



WEEK 1&2

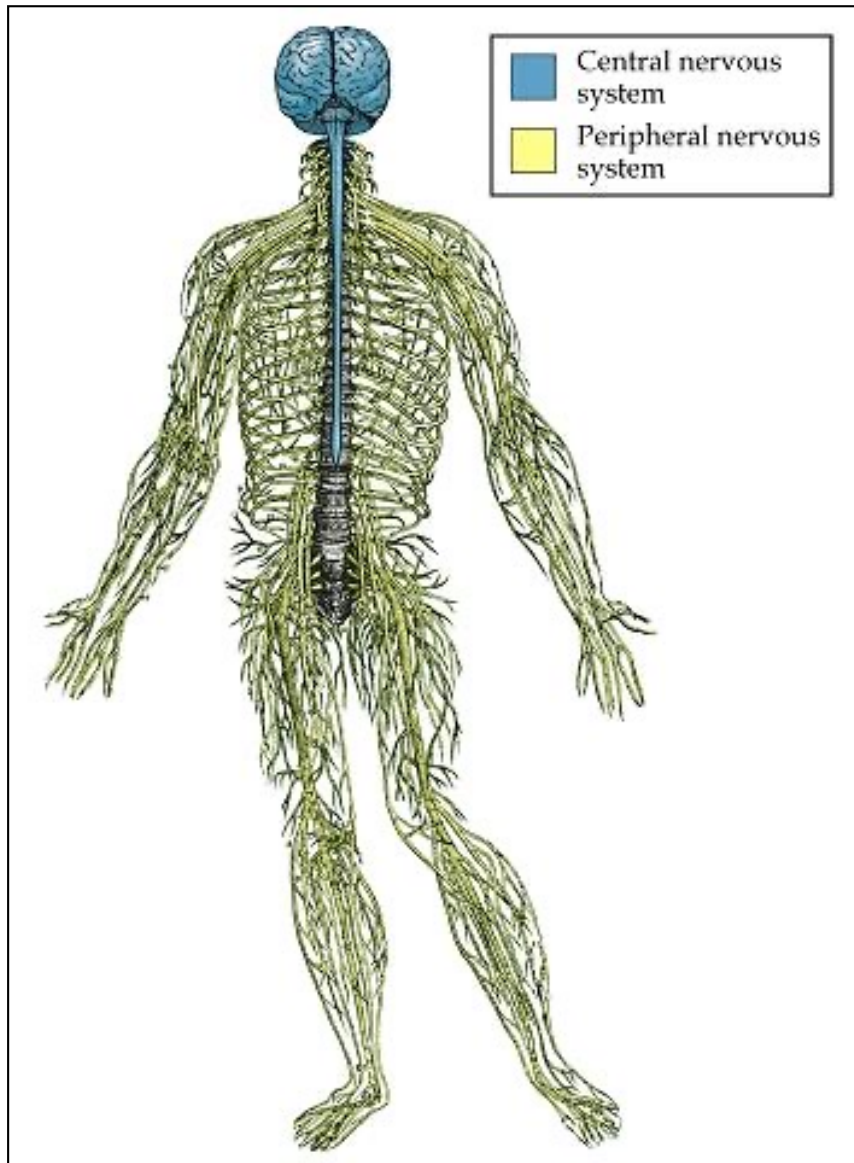
BRAIN ANATOMY

Learning objectives

- Know about the major cell types of the brain
- Know about the brain's protection mechanisms
- Know the major subdivisions of the brain
- Know about brain areas implicated in learning
- Know about brain areas implicated in movement control

Learning objectives





- **CNS (central nervous system)**
 - Brain, Spinal Cord
 - 12 pairs of cranial nerves (originate from cranium)
- **PNS (peripheral nervous system)**
 - 31 pairs of spinal nerves
 - Somatic and autonomic nervous system
 - Serves to bring information into the CNS and to carry signals out of the CNS

Brain anatomy – overview

- 1) What's contained within the brain ?
 - Cell types of the CNS
- 2) What protects the brain?
 - Physical and chemical protection
- 3) Major subdivision of the brain and their function

Brain anatomy – overview

1) What's contained within the brain ?

- Cell types of the CNS

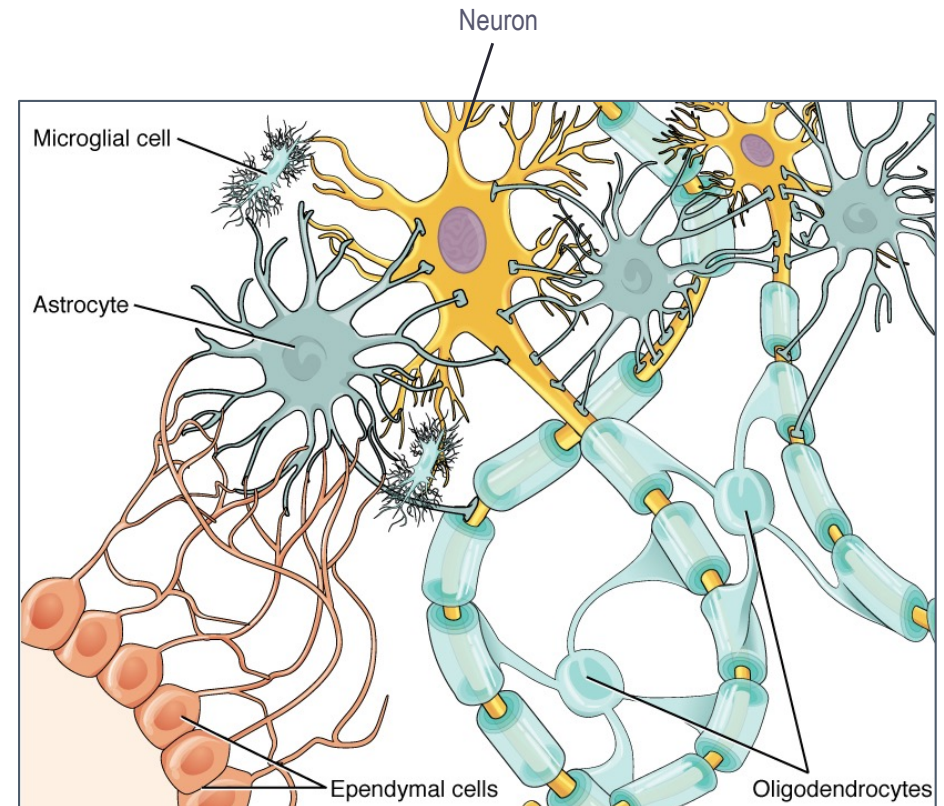
2) What protects the brain?

- Physical and chemical protection

3) Major subdivision of the brain and their function

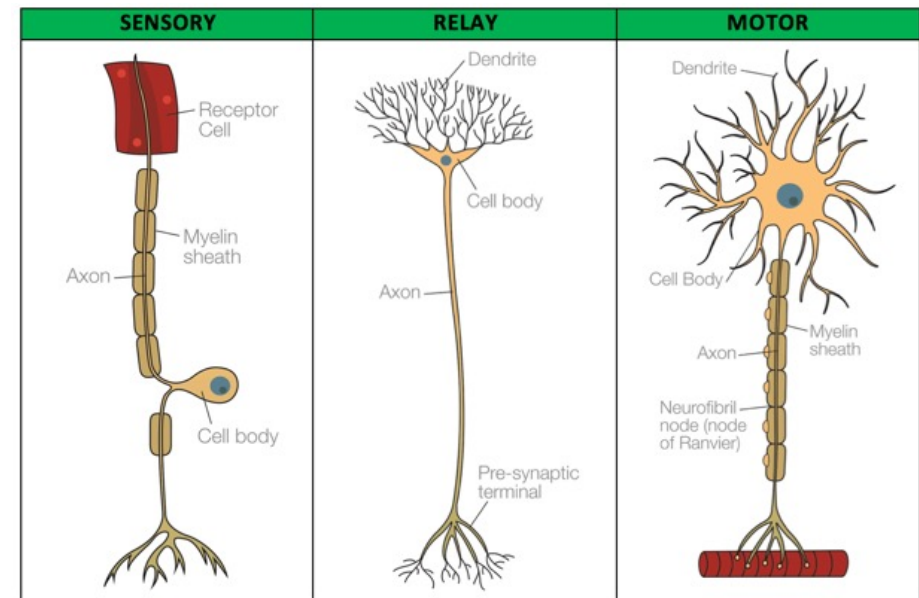
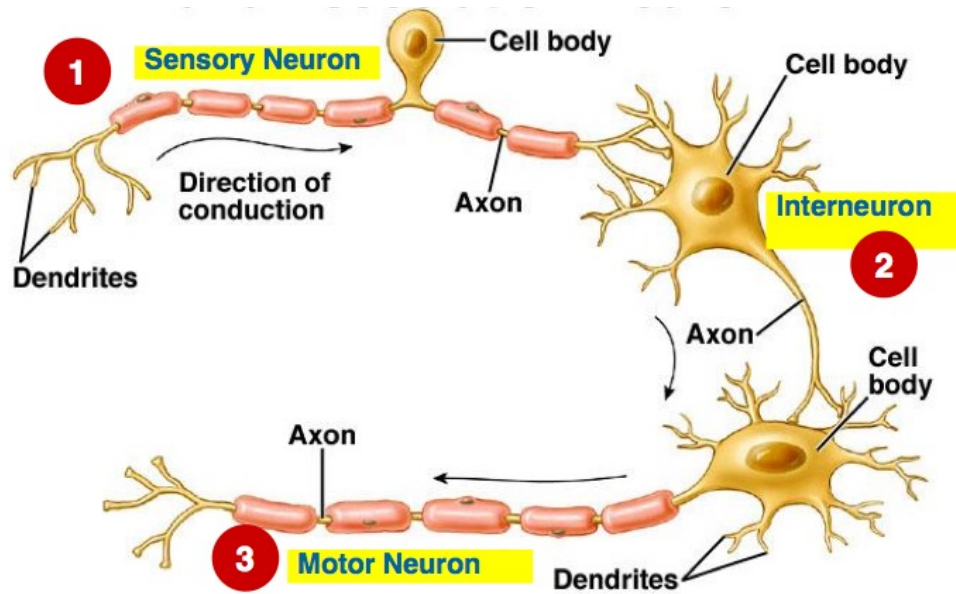
Cell types of the nervous system

