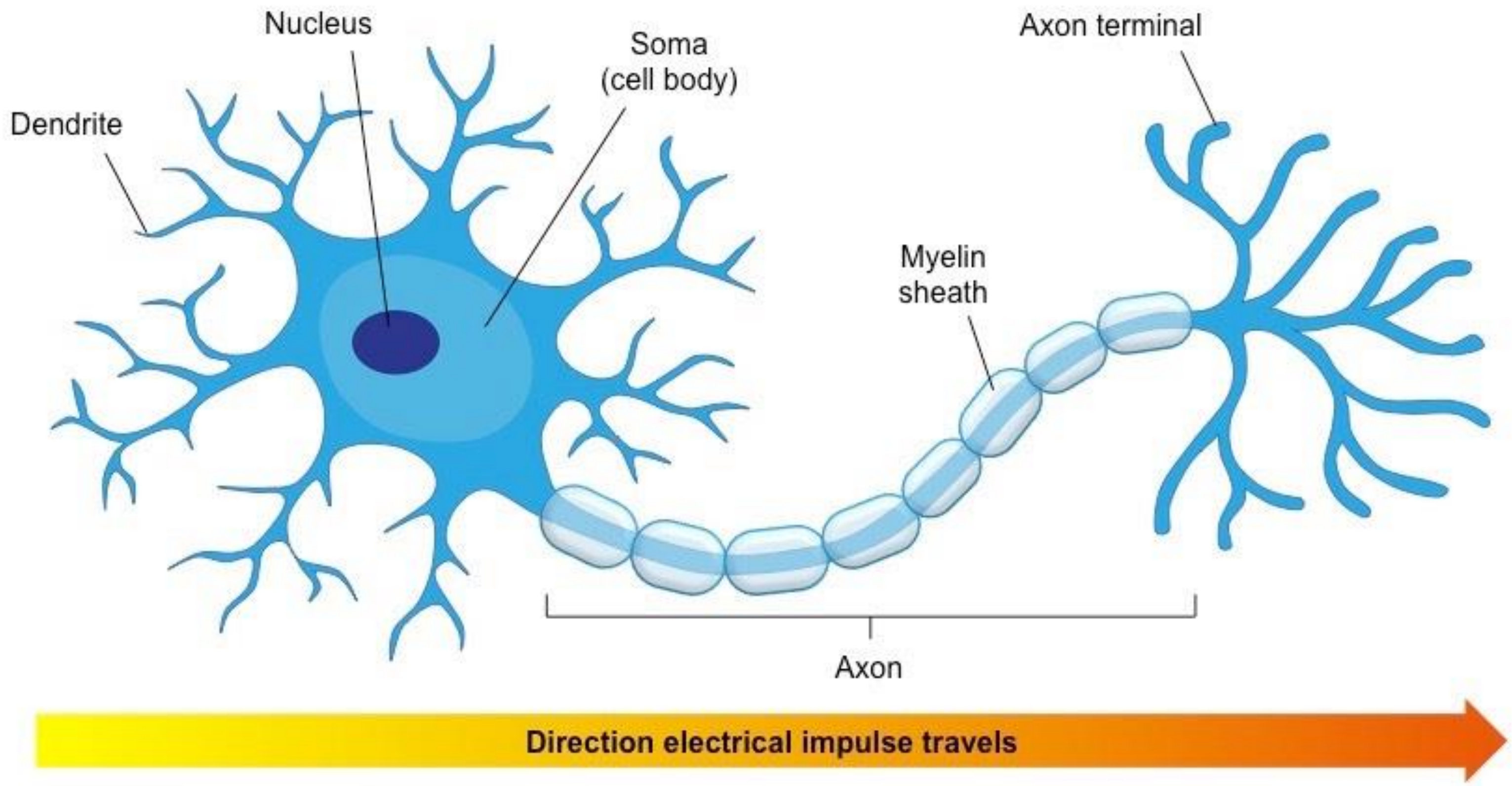
Biological Bases of Behaviour: Neurons

What is a neuron, and how do they work?



