nervous system structure & function

skull & spinal cord

- skull: protects the brain from measurable amount of force.
- spinal cord: protected by the spinal column
  - ↳ individual components are vertebrae
  - ↳ scand brain are connected.
- CSF flows between the arachnoid and pial layers.

Layers of Meninges: (outer to inner layer):

1. Dura
2. Arachnoid
3. Pia

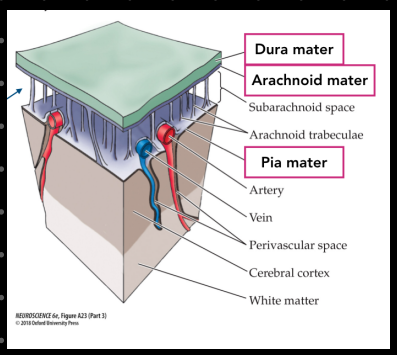
↳ made up of collagen fibers (elastic).

cerebrospinal fluid

- CSF: balanced ionic concentration
- CSF movement is via the pulsation of the blood vessels.
  - drainage into the sagittal sinus to join back into the bloodstream.
- rate of flow: under circadian rhythm
  - ↳ fastest when asleep.
- The CSF: made via the ependymal cells in the choroid plexus of the ventricles.
- CSF production in mice: increased under anaesthetic
  decreased under AD gene mice.

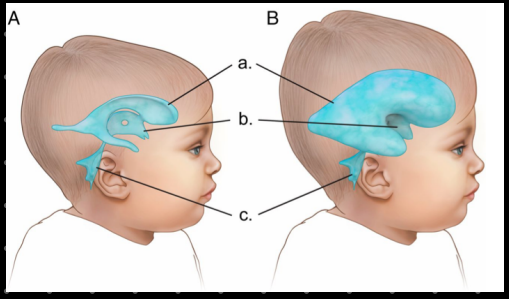
Functions

1. cushion the brain from dmg
2. maintains homeostatic environm.
3. provide neurotrophic factor for the growth of axons.
4. waste removal.



WHAT HAPPENS WHEN CSF BUILDS UP?

- in children: hydrocephalus → the skull bones are not fused yet, so the brain starts to swell.
  - neurological deficits.
- in adult: the skull bones are all fused together, so the ICP would increase.
  - resolved with trephination (hole in the brain)



NEURON DOCTRINE

- Neuron doctrine: original arguement
  - = the neurons are reticulum or discrete cells.

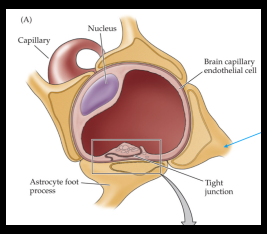
observations that it's reticulum:

- golgi stain = only 5-10% of cells were stained.
- revealed neurites (hairy processes)
- the neurites were growing out of a cell body.

observations that it's discrete:

- the sub-cellular processes: fibril structures were discontinuous
- proven by EM: the neuron's neurites were able to touch but the membranes were non-continuous.

BLOOD BRAIN barrier



- BBB = made via the glial cell processes → the astrocyte foot process wraps around the blood vessel.
- Astroglia are the support cells that are contributing to the maintenance of the BBB.
  - ↳ locally controls the blood vessel diameter.
- molecular transport: transporter proteins are required to move the glc across the membrane.
  - ↳ use ATP to move essential molecules.

Drugs to penetrate the BBB: hydrophilic to move thru blood. hydrophobic to move thru membrane.

* need specialized transport proteins for each molecule *

- the longer you wait after the axonal death, the longer the axon would grow back.

Neurons have to have:

① Transmission of information → the movement of information from the denarite of the neuron → the axon.

② The neurons have to be able to move information from one neuron to another: passing information

Neuron Doctrine

① The basis of the nervous system = the neuron.

② The neurons are distinct and non continuous.

DIRECTIONAL FLOW

- directional flow was determined via the dendrite and axon
  - the dendrites in the sensory neurons are always farthest from CNS, and the axons are closest into the CNS.

Synapses

- info: transmitted from one cell → next via synapse.
  - 2 main kinds of synapse: electrical and chemical synapse.

