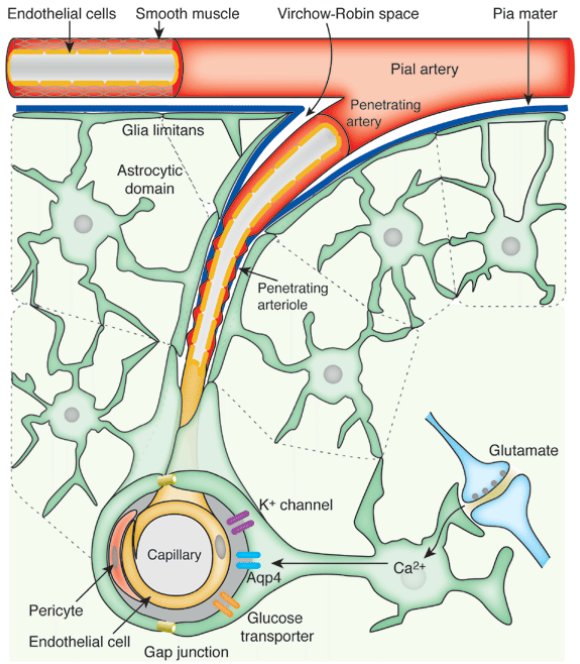
New insight into the production and resorbtion of CSF

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)





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

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CNS lymphatic drainage

- Cervical lymph nodes
  - Nasal lymphatics
  - Dural lymphatics
  - Alongside nerves
  - Alongside vessels (no
- Lumbal lymph nodes
  - Alongside nerve roots

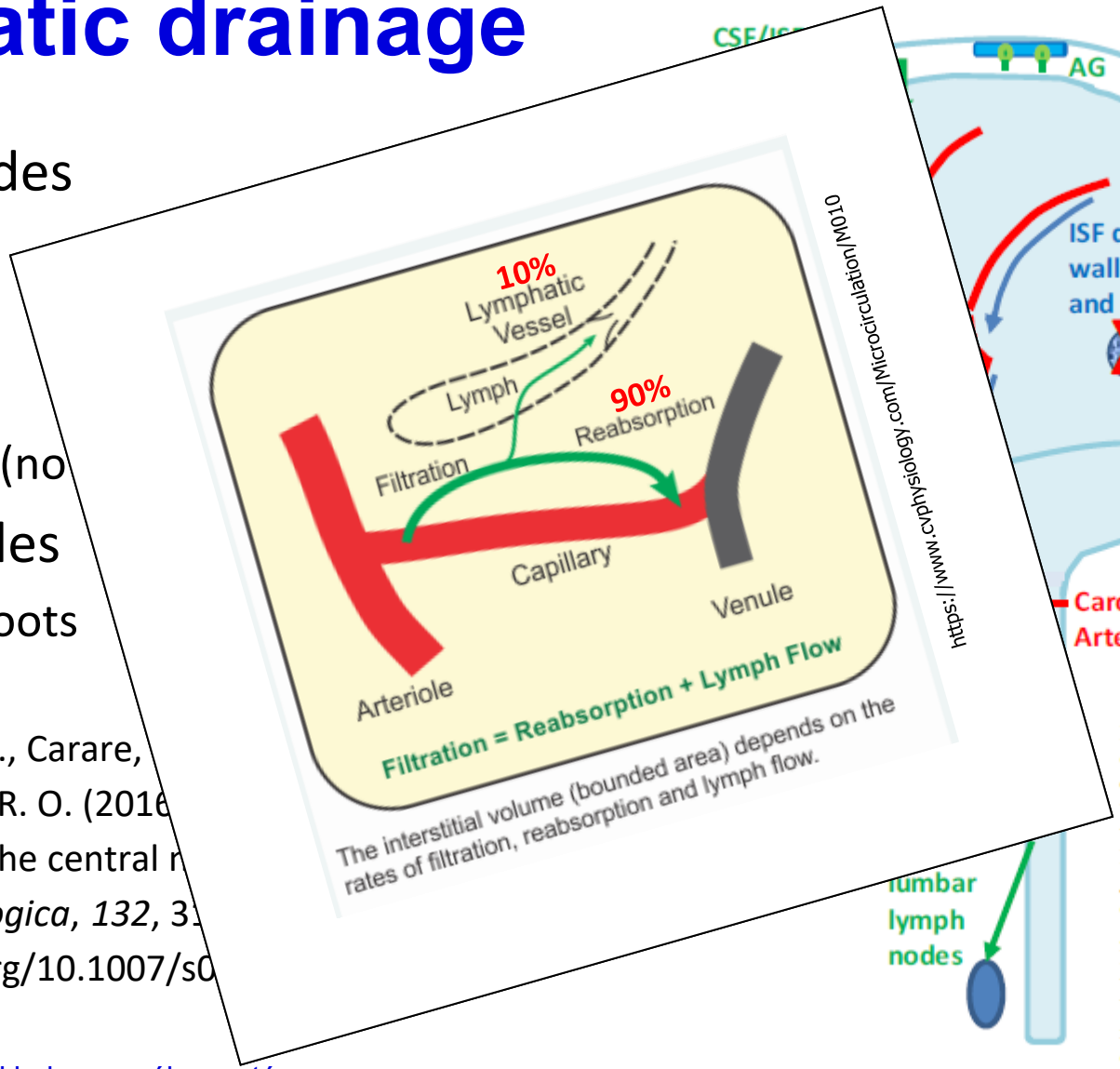

Fig. 1 Drainage pathways for CSF and interstitial fluid (ISF) to cervical lymph nodes. CSF and ISF drain to lymph nodes by different and distinct pathways. In humans, CSF drains into the blood of venous sinuses through well-developed arachnoid villi and granulations (AG). Lymphatic drainage of CSF occurs via nasal and dural lymphatics and along cranial and spinal nerve roots (outlined in *green*). Channels that pass from the subarachnoid space through the cribriform plate allow passage of CSF (*green line*) T cells and antigen-presenting cells (APC) into nasal lymphatics (NL) and cervical lymph nodes (CLN). CSF from the lumbar subarachnoid space drains to lumbar lymph nodes. ISF from the brain parenchyma drains along basement membranes in the walls of cerebral capillaries and arteries (*blue arrows*) to cervical lymph nodes adjacent to the internal carotid artery just below the base of the skull. This narrow intramural perivascular drainage pathway does not allow the traffic of APC. There is interchange between CSF and ISF (convective influx/glymphatic system), as CSF enters the surface of the brain alongside penetrating arteries

Engelhardt, B., Carare, D., & Weller, R. O. (2016 gateways of the central r *Neuropathologica*, *132*, 3 https://doi.org/10.1007/s0