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Summary

What is a neuron?

- What is the anatomy of a neuron?
- On what dimensions can different types of neurons differ

What is an action potential?

- How does it work?

Neural activity is the bases of behaviour

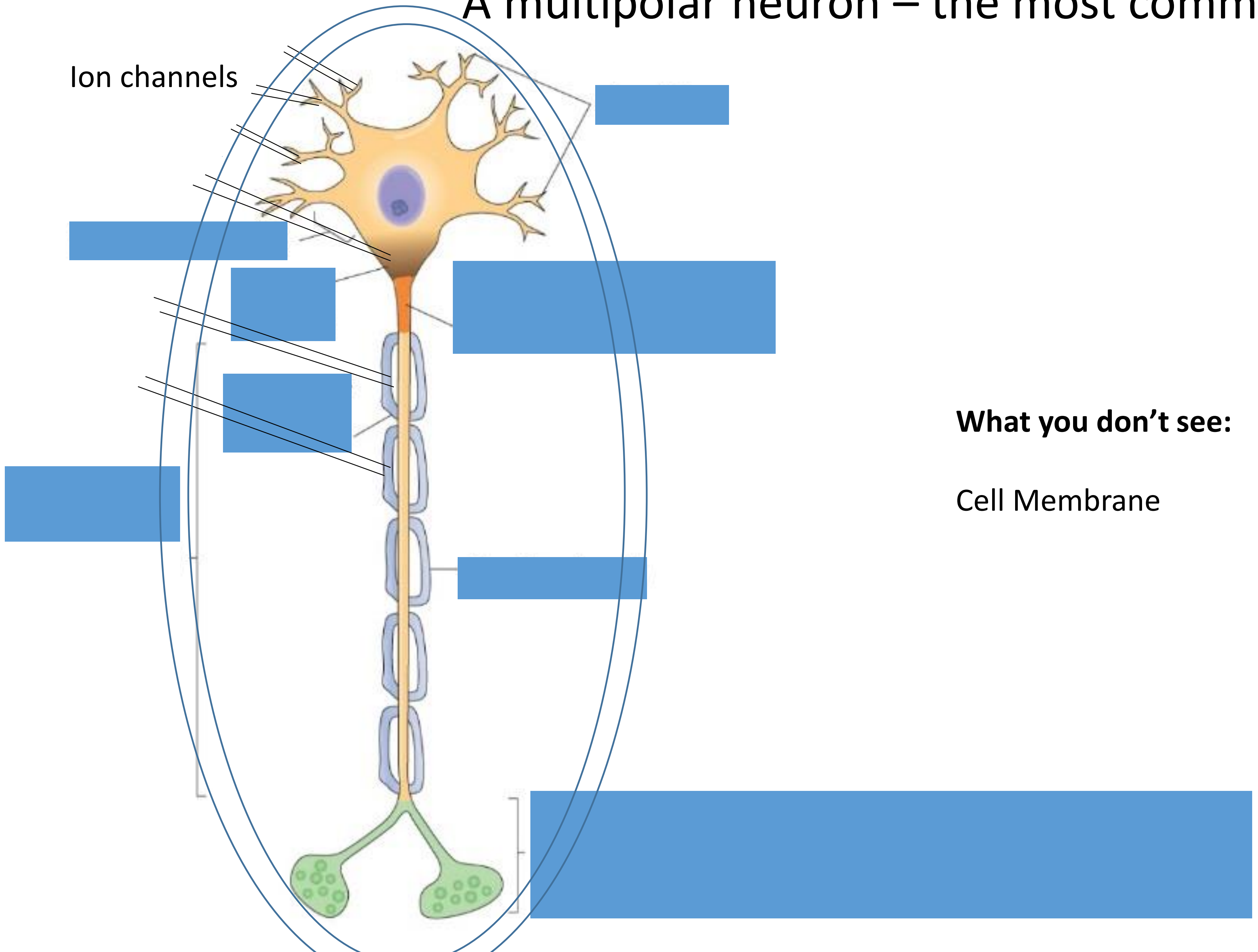
Neurons are just cells – the smallest building block of life