- 2 types of cells in nervous system
 - **Neurons**
 - “grey matter”
 - much larger (axon can be 0.1mm to 2m)
 - different in shape
 - **Glia**
 - surround neurons – from the Greek for ‘glue’
 - “white matter”



↗Lecture on Glia

3 types of neurons

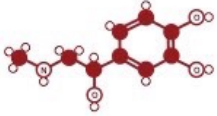









Receptor → CNS

CNS → CNS

CNS → Effector

Types of neurons – types of neurotransmitter

| | | | |
|---|---|--|---|
| ADRENALINE | NORADRENALINE | DOPAMINE | SEROTONIN |
|  |  |  |  |
| Fight or flight neurotransmitter | Concentration neurotransmitter | Pleasure neurotransmitter | Mood neurotransmitter |
| GABA | ACETYLCHOLINE | GLUTAMATE | ENDORPHINS |
|  |  |  |  |
| Calming neurotransmitter | Learning neurotransmitter | Memory neurotransmitter | Euphoria neurotransmitter |

➤ Adrenergic neuron

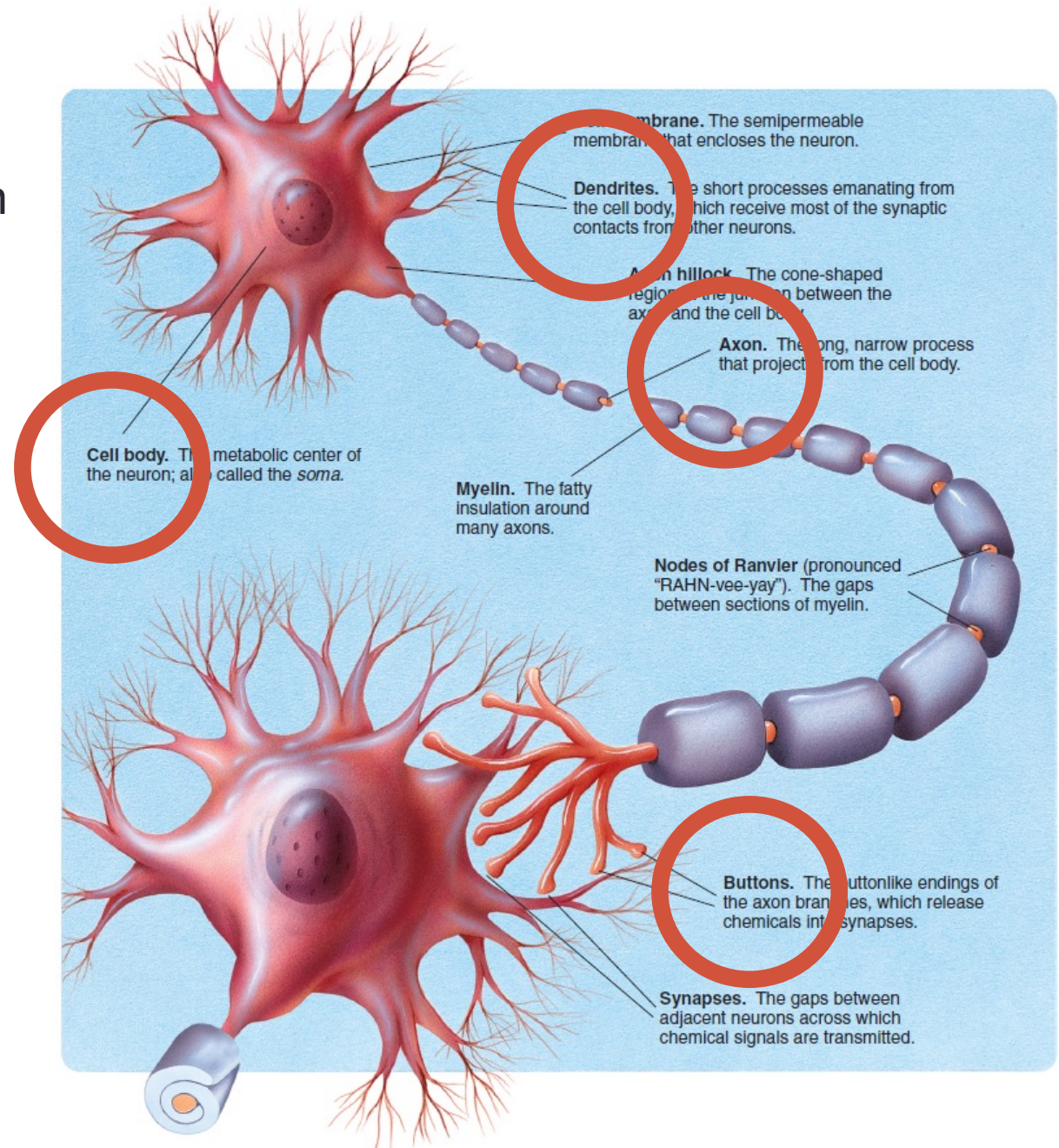
➤ Dopaminergic neuron

➤ Serotonergic neuron

➤ ...

Neurons

- $\sim 10^{12}$ in the human brain
- General structure:
 - 1 Dendrites
 - 2 Cell body
 - 3 Axon
 - 4 Buttons (pre-synaptic terminals)



Neurons

- General structure:

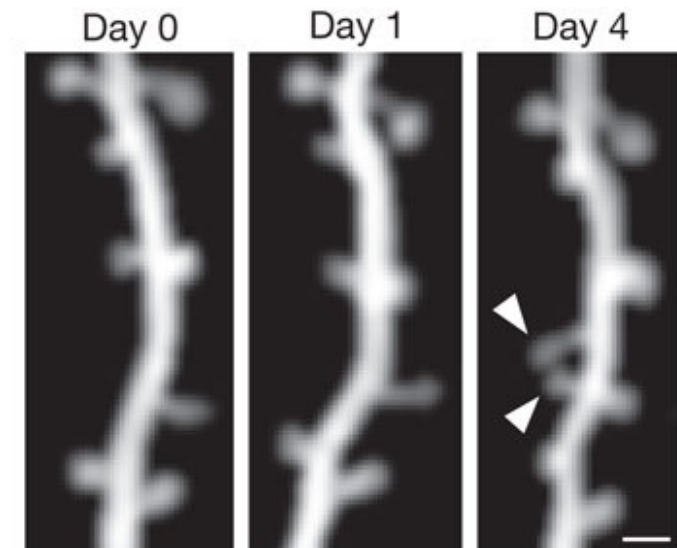
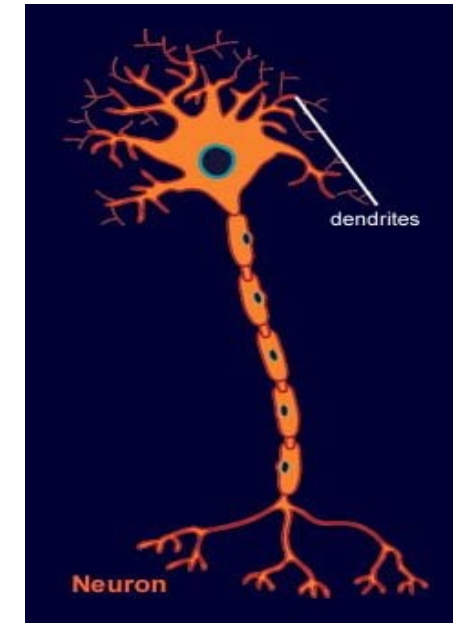
- 1 Dendrites
- 2 Cell body
- 3 Axon
- 4 Buttons (pre-synaptic terminals)

General **function**:

- 1 receiving input
- 2 integrating – cellular response
- 3 intracellular communication
- 4 intercellular communication - output

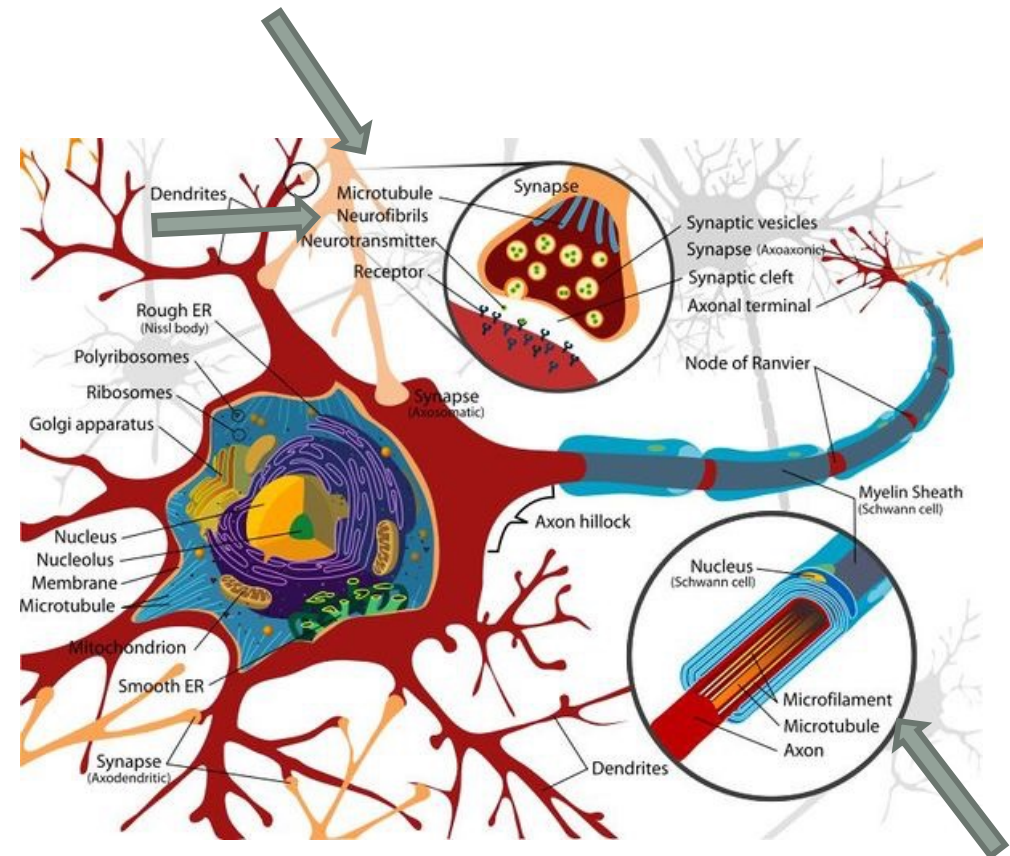
1 Dendrites

- Extensions which receive signals from other nerve cells (message **IN**)
 - Carry impulses from other neurons or receptors toward the cell body
 - Most neurons have several dendrites
 - Dendritic spines: Little protrusions where incoming synapses connect
 - Dendritic spines grow after learning:

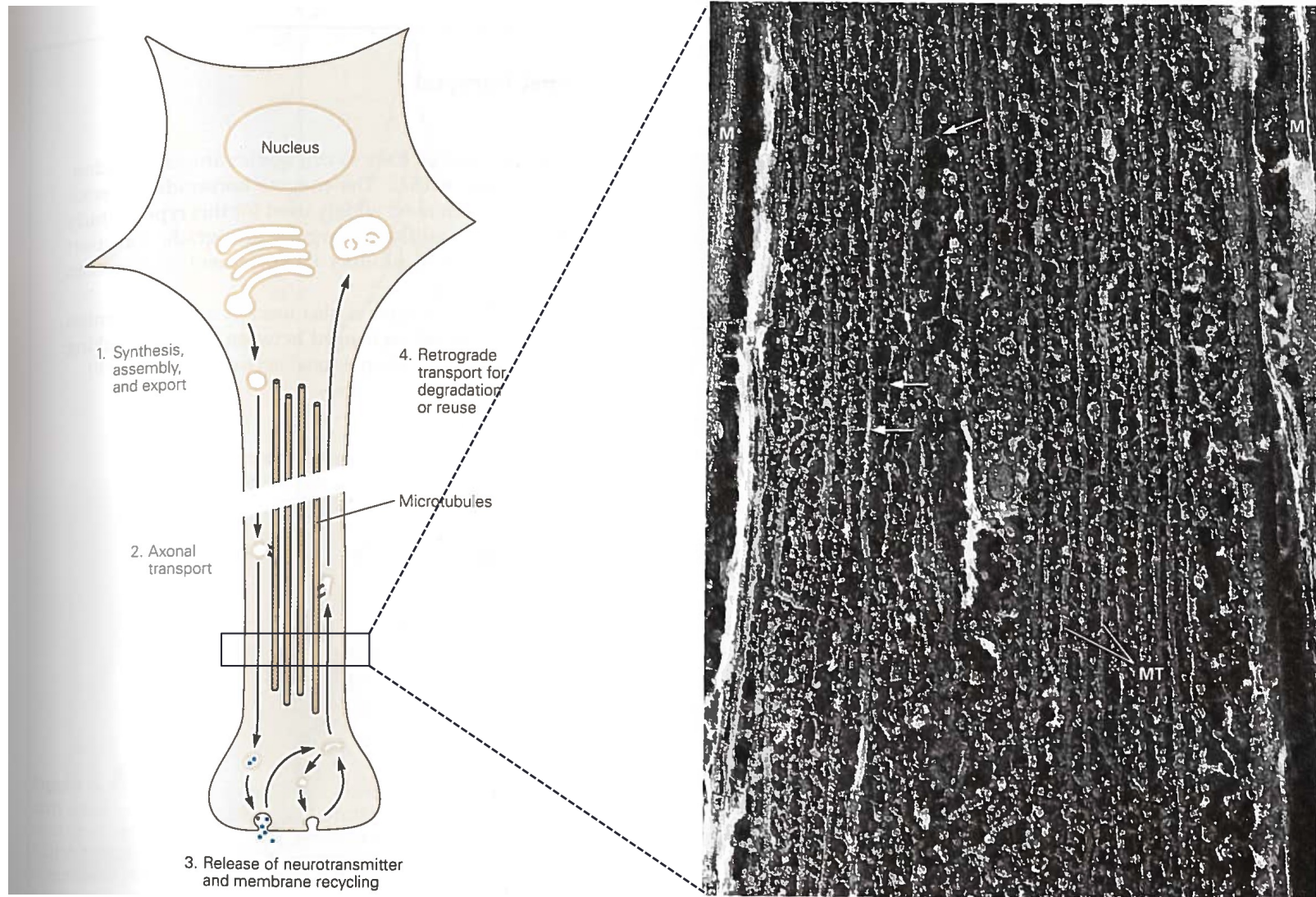


2 Cell body

- Structural elements
 - Microtubules
 - 20nm thick tubes
 - Consist of α and β -tubulin
 - Intracellular movement
 - Microtubule-associated proteins
 - e.g., tau (disrupted in AD)
 - Neurofibrils
 - 10nm twisted cables
 - Consist of several NF-molecules
 - Structural support
 - Microfilaments
 - 5nm thick doublehelix
 - Consist of actin molecules
 - Cytoskeletal support

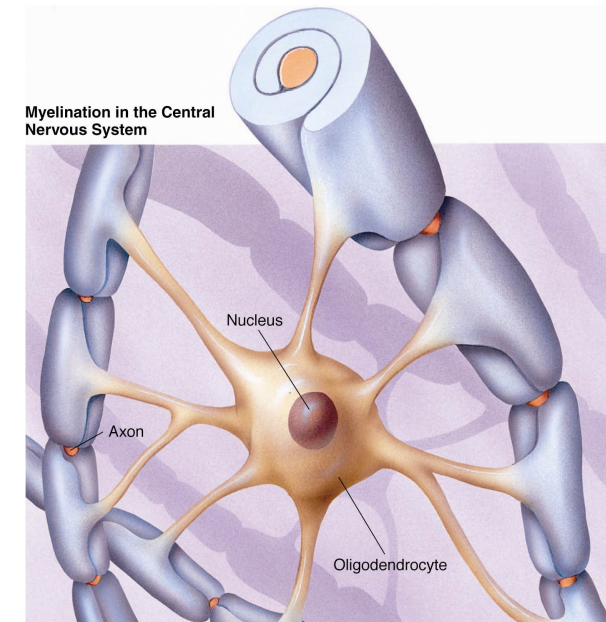
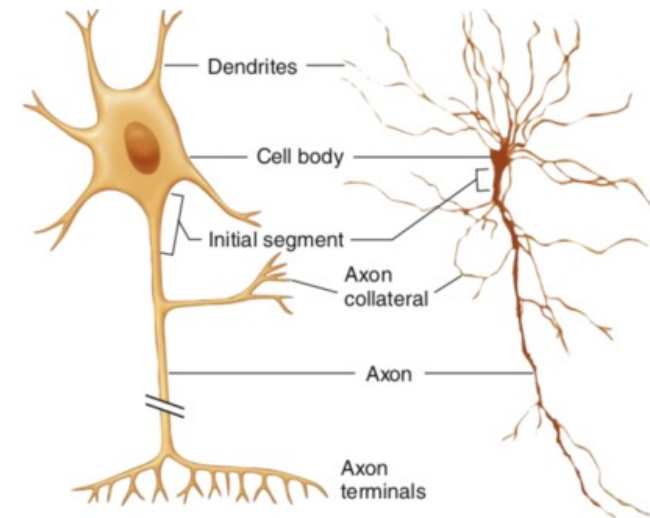


Microtubules – supplemental information



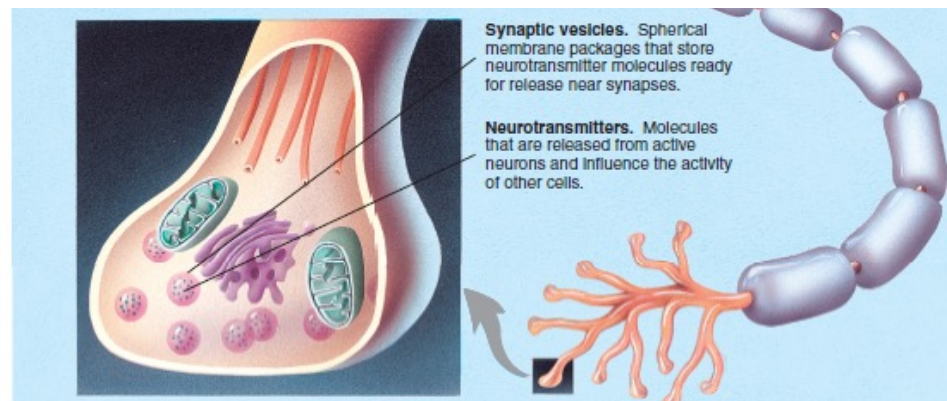
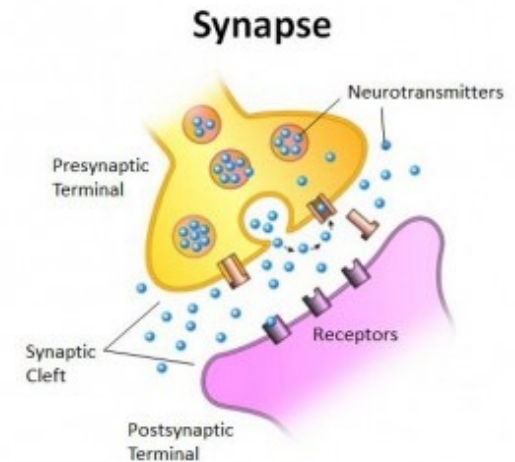
3 Axon

- Main conducting unit of the neuron
- Carries impulses away from the cell body to other neurons or to effectors (message **OUT**)
- **Axon terminal (terminal bouton)** – the end of the axon
- Wrapped around by a **myelin sheath** (myelination) in vertebrates
 - produced by oligodendrocytes (glia)
 - facilitates electrical communication (“saltatory conduction”)