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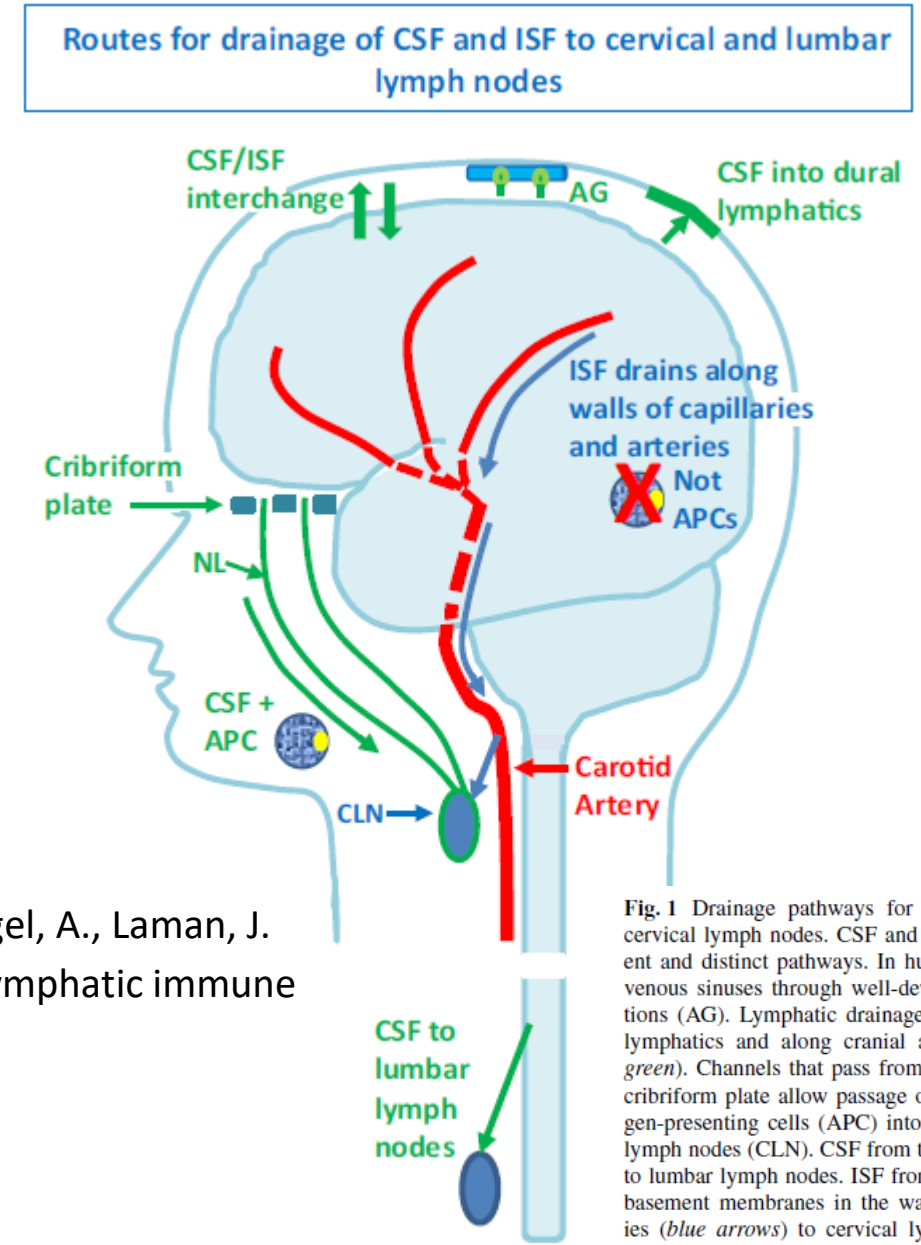

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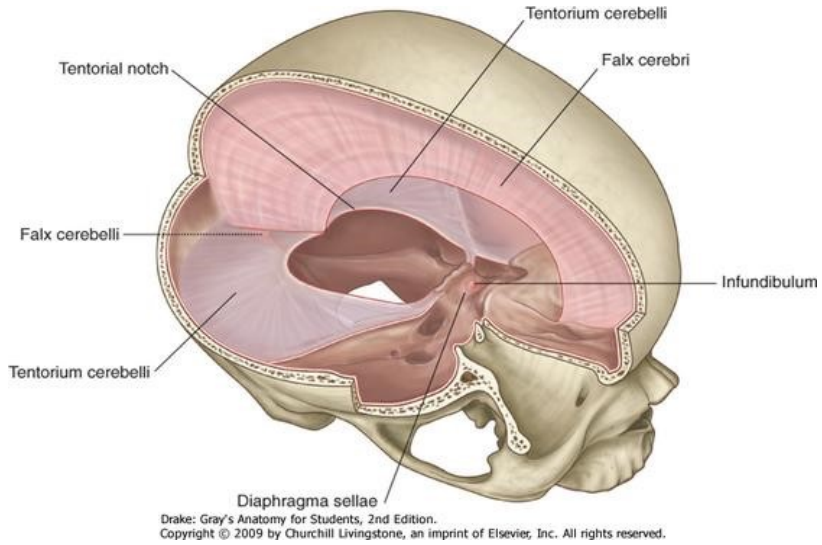
Engelhardt, B., Carare, R. O., Bechmann, I., Flügel, A., Laman, J. D., & Weller, R. O. (2016). Vascular, glial, and lymphatic immune gateways of the central nervous system. *Acta Neuropathologica*, *132*, 317–338. https://doi.org/10.1007/s00401-016-1606-5

Intracranial compartment

- Brain
- Cerebrospinal fluid
- Blood (intravascular)

- Intracranial pressure (ICP)
  - Critical determinant of cerebral perfusion

- Cerebral perfusion pressure (CPP) pressure gradient driving blood flow intracranialy



http://edutoolanatomy.wikispaces.com

!!! CPP = MAP – ICP !!!

Cerebral perfusion pressure | Mean arterial pressure | Intracranial pressure

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Cellular base of nervous system

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

Cellular base of nervous system

- Neuronal cells
  - Reception, integration and propagation of information
  - Unique, irreplaceable
- Neuroglial cells
  - Support for neuronal cells
  - Easily replacable
- The total amount of neuronal cells - 100 billions (10^{11})
- Neruon/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

    (liquro-encephalic barrier)

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    (liquro-encephalic barrier)

Peripheral nervous system

- Satelite cells
  - Support functions in PNS

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  - Support functions in PNS
- Schwan cells
  - Myelin sheat