You have around 100 billion neurons in your brain and spinal cord

- There are trillions of connections between neurons
- Each neuron works by creating electrical impulses (action potentials) and releasing chemicals to communicate
    - other neurons, muscles and glands
- Different types of neurons vary in
    - Size
    - Shape
    - Function

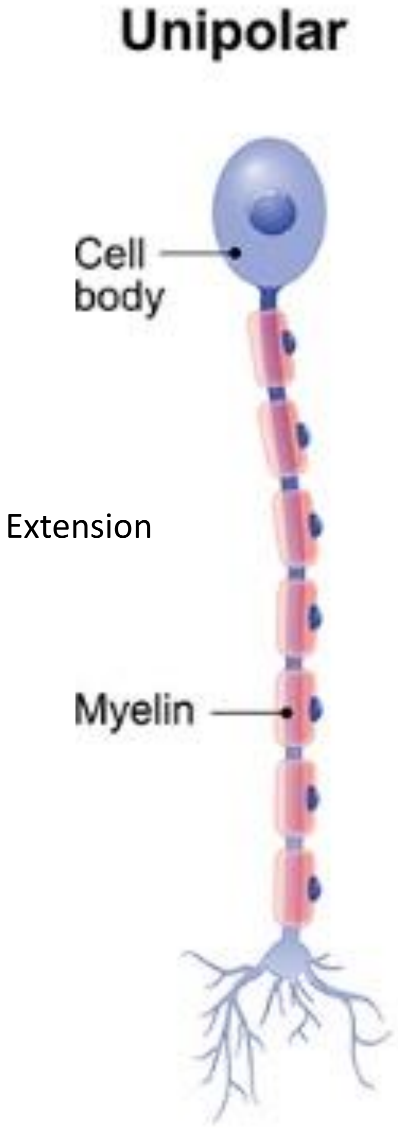
Structure of a Neuron

A multipolar neuron – the most common type



What you don't see:

Cell Membrane

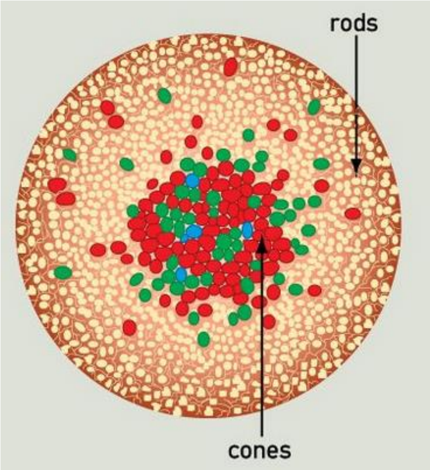


Something you don't see:

Axon length can different massively. Some neurons have short axons (a few mms) but the longest may be over a meter.

Some types of neurons (**from spinal cord**)

Sensory neurons: Respond to external stimuli.
Carry information towards the central nervous system.
Mostly pseudounipolar



Rods and cones in your eye

Motor neurons: Carry information away from the central nervous system. Mostly multipolar

Interneurons: Connect neurons to each other -- both motor and sensory as well as other interneurons

Some types of neurons (**from brain**)