Chemical Synapse

- no specialized structure to move chemical from one neuron → next.
  - ↳ the NT are released into the synapse (the gap) and diffuse into the next neuron.

Electrical currents are metabolically more efficient.

Advantage of chemical synapse

- signal modification (signals can be changed plastically).
- signal amplification
- computation: can invert the signal from + → - ve.

Electrical Synapse

- Specialized junction for the movement of electrical signals from one neuron → next.
  - ↳ the electrical signals move directly from the prev to the next neuron.
- Current flows directly into the next neuron.

Experiment: Frog Hearts

1. Stimulate donor heart to decrease HR via CN10.
2. ECF w/ chemicals from donor heart given to the recipient and the recipient heart also had ↓ HR.

→ the electrical stimulation resulted in chemical changes that altered the HR on another heart w/o the vagus nerve.
→ chemical stim could work independently of the electrical stimulation.

the HR was measured by Heart tension (↓ T = ↓ HR when chemical used).

Neuron diversity

3 main kinds of neurons

- **Sensory neuron** - brings in info from outside of the CNS
- **Interneuron** - connects the sensory/MN.
- **Motor neuron** - brings the info out into the periphery.

4 kinds of neuronal diversity:

1. **Structural**: number + arrangement of neurites.
2. **Connectivity**: converge/diverge
3. **Chemical**: diff NT for diff neurons
4. **Electrical**: diff AP frequencies.

neuronal classification:

- modern method = RNA sequencing, via. seperating the neurons and testing their RNA sequences.
- previous categories of neurons can be split into 17 individual neurons bc of the RNA sequencing.

Problems w/ diversity

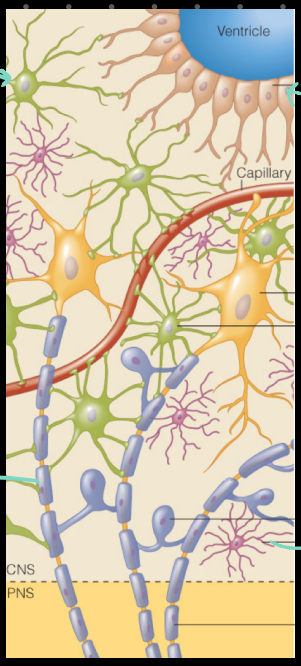
- Maintaining polarity: packing, sorting, mvmt of the proteins
- site and transport
- the use of metabolic energy = very high.
  - need to make/resorb NT.
- switching from chemical/electrical signals fast and reliably.

Neurons overcome this problem via the use of support cells.

glial cells

- glial cells are non-excitable cell that support the neurons.
  - ↳ glial cell : neuron ratio ~ 1:1

Astrocytes
- most abundant cell type involved:
  - EC concentration [ions]
  - growth regulation
  - homeostatic regulation
  - neurotrophic factors.



ependymal cells
- involved in secretion of fluid that becomes CSF
- permissive form of BBB.
- in the choroid plexus of the ventricles.

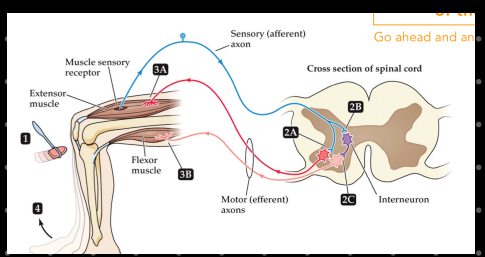
Myelinating cell
- myelinating cell: cell that make the myelin (which makes outgrowths & wraps around axons).
  - ↳ oligodendrocyte CNS, Schwann cell PNS.

Microglia
- macrophage descendants
- involved in: inflammation
  neuroplasticity of
  axon growth
  scavenging.

Nervous system organization

- **Complete circuit:** one sensory and one motor neuron.
- when you have more neurons in the circuit → the neurons are more specialized.
- **Signal integration:** occurs @ the soma, not the axon.
  - ↳ the signals are generated @ axon but not integrated.
- vertebrate reflex arc:

Stimulus (on sensory neuron) → IN
- ipsilateral flexion, inhib extension.
- the same sensory neuron can diverge.
- IN can send signal across midline of SC. → contralateral extension, inhib flexion.