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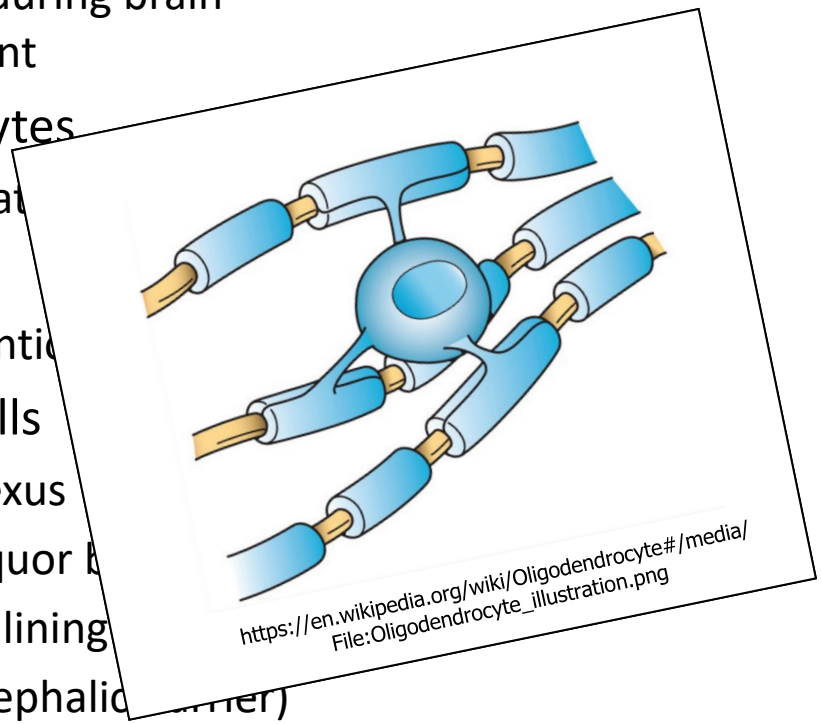
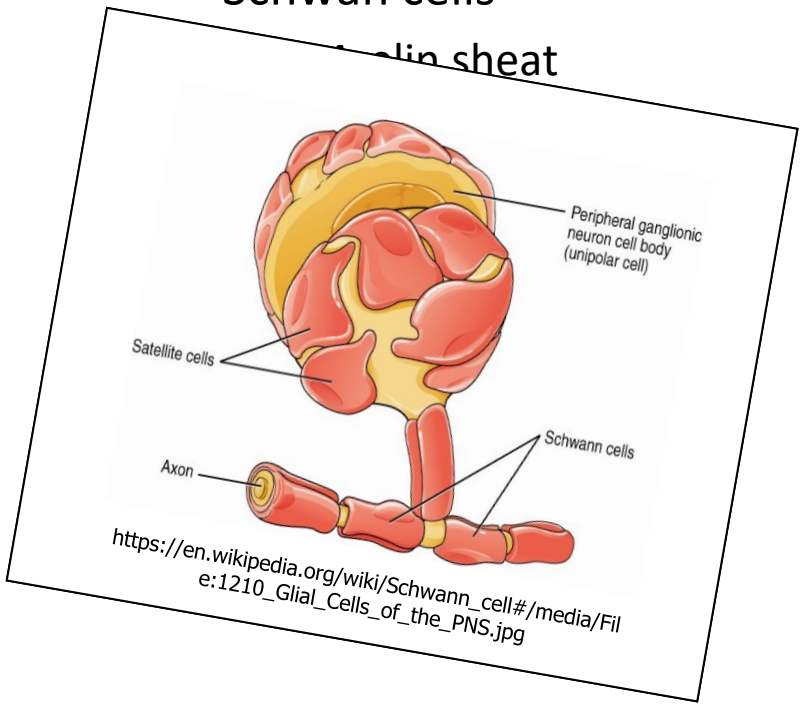
  - Immune funti
- Ependymal cells
  - Choroid plexus
  - (hemato-liquor b
  - Ventricular lining
    (liquro-encephalic [illegible])


https://en.wikipedia.org/wiki/Oligodendrocyte#/media/File:Oligodendrocyte_illustration.png

Peripheral nervous system

- Satelite cells
  - Support functions in PNS
- Schwan cells
  - [illegible]elin sheat



https://en.wikipedia.org/wiki/Schwann_cell#/media/File:1210_Glial_Cells_of_the_PNS.jpg