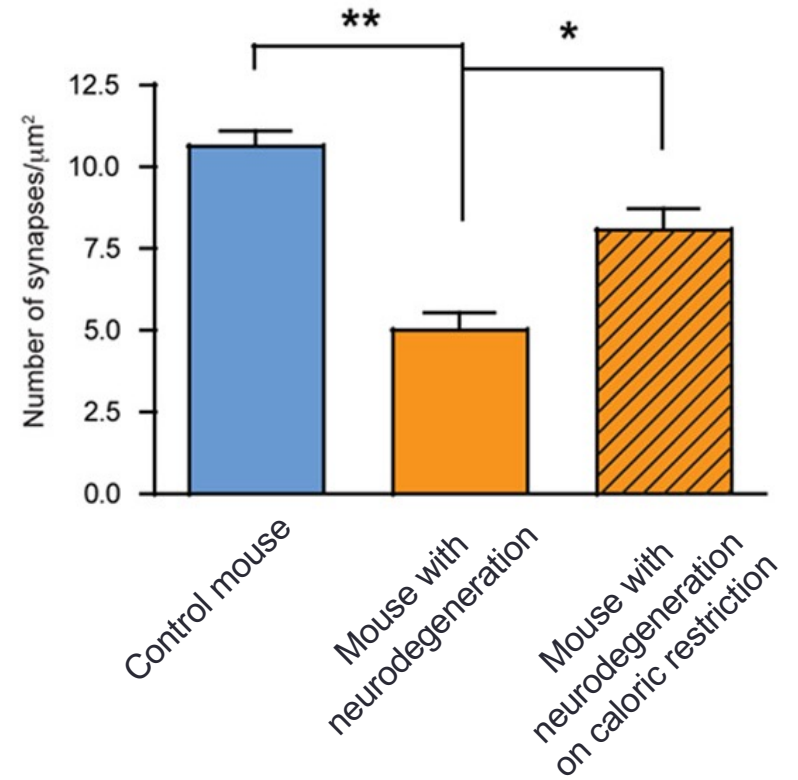
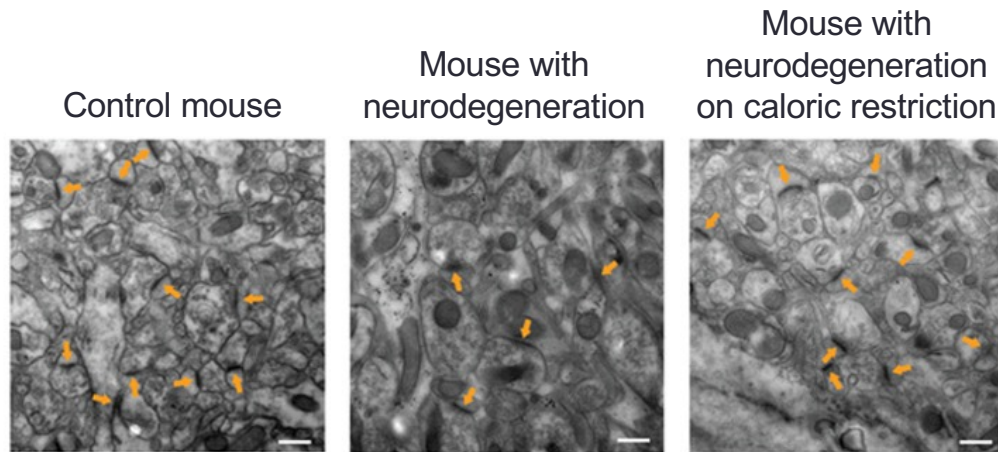


4 Buttons/Presynaptic terminals

- Neurons communicate via **synapses**
 - Cell transmitting a signal = **presynaptic**
 - Cell receiving = **postsynaptic**;
can be another neuron or an effector such as a muscle or gland
 - In between: **Synaptic cleft**
- Signal within cells is electrical, but between cells is chemical
 - Chemical messengers which transmit the signal = **neurotransmitters**



The synapse in neurodegeneration



Brain anatomy – overview

1) What's contained within the brain ?

- Cell types of the CNS

2) What protects the brain?

- Physical and chemical protection

3) Major subdivision of the brain and their function

- **Brain protection**



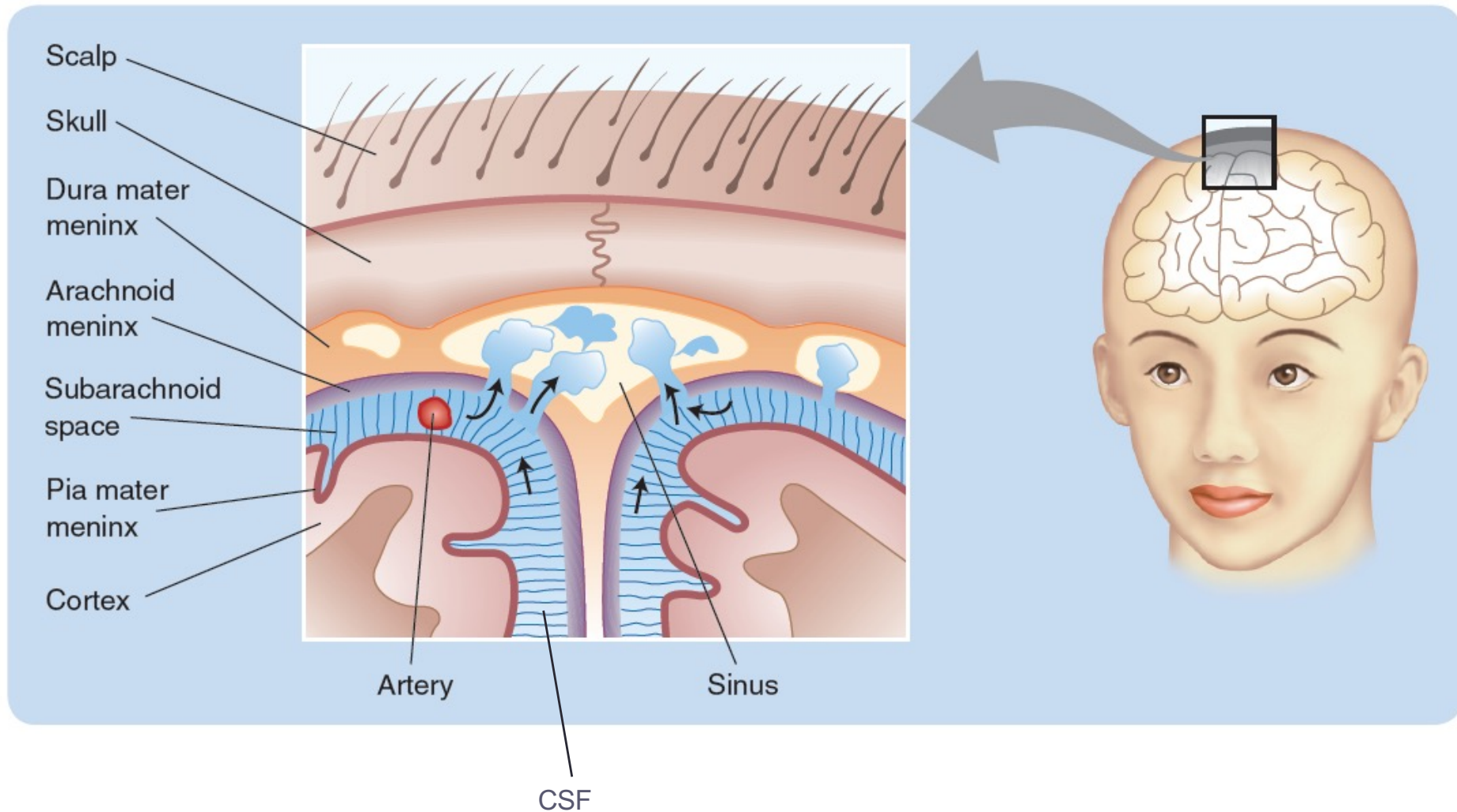
1) **Physical**

- Skull
- 3 meninges
 - Dura mater
 - Arachnoid membrane
 - Pia mater
- Cerebrospinal fluid (CSF)
 - Ventricles
 - Subarachnoid space

Physical protection

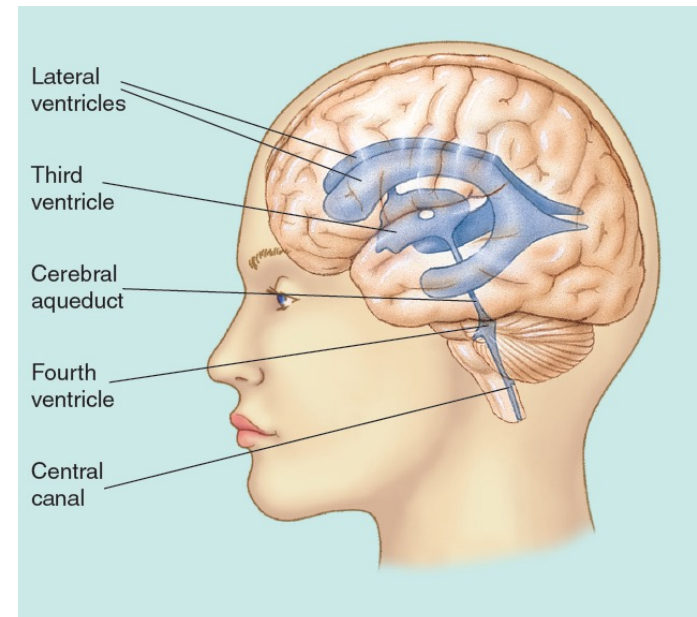
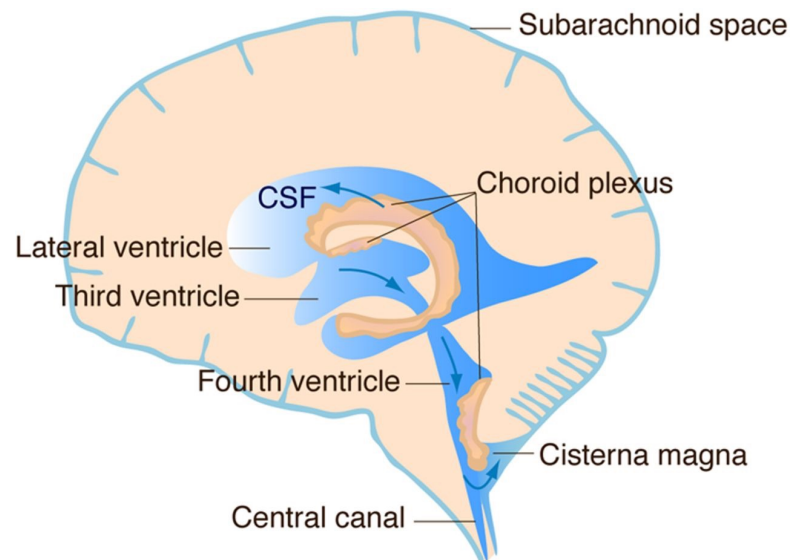
Buoyancy and shock absorption