Hub & Spoke NS
- CNS / PNS distinction: CNS > PNS (size, cell #).
- CNS → PNS connection, not PNS-PNS.
- unidirectional info flow
- specialized neurons
  - ↳ distinct afferent/efferent/IN.

Neural Net NS.
- no CNS / PNS distinction.
- no central ganglia: info just flows everywhere.
- bidirectional information flow.
- no specialization of cell/neuron function.
  - ↳ efferent/afferent are all in one neuron.

AP vs. PSP

- AP: non decaying. travels @ one magnitude (binary signal) → electrical mechanism of signal transduction.
  - ↳ detectable via the extracellular recording.
- PSP: decaying, travels @ graded potentials → current due to the NT activating receptor.
  - ↳ detected only via intracellular recording.

Types of PSP:

① Excitatory PSP → they cause the cell to be more likely to fire.

② Inhibitory PSP → cause cell to be less likely to fire.

③ Modulatory → they alter the synapses around the cell, making it altered.
↳ not distinctly excitatory / inhibitory.

Recurrent Inhibition / Excitation

recurrent inhibition

(-ve feedback, activation means turning off the neuron that initiated it)

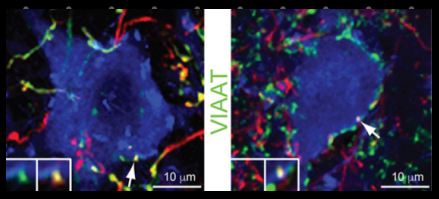
recurrent excitation

(+ve feedback, the activation of the cell continuously activates itself)

↓

needs external source to turn off.

renshaw cell



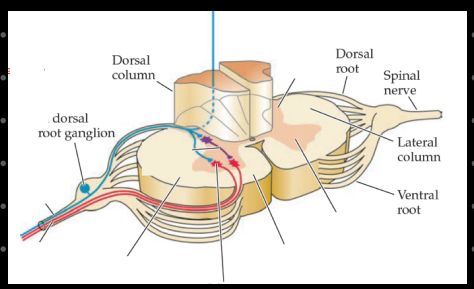
- determined by staining for protein:

a) calbindin → exclusive to the renshaw cell in SC.

b) AchR → b/c R cell get input from the motor axons.

Renshaw cell: inhibitory.
- receives collateral from the MN
- also has one extension of axon back to MN.

spinal cord



- White matter: myelinated axons.
- Gray matter: neuropil, soma.
  ↓
  axon terminal, dendrite, synapse.

- WM > GM in cervical SC: b/c there's more axons going to/from brain to diff regions.
  ↳ basis of localization of fcn.

SC: mapped topographically: mapped by fcn.
somatotopy: mapping of the diff body parts along vertical axis of SC.

- Distal muscles: innervated by lateral GM.
- Proximal muscle: innervated by medial GM.

Exp: changing sensory - Motor neuron connection.
- Mice muscles in ventral horn of GM = matched to the soma via injecting dye
  ↳ the injection of dye from terminal → goes to soma.
- deletion of FOXP1 gene: MN oriented diff.
  ⇓
  lots of fine motor scale; movements are non-smooth.
  mapping of MN.

↓
more distal muscle = more ventral soma.

ANS

- sympa/parasympa NS.
- uses 2 neurons to get to organ → CNS uses 1.
  - still have 1 sensory 1 motor.
  - ↳ pre/post-ganglionic neurons.
- innervates the visceral organs.
- sympa & parasympa (time): b/c the syma = used to get the body ready for fight/flight.
  - ↓
  - doesn't actually innervate the muscles to move them.
- metabolic balance of the 2 maintains the metabolic functioning of the body.

ENS

- can act independently of the CNS.
  - mainly involved in the innerv. of the GI.
  - ⇓
  - the parasympa would synapse on the ENS neurons (they're found in plexuses of GI) rather than the non-neuronal GI cells.