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Neuron

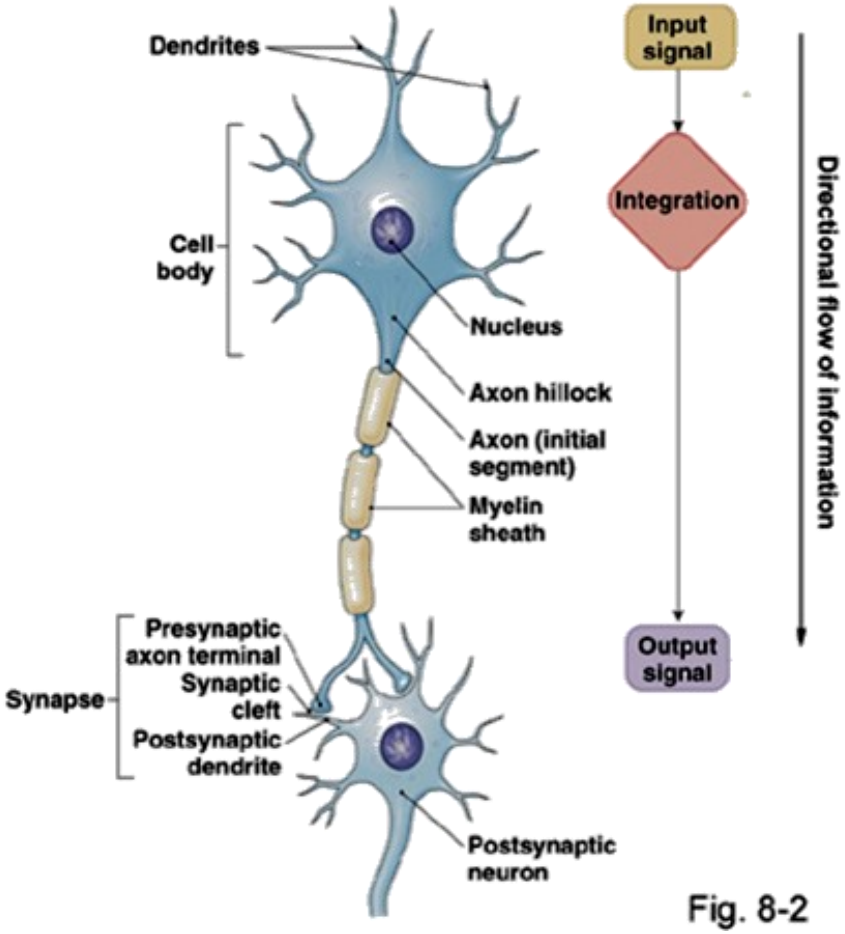

Fig. 8-2

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

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Neuron

Background Activity

The inside of the cell

- ✓ …
- ✓ Synthesis
- ✓ Transport
- ✓ …

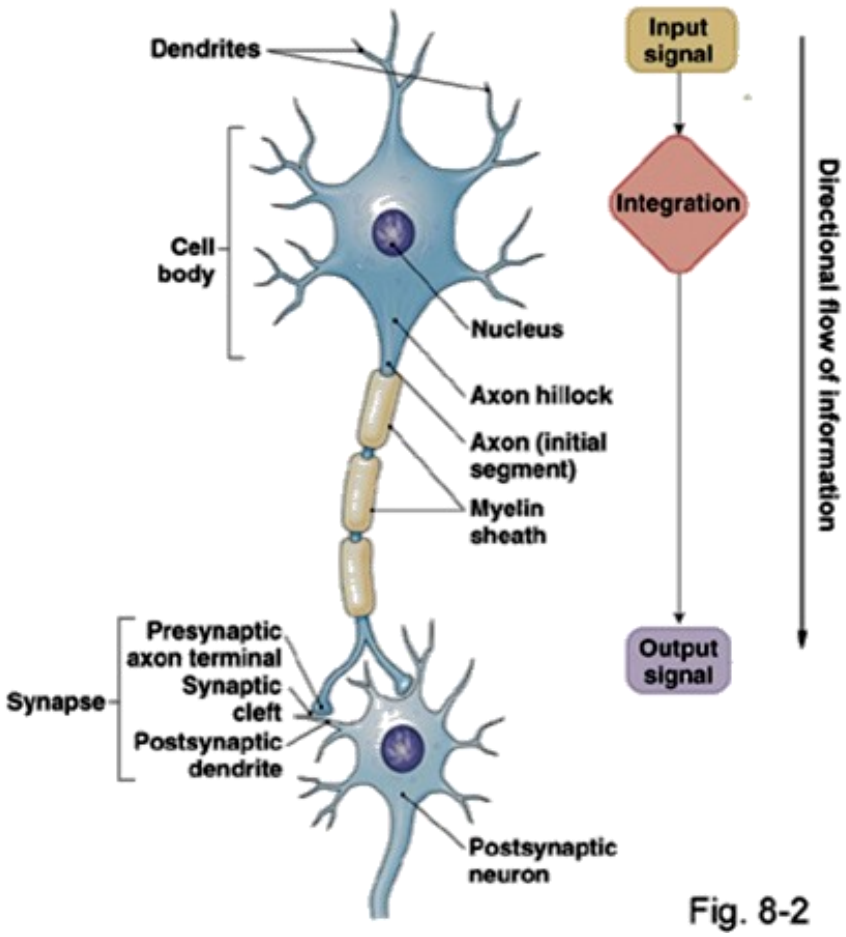

Fig. 8-2

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Information processing and transmission

The membrane

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

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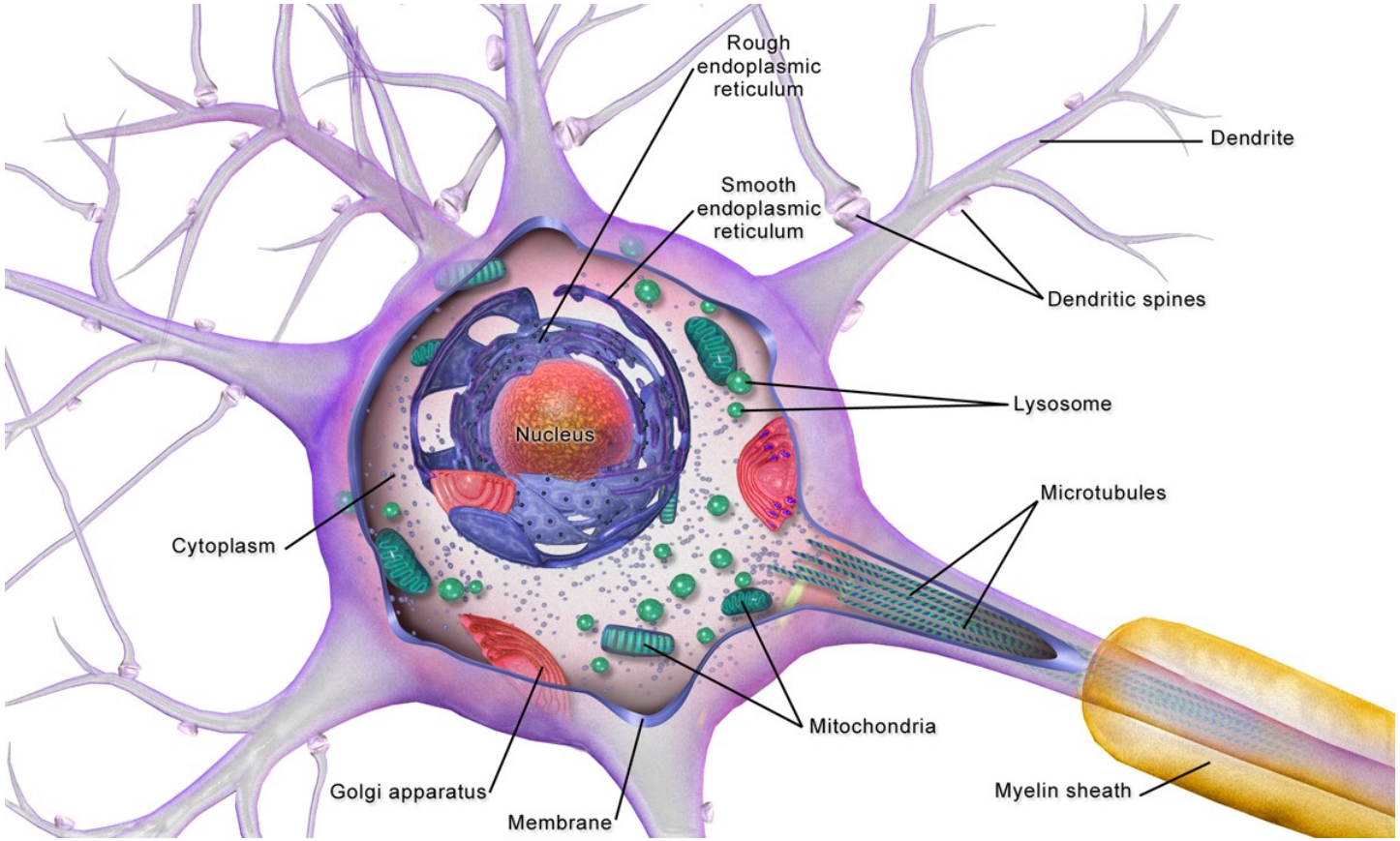
Background Activity