Meninges and CSF



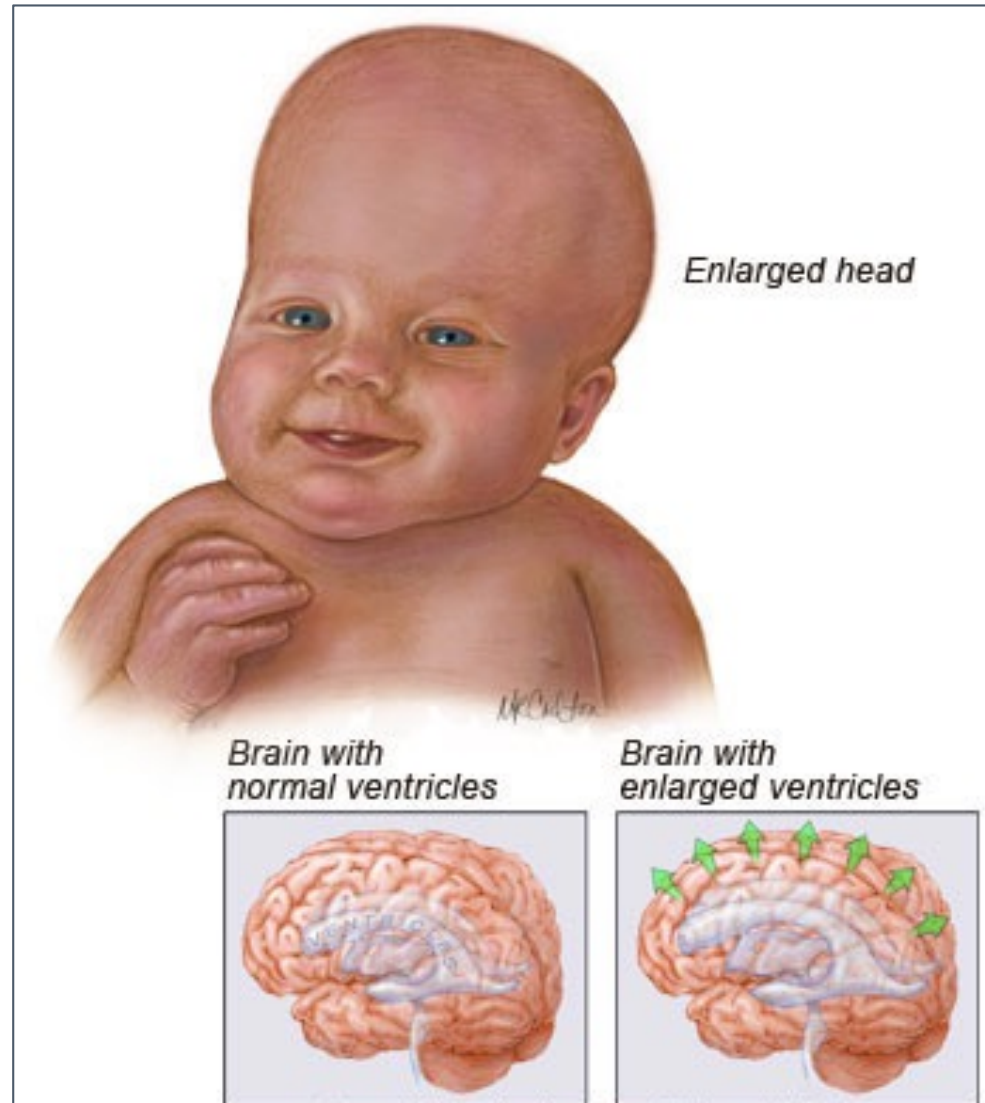
CSF

- Produced by choroid plexus
- Filling the ventricles



- Functions:
 - Mechanical cushion
 - Removal of brain metabolites
 - Provide a constant extracellular environment for neurons and glia

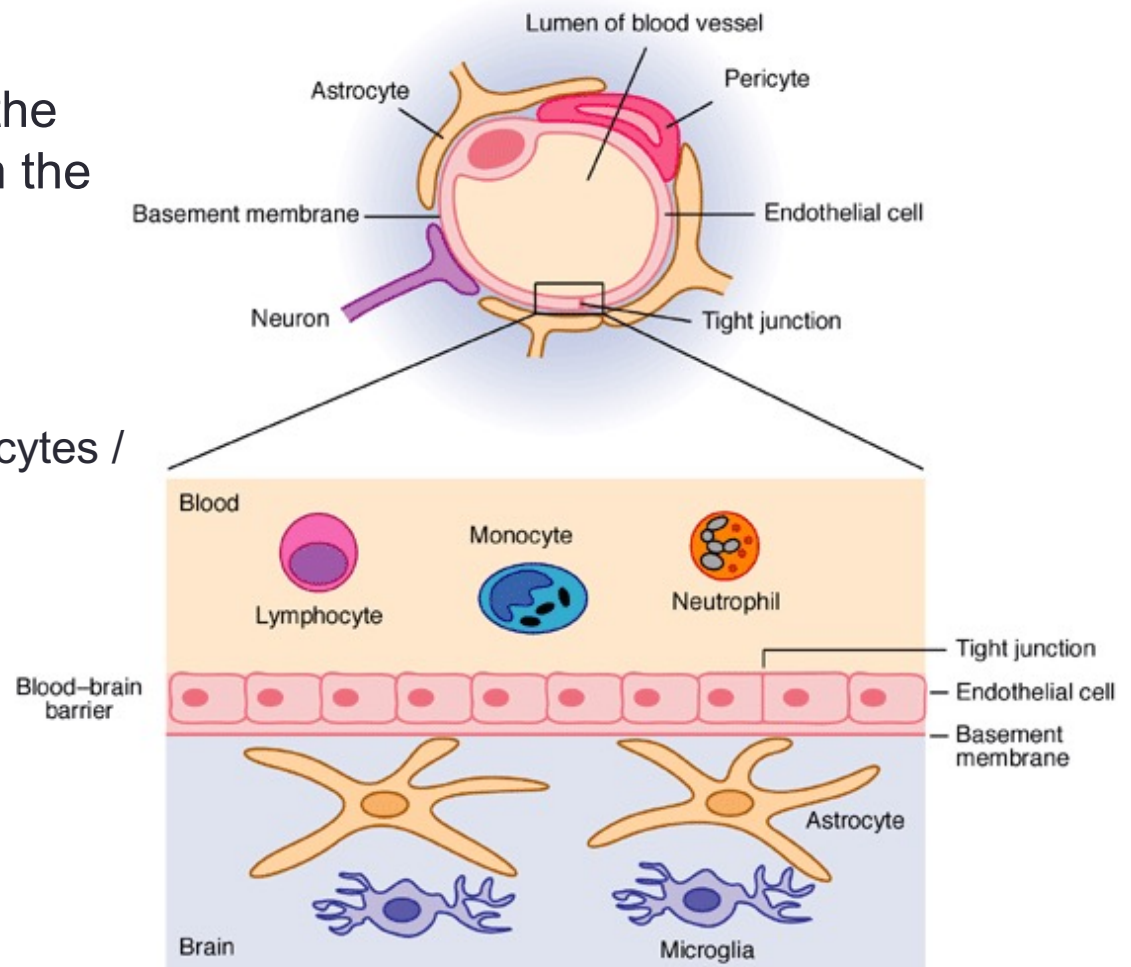
Hydrocephalus – no draining of CSF



• Brain protection

2) Chemical: Blood Brain Barrier

- Specialized structure preventing the entry of toxins (and drugs...) from the blood into the brain
- Composed of
 - Endothelial cells / astrocytes / pericytes / basal membrane
- Selective permeability:
 - “Tight junctions”

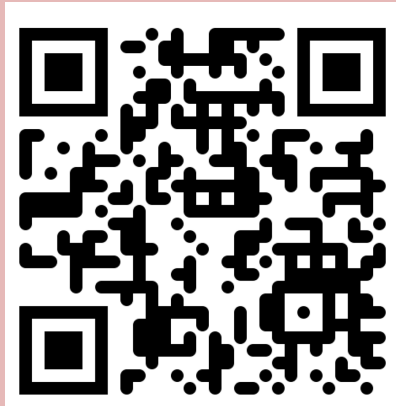


BBB dysfunction and consequences

| Diseases | BBB proteins and affected mechanisms |
|------------------------|--|
| Alzheimer's disease | BBB disruption and permit peripheral IgG to brain. Decrease P-gp and accumulate amyloid- β in brain [67]. |
| Parkinson's disease | BBB disruption increases therapeutic agent concentration and reduces efficacy of Pgp [6]. |
| Stroke | Astrocytes secrete TGF β that downregulates tissue plasminogen activator (tPA) and anticoagulant thrombomodulin (TM) [68]. |
| Epilepsy | Transient BBB opening and upregulation of multiple drug resistance (MRD1) Pgp [69]. |
| Trauma | Opening of BBB, release of IL-6 from astrocytes, and neuroinflammation [70]. |
| HIV | BBB TJ disruption. Loss of glycoproteins and apoptosis of endothelial cell lead to increase diameter of cortical vessels [71]. |
| Infectious processes | Increase CSF/serum albumin ratio. Bacterial lipopolysaccharides affect BBB TJ [72]. |
| Brain tumours | Breakdown of BBB TJ, overexpress folate, insulin, and transferrin receptor, and downregulation of claudin 1/3 [73]. |
| Ischaemic brain oedema | BBB breakdown due to MMP9 release by neutrophils and degradation of occludin, claudins, and JAM [74]. |

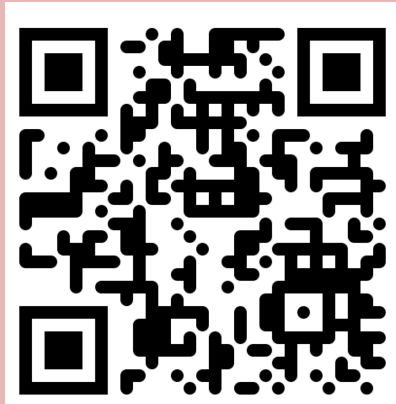
Which of the following is true?

