M3a: Biology & Neuroscience

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The Nervous System

- Can be divided into two sections
  - Central nervous system
    - Brain
    - Spinal cord
  - Peripheral nervous system
    - Nerves to and from the rest of the body
- The peripheral nervous system sends and receives messages from the central nervous system, allowing us to integrate information from our environment and respond accordingly

The brain: Fun facts

- Adult: ~3 lbs
- Newborn: ~1 lbs
- ~78% water, ~10% fat
- Although we divide the brain up conceptually into areas of specialization, in reality, it's just a fairly uniform wrinkly blob
- The wrinkles increase the surface area of the brain
- If we stretched brain out and laid it flat, it would cover 2.5 square feet
- It uses about 20% of your energy
- Specialized laterally (left and right hemisphere) - lateralized function
- Each hemisphere controls the opposite side of the body

Neurons

- Nervous system has specialized cells called neurons
- ~100 billion neurons in our body
- Similar shape in all animals, but we have many more
- Many shapes and sizes, but all have common basic structures
- Communication cells
- Transmit action potentials (nerve impulses) from one part of the body to another

Types of cells in the nervous system

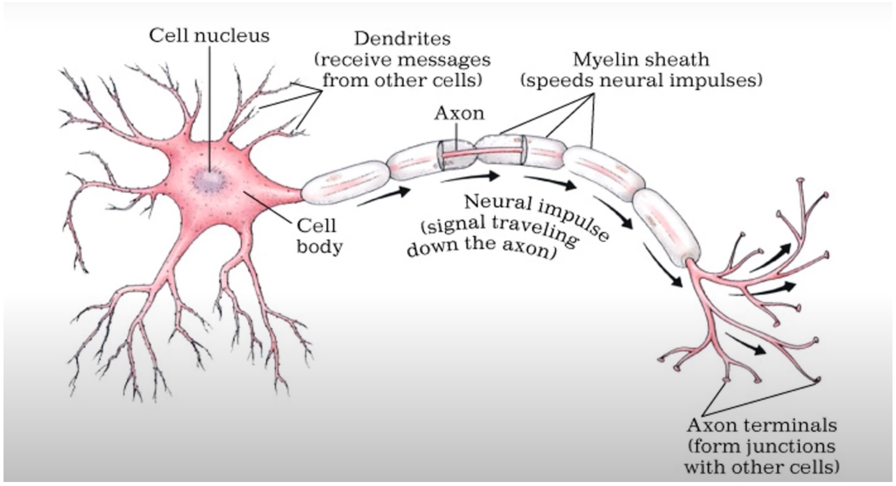
<u>Neurons</u>

- Sensory neurons
  - Carry information from the body to the brain
- Motor neurons
  - Carry commands from the brain to the body
- Interneurons (most numerous)
  - Connects neurons to one another
  - Process information between other neurons

<u>Glial cells</u>

- Provide structural support, nourishment, and insulation for neurons

Basic structures of neurons



- Terminal buttons do not physically touch dendrites of other neurons, but synapse on it by releasing neurotransmitters across a very small distance
- Signal = action potential
- Signal driven by a chemical exchange that leads to a change in electrical excitation across the cell membrane
- A neuron gets excited and transmits an electrical charge from one end to the other, sending it on to another neuron

Myelin sheath

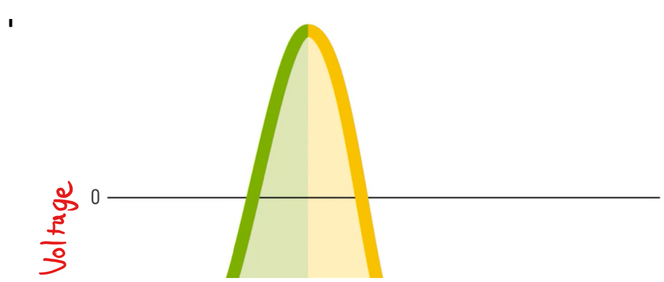
- A fatty tissue that coats the axon, speeding up transmission
- Allows nerve impulses to jump from node to node

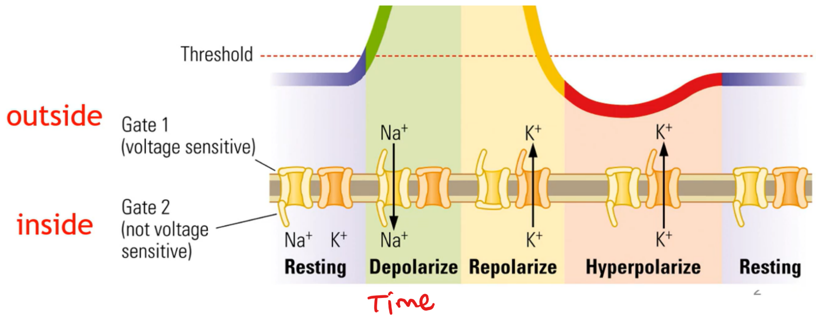
Multiple sclerosis

- Autoimmune disease
- Immune system attacks proteins in myelin causing it to become inflamed and damaged
- Because of this inflammation and damage, nerve signals are not transmitted adequately
- Symptoms depend on where the damage is (CNS or PNS)

Action potential

- An electrical charge that travels down the axon driven by the chemical exchange of ions which are electrically charged particles in our bodies
- Some ions carry a positive charge and others carry a negative charge
- Exchange of ions can affect the overall charge inside the axon





- At different components of the action potential, different ion channels are open or closed
- At rest, the cell membrane has a resting potential of about -70 mV
- When cell fires, its charge briefly changes to a positive charge, then returns to its negative charge, where it is once again ready to fire
- The ions are stuck on one side or the other of the cell membrane