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

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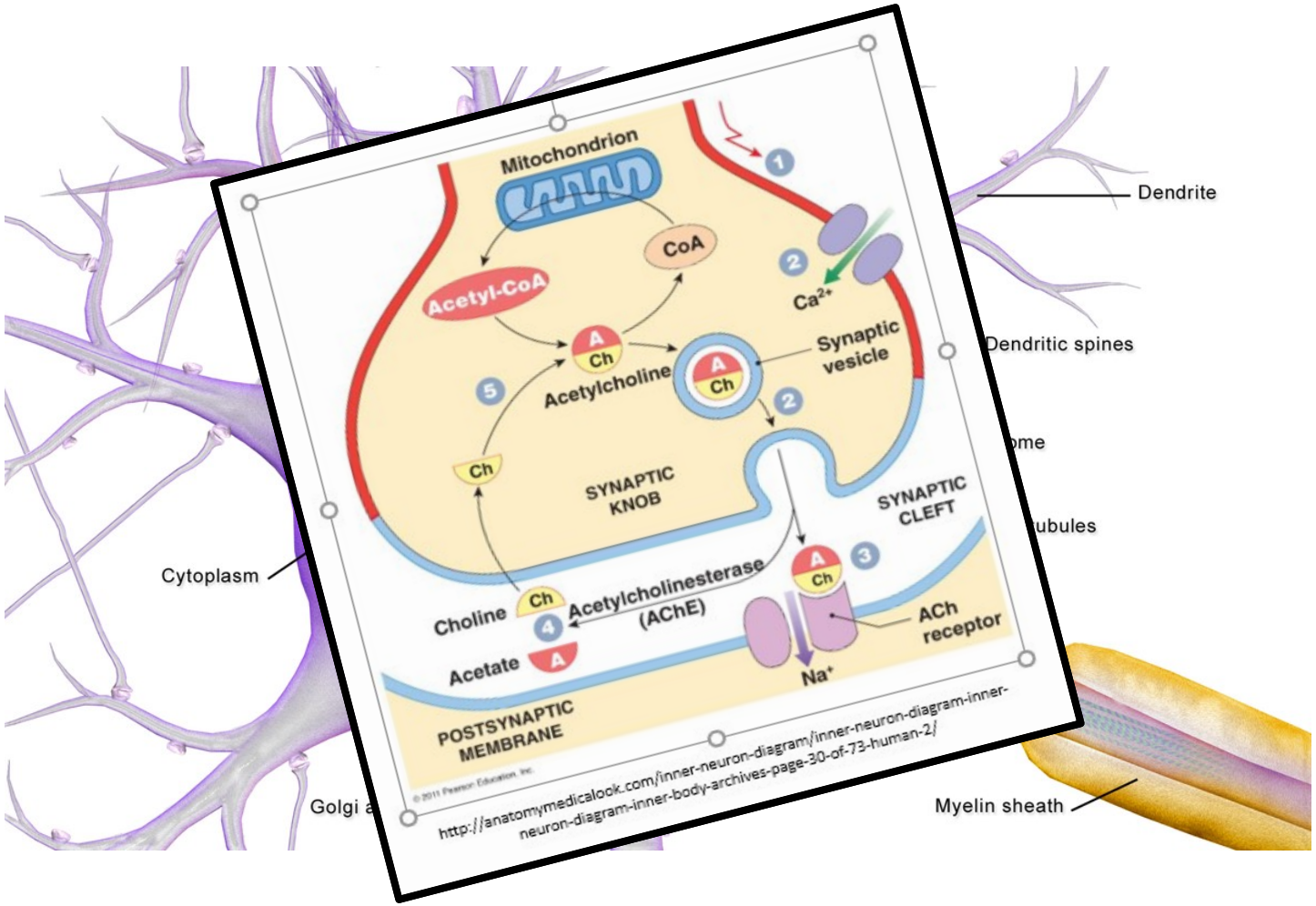
Background Activity



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

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Background Activity

Fast axonal transport

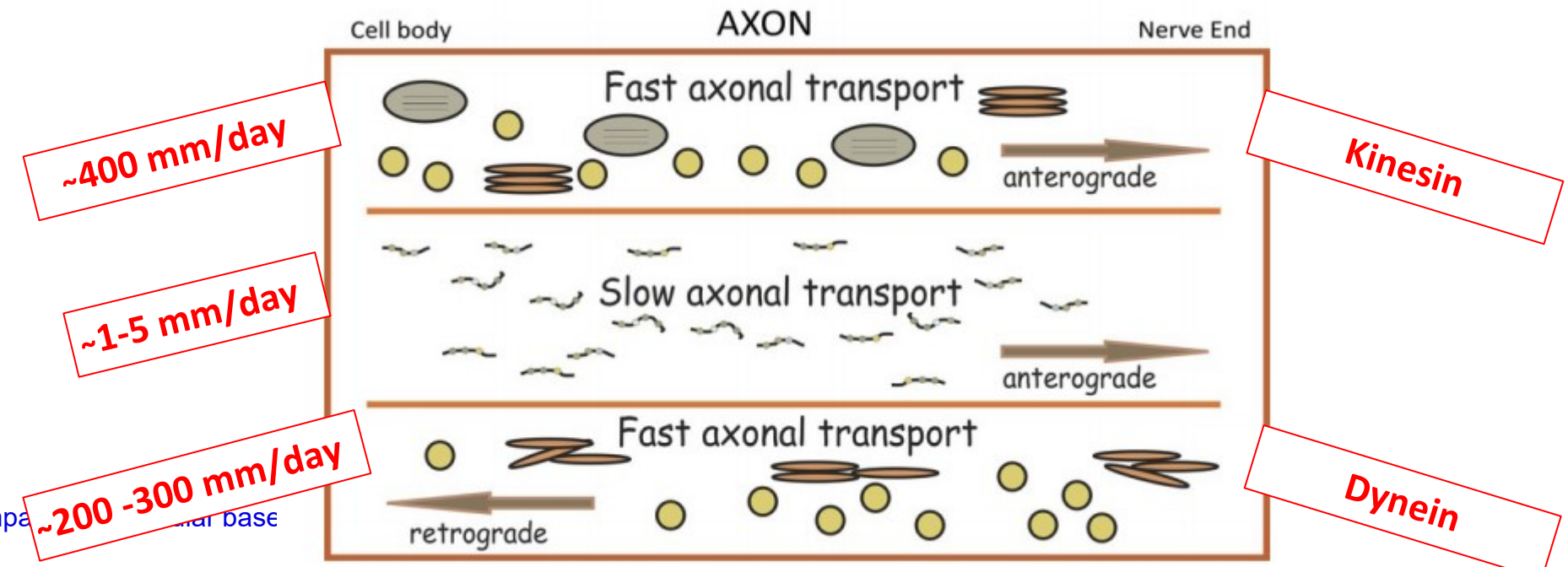
- bidirectional
- ATP dependant
- associated with microtubules: dynein and kinesin

Slow axonal transport

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

Fast axonal transport
Golgi derived vesicles
lysosmes, mitochondria
structural elements of
endoplasmic reticulum