- A. Microtubules stabilize the synaptic cleft
- B. Microtubules stabilize the axon
- C. Microtubules stabilize dendrites



Synaptic transmission is electrical

- A. True
- B. False



How is the brain protected?

Brain anatomy – overview

1) What's contained within the brain ?

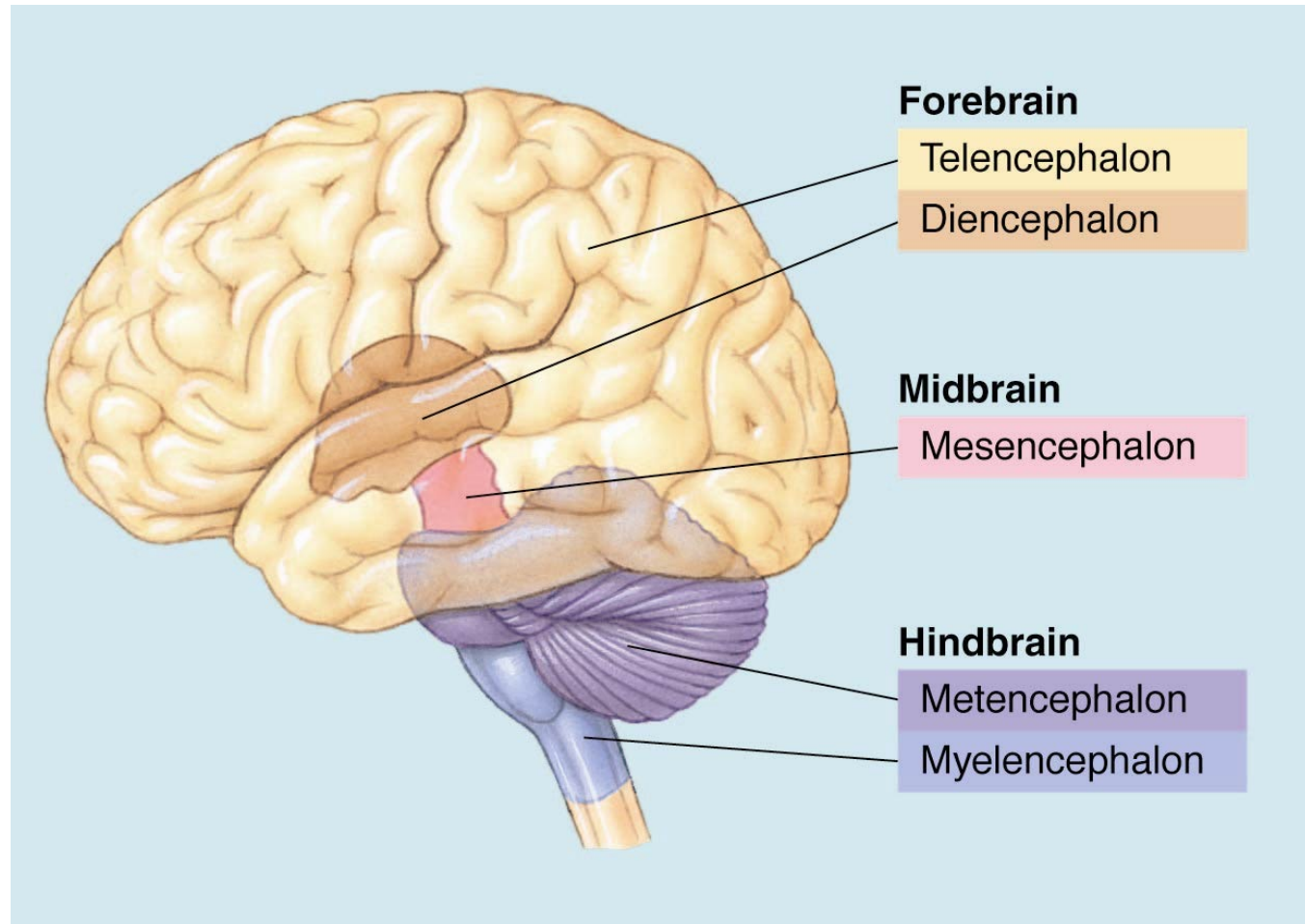
- Cell types of the CNS

2) What protects the brain?