Cell membrane: resting (the resting potential)

- When the neuron is not active
- Mainly negatively charged ions inside the axon
- Mainly positively charged ions outside the axon
- Difference in charge across the membrane: resting potential
- The cell is in a state where it is ready to fire if a signal comes along
- Positive ions cannot pass through the cell membrane at this point because Na+ channels are closed

Cell membrane: firing (depolarization)

- When a stimulus arrives that is sufficient for the neuron to fire, Na+ channels open allowing Na+ ions to rush into the cell
- Very shortly after, K+ channels upon, allowing K+ ions to rush out of the cell
- This happens all the way down the axon, with channels opening briefly and then closing as the upcoming ones open
- The signal keeps moving forward along the axon because of refractory period (hyperpolarization)
- Before the cell is ready to fire again, Na+ needs to be pumped back out of the neuron

Response

- At rest, Na+ channels are closed, blocking Na+ outside the axon from entering and keeping the inner charge at -70 mV
- When the neuron receives enough stimulation to reach its threshold, it fires (depolarizes), changing from a negative inner charge to a positive inner charge
- Happens because Na+ channels have opened and allowed Na+ into the cell
- As the action potential move along the axon, the Na+ channels close and K+ channels open because the inside of the cell now has a net positive charge
- Positively charged K+ ions rush out of the cell, moving the cell back towards a negative charge (repolarization)
- This happens a bit to the extreme, so that the cell momentarily has a net negative charge lower than -70 mV (hyperpolarization)

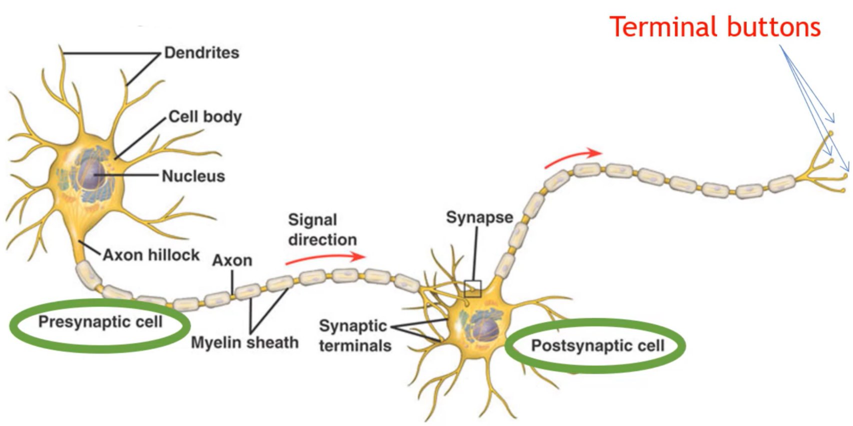
- By the end of this process, the cell returns to a resting stage with a charge of -70 mV

All-or-none response

- Each neuron receives messages from *many* other neurons
  - Excitatory: move the charge of the cell towards a positive charge (more likely to fire)
  - Inhibitory: move the charge of the cell towards a more negative charge (less likely to fire)
  - If excitatory > inhibitory: FIRE
  - If excitatory < inhibitory: DO NOT FIRE
- Response is all-or-none, meaning that the neuron fires at the same level no matter what the stimulus is
- Intensity of sensation/response is coded by the **number and frequency of neurons** firing, not by the size of the response each neuron gives

Neural communication

- Neurons communicate with one another
- How? At the **synapse** via chemical exchange of neurotransmitters
- A single neuron on its own does not do much
- What really drives our behaviour is the communication that happens between different neurons
- Neuron that sends the signal: presynaptic neuron
- Neuron that receives the signal: postsynaptic neuron



- The action potential travels down to the terminal buttons of the presynaptic neuron
- Within the terminal button, there are synaptic vesicles that contain neurotransmitters
- Neurotransmitters are chemical messengers
- They get released in the synapse and act on the postsynaptic cell
- Several receptor sites on the postsynaptic cell
- Receptors (like locks) have a particular shape that only fits a particular type of neurotransmitter
- As the neurotransmitters are released from the presynaptic cell, they float into the synapse and some of them bind to the receptor sites on the postsynaptic cells

Neurotransmitters

- Different pathways in the brain are specialized to use different neurotransmitters
- Once the neurotransmitter binds to the postsynaptic cell, it influences its activity
- There are many types of neurotransmitters, each with a distinctive molecular shape
- Different neurotransmitters are associated with different areas of the brain
- Some neurotransmitters are excitatory (make postsynaptic neuron more likely to fire, depolarization)
- Other neurotransmitters are inhibitory (make postsynaptic neuron less likely to fire, hyperpolarization)
- At any moment, a given neuron will be synapsing on several neurons, receiving a combination of excitatory and inhibitory signals
- Only when or if the signals exceed the threshold of the neuron does it fire, sending an active potential

Leftover neurotransmitter

- Many more neurotransmitter molecules than receptor sites
- Postsynaptic neuron will not be able to bind to all of the available neurotransmitter
- The leftover neurotransmitter gets broken down by enzymes and absorbed back into the presynaptic neuron, ready for the next action potential

Drugs

- Psychoactive drugs work by mimicking the effect of a neurotransmitter or by preventing the effects of a neurotransmitter
- Agonists: mimic NT
- Antagonists: block NT effect
- Partial agonists: bind and activate receptor but with less power

Example of agonist drug

- SSRIs (selective serotonin reuptake inhibitors) function by slowing reuptake of serotonin that is not used in the initial synaptic response, making it available for longer
- Serotonin is implicated in mood and people with depression tend to have lower levels of serotonin than the general population
- SSRIs make more serotonin available for processing, thus potentially improving mood
- SSRIs are serotonin agonists