Slow axonal transport
microfilaments, microtubules
neurofilaments
cytosolic protein complexes



http://www.oapublishinglondon.com/images/article/pdf/1397255957.pdf

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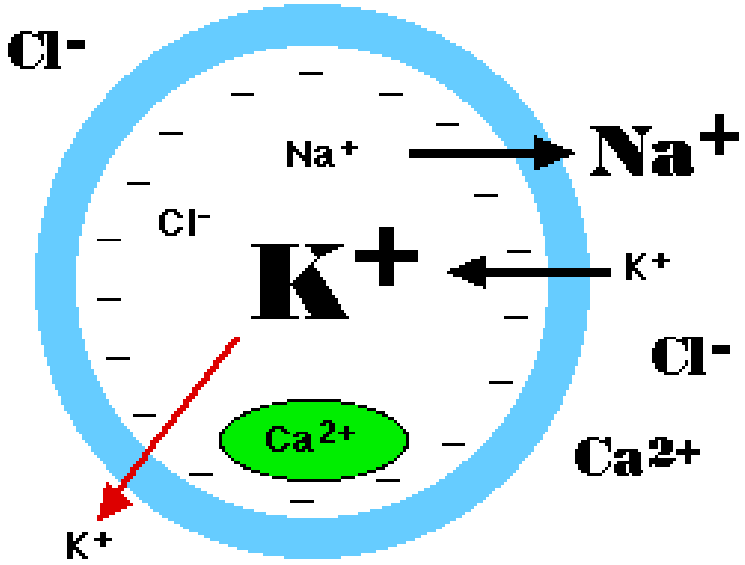
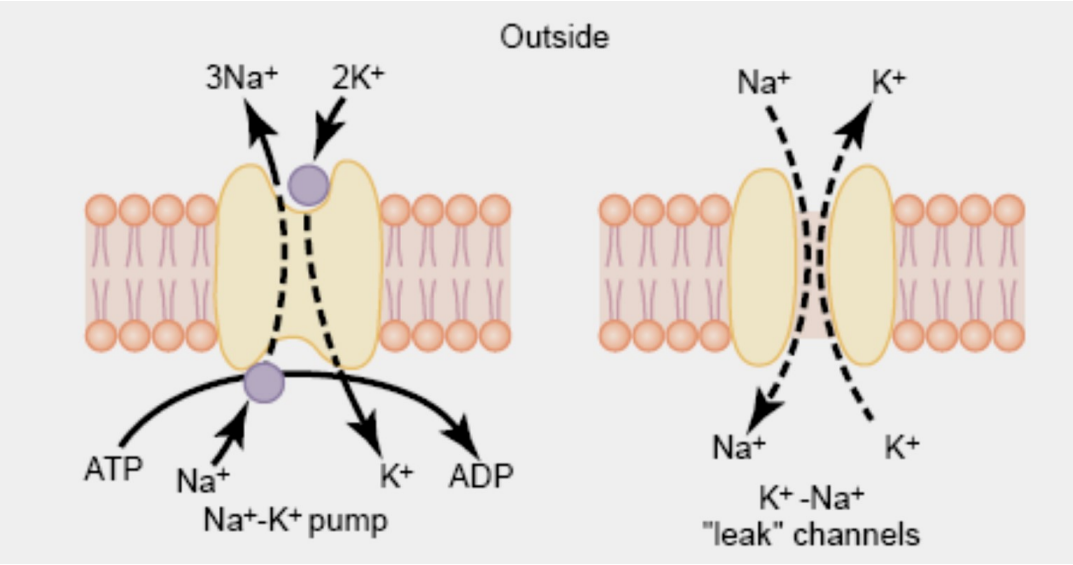
Membrane potential

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





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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

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Action potential

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

Treshold potential around -55 mV

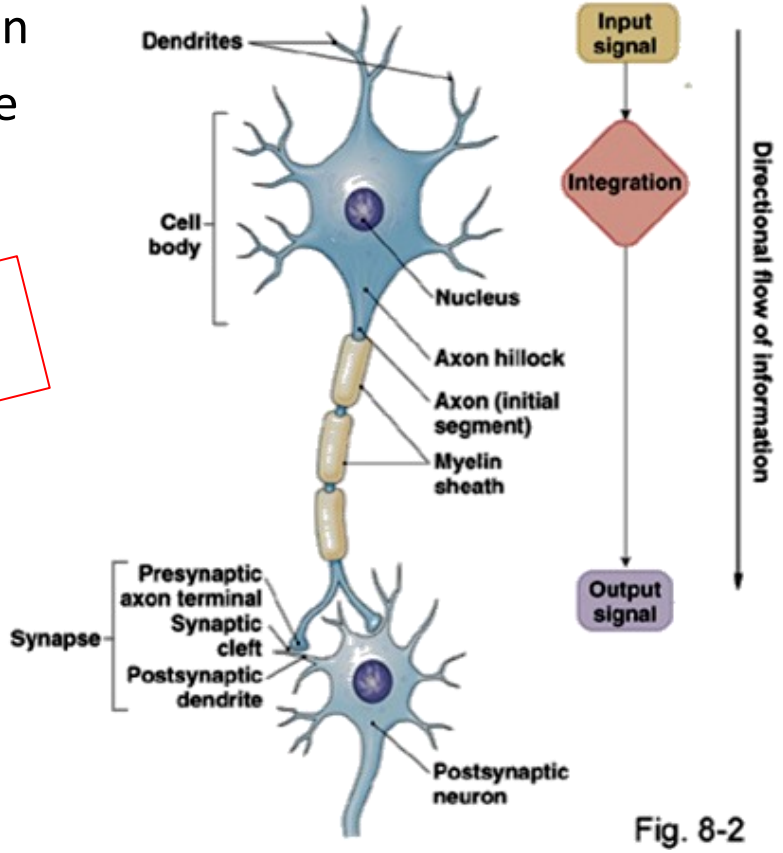
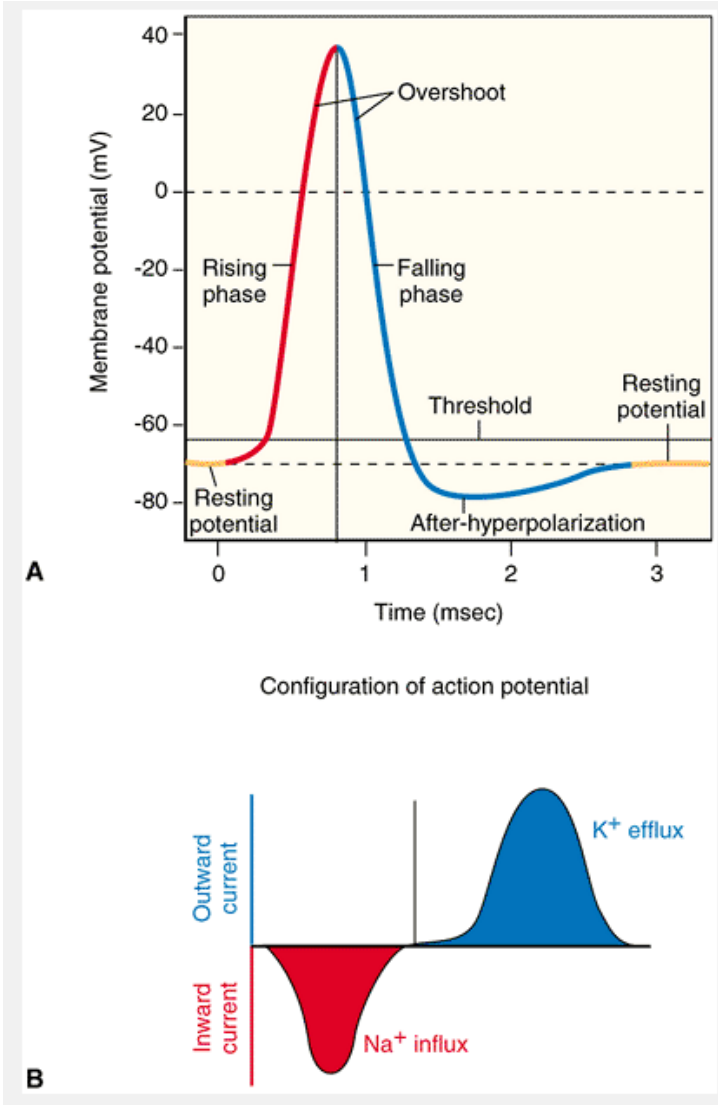