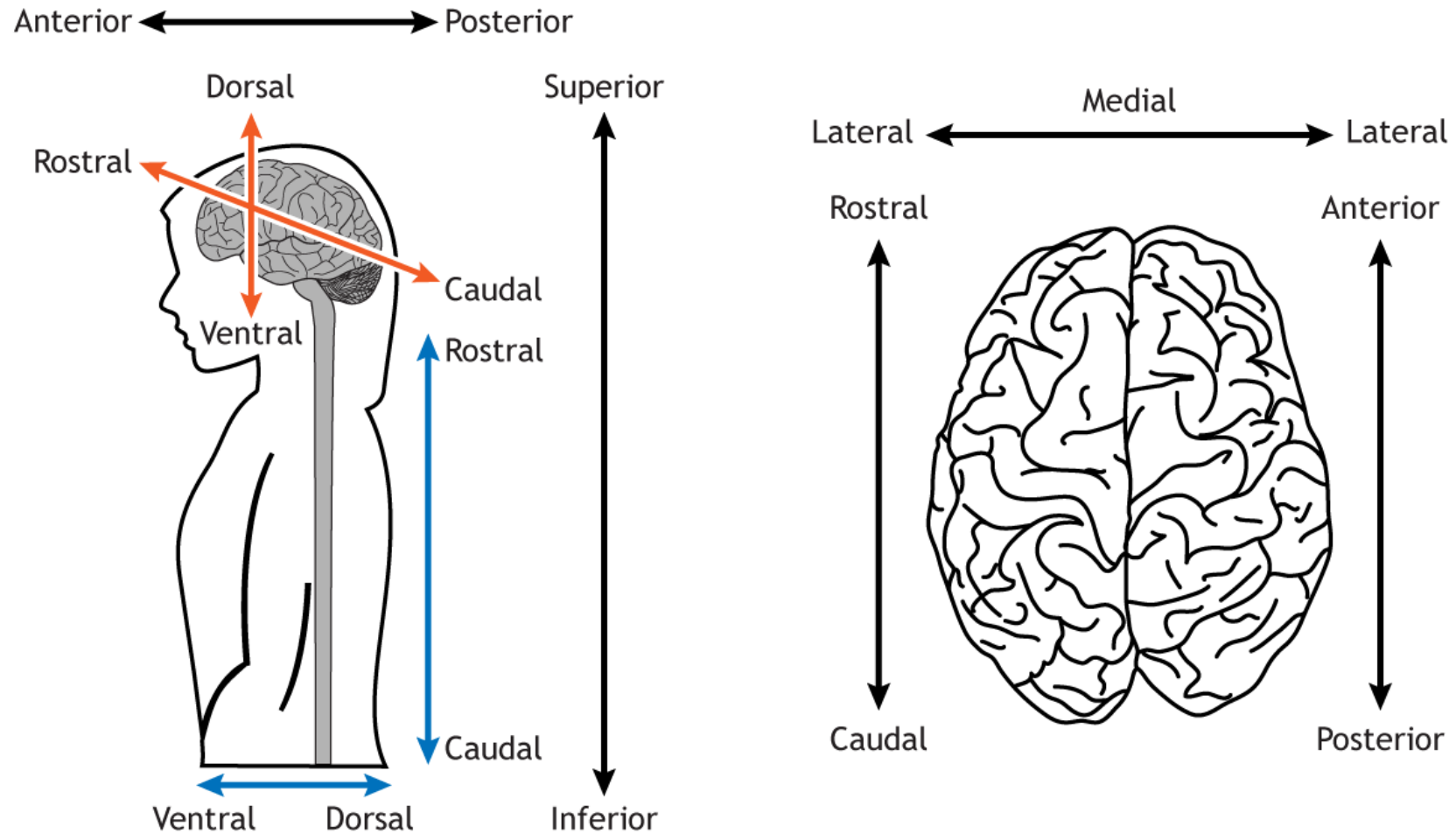
- Physical and chemical protection

3) Major subdivision of the brain and their function

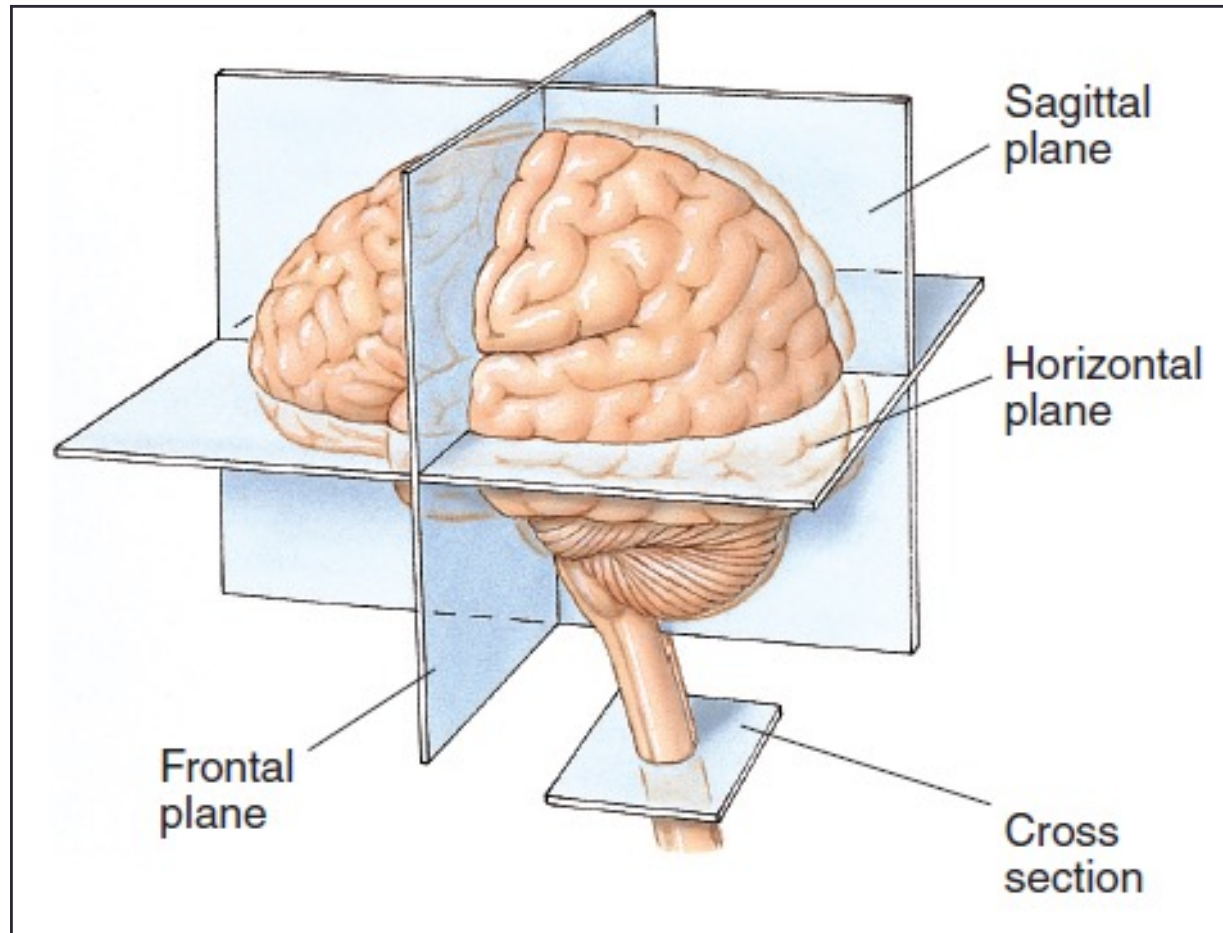
The 5 Major Division of the Brain



Orientation in the brain

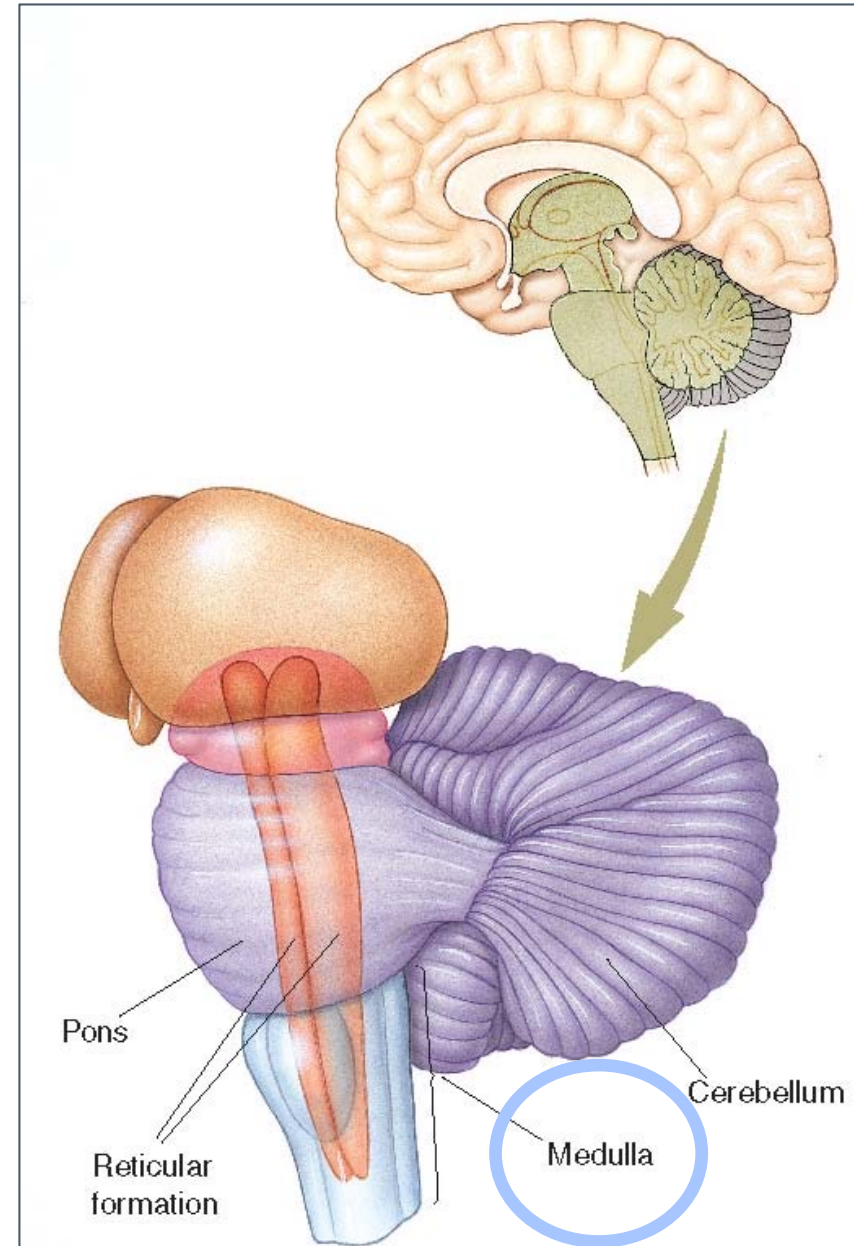


Orientation in the brain

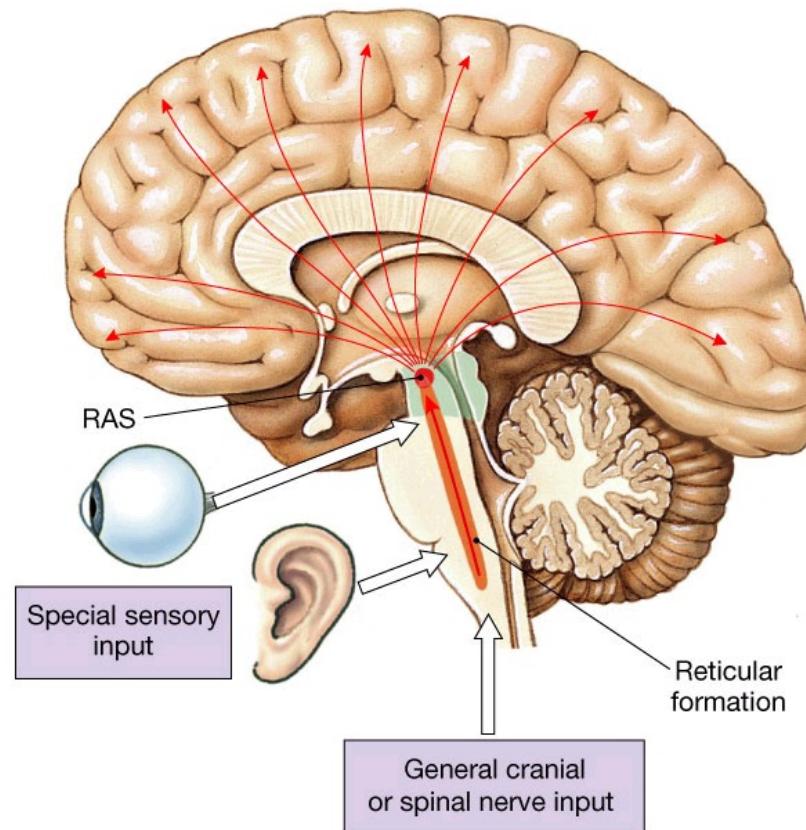


1) Myelencephalon (Medulla)

- Site of **reticular formation**
 - Regulates basic life functions
 - respiration
 - heart rate
 - vomiting
 - salivation
 - Also implicated in vision, audition and other functions via Reticular Activating System (RAS)