Fig. 8-2



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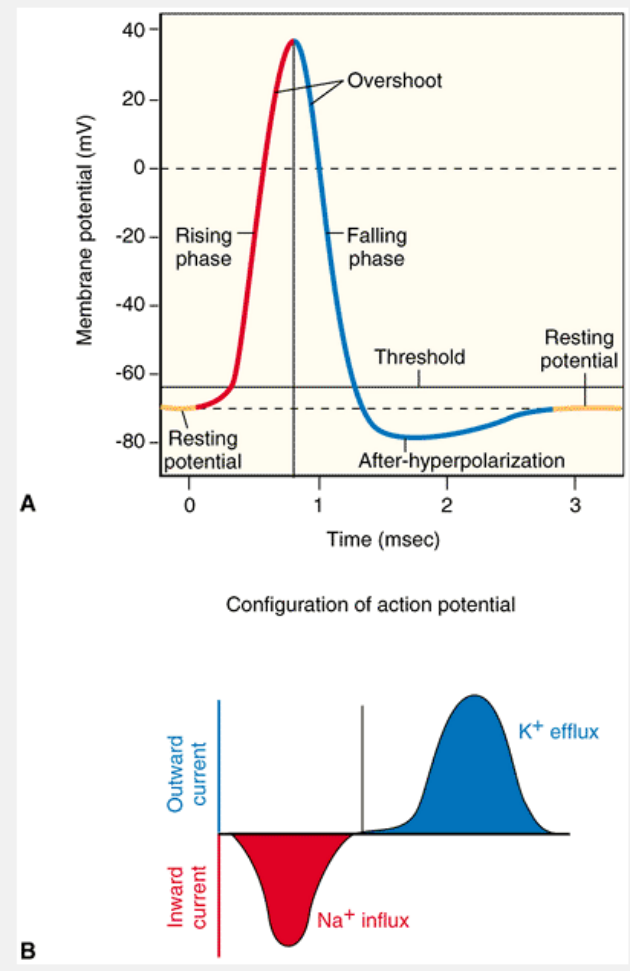
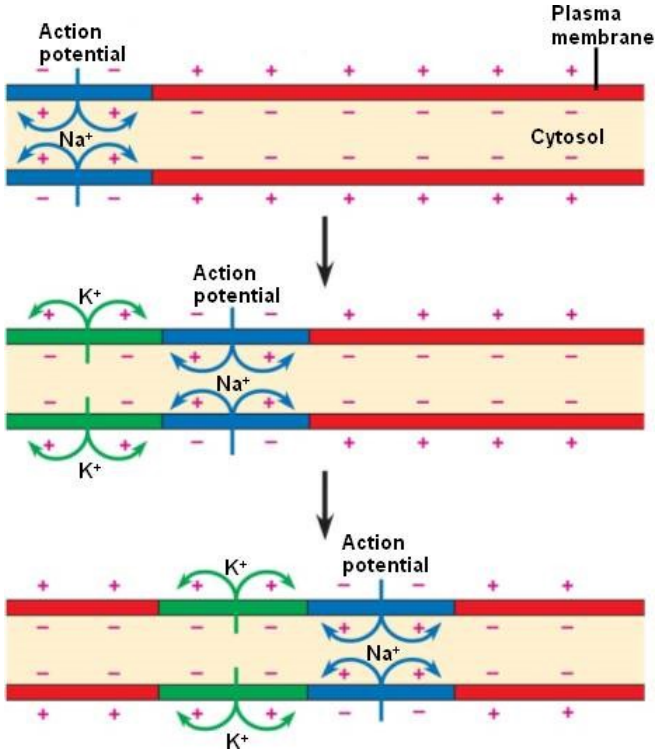
Action potential spreading





- Local currents
- Anterograde

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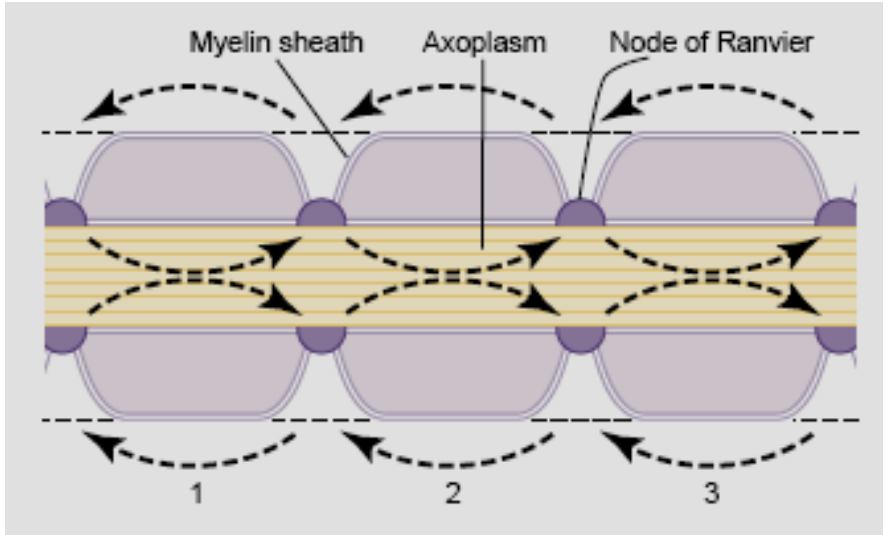
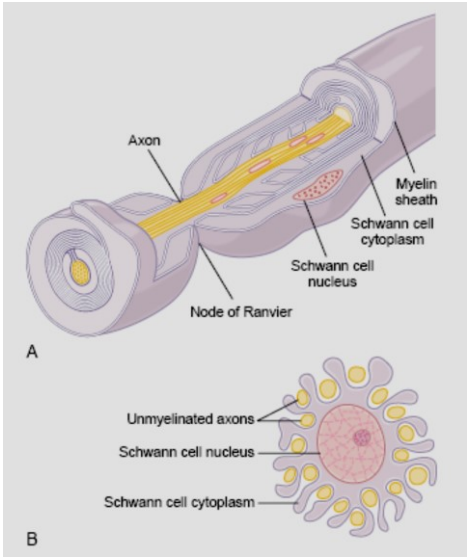
Saltatory conduction