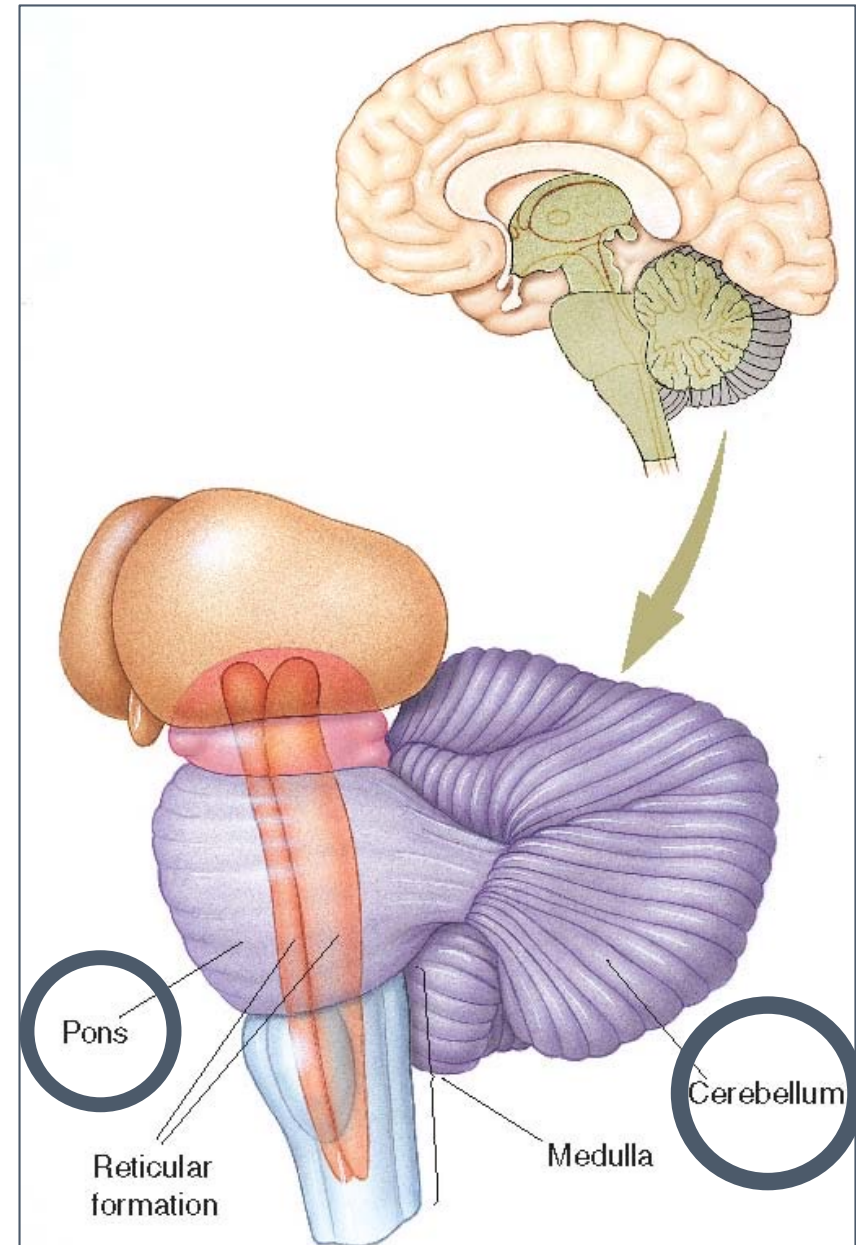
1) Myelencephalon – Reticular Activating System



Because of its myriad of basic life functions, damage to the reticular formation often leads to coma or death

2) Metencephalon

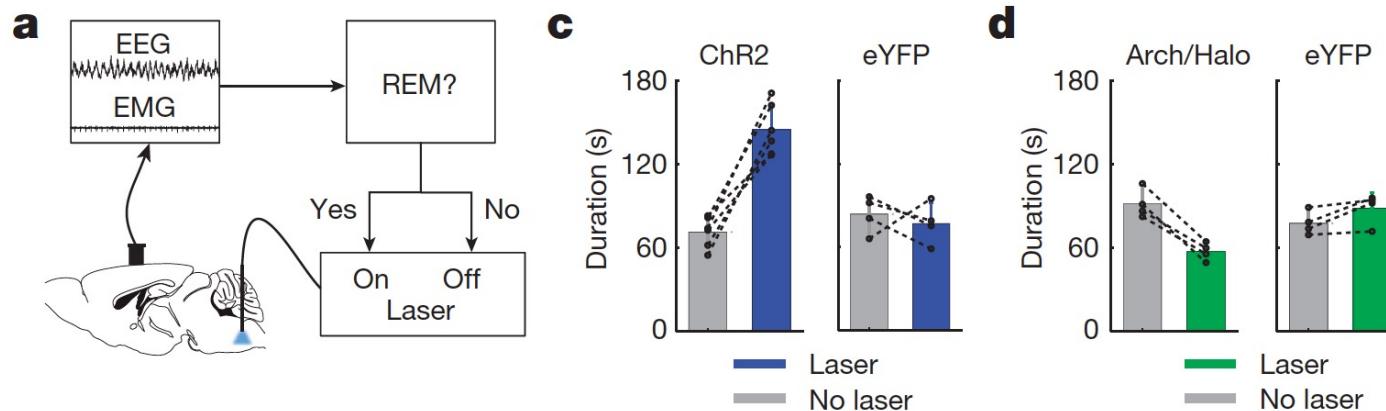
- Site of **reticular formation**
- **Pons**
 - a “bridge” for many fibers passing from one side of the brain to the other
- involved in
 - sleep
 - arousal
 - muscle tone



2) Metencephalon – supplementary information

- **Pons and sleep**

- Closed-loop optogenetic experiment

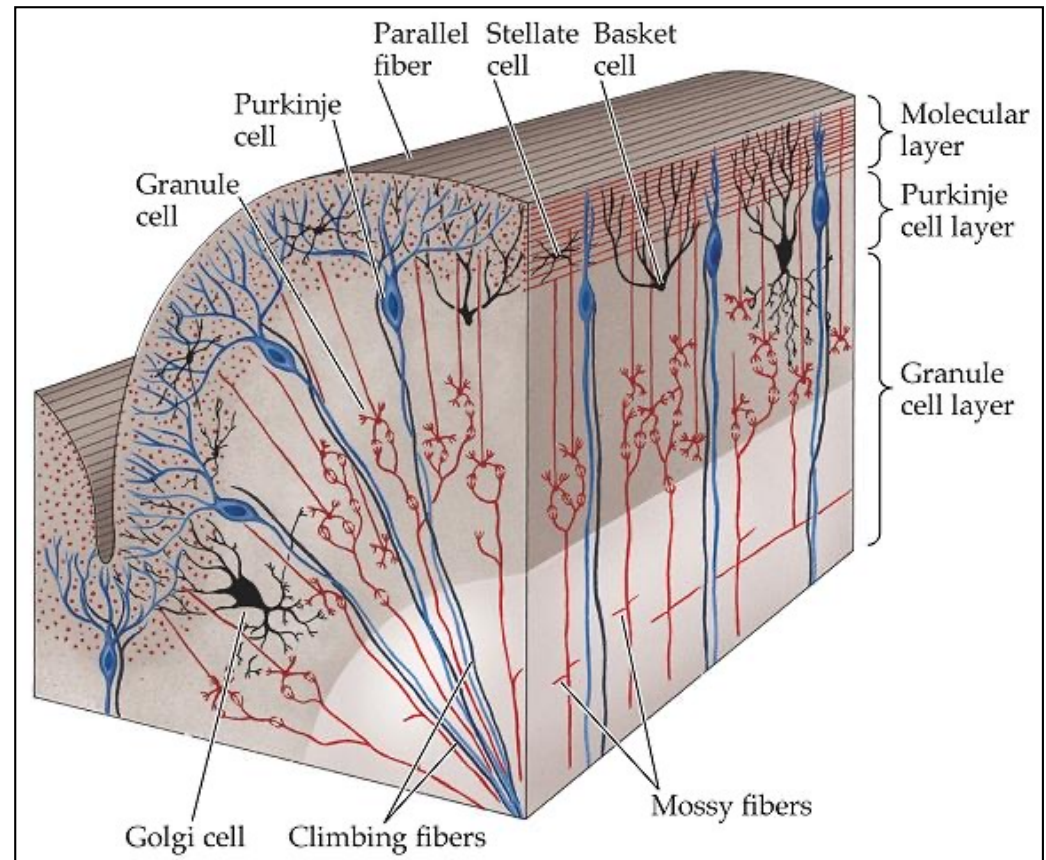


c, d, duration of REM sleep;
eYFP=control virus
ChR2: Channelrhodopsin, activatory opsin
Arch/Halo: Archerhodopsin, halorhodopsin=inhibitory opsins

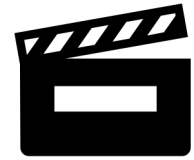
2) Metencephalon

• Cerebellum

- Specialized cell layers
 - Molecular Layer (output)
 - Purkinje Cell Layer (regulatory – inhibitory)
 - Granule Cell Layer (input)
- Major Functions
 - Balance
 - Motor Coordination
 - Timing and sequencing of rapid movements
 - Sensorimotor Learning



2) Metencephalon



- **Damage to the cerebellum:**

Control



Alcoholic



- **Environmentally (toxin)-induced cerebellar ataxia:**
 - Damaged and dysfunctional cerebellum
 - Poor coordination, unsteady gait, and difficulty with fine motor tasks
 - Can be caused by toxins, stroke, vitamin deficiency, immunological disorders

2) Metencephalon

- **Genetically determined cerebellar ataxia: Niemann-Pick Type C**

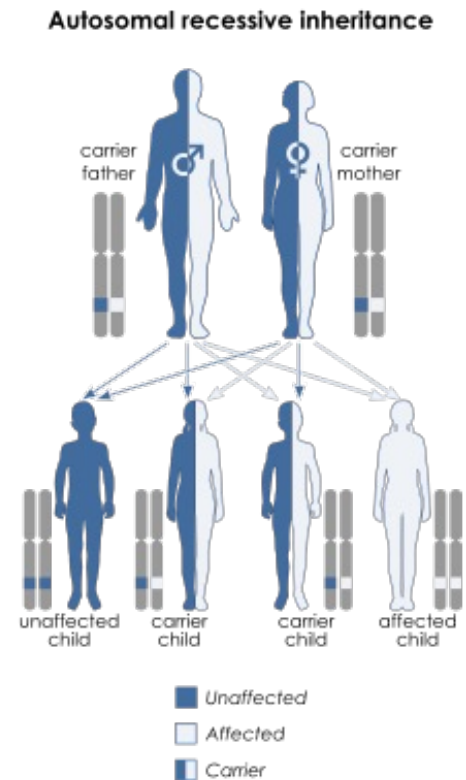
- Monogenetic neurodevelopmental disorder

- Affected genes: NPC1 and NPC2

- Prevalence 1:150'000

- Metabolic dysfunctions

- Loss of myelination in the cerebellum



The 5 Major Division of the Brain