- Myelin sheat
- 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





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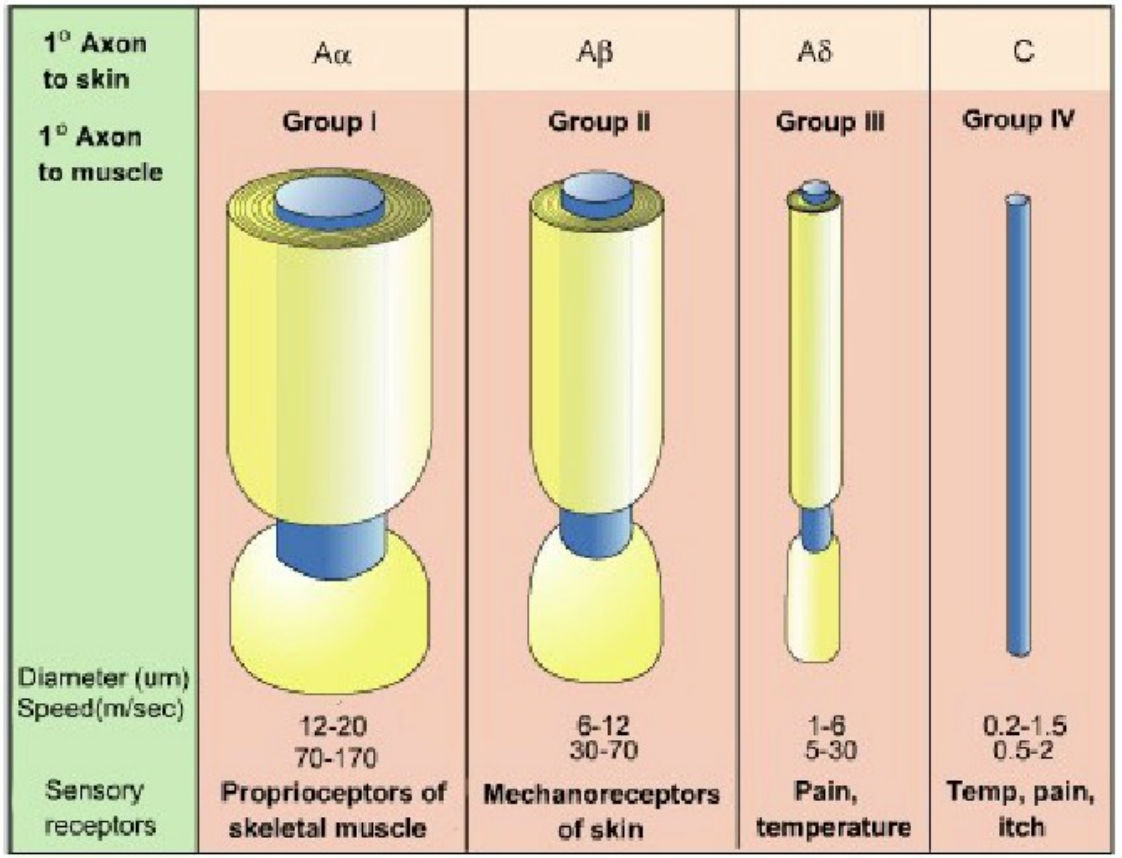
Classification of nerve fibers

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



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

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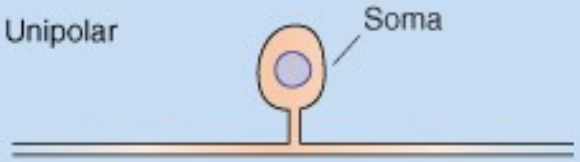
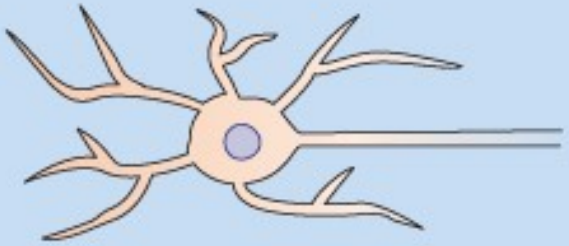
Neuronal classification

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

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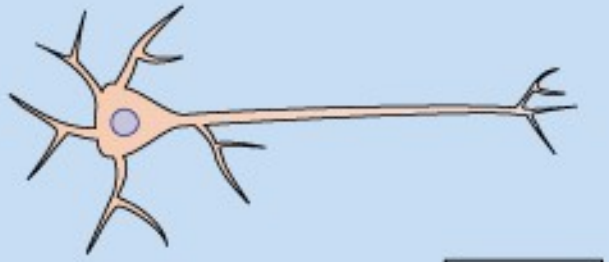
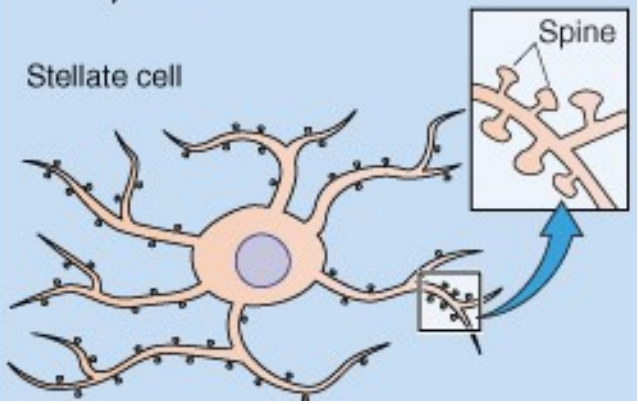
Neuronal classification

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

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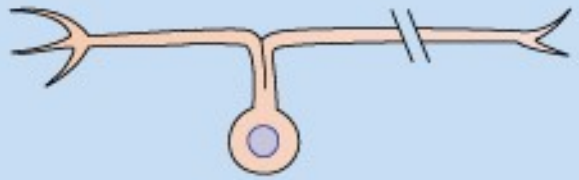
Neuronal classification

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

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68. Cellular base of nervous system

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

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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

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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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