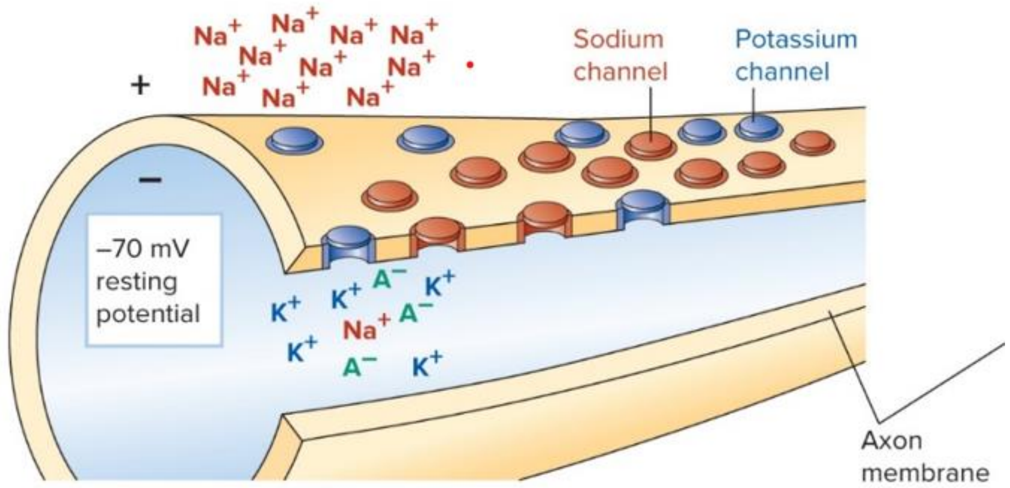
Far more complicated because there are far more types (200+) with many more functions

Neuron dynamics

What is an action potential?

At rest, a neuron has an electrical resting membrane potential

- The difference between the electrical charge of a neuron and its surrounding (~70 millivolts), with the neuron being more negative the surrounds
  - More potassium ions (K+) and negatively charged protein molecules (A-) inside the neuron than outside, and more sodium ions (NA+) on the outside than the inside
  - It is *polarized* because it has a more negative charge than the surrounds



(a) Resting potential: The 10:1 concentration of sodium (Na^+) ions outside the neuron and the negative protein (A^-) ions inside contribute to a resting potential of –70 mV.

What is an action potential?

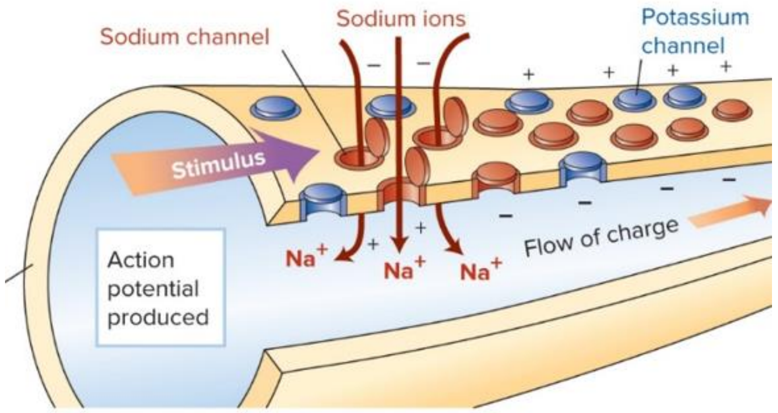
When stimulated, ion channels are opened and let in positively charged sodium ions from outside

The neuron becomes **depolarized** (more positive than the outside)

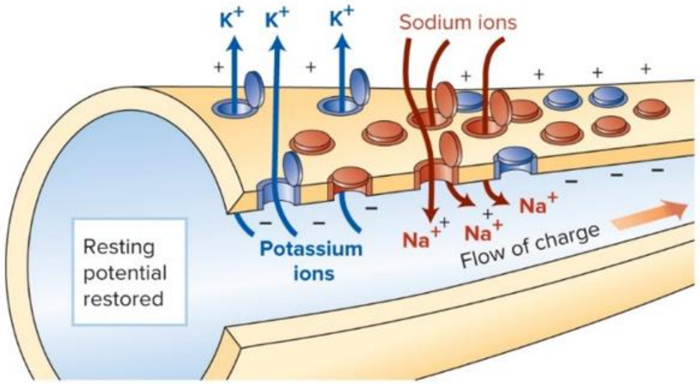
Thus, the electrical charge of the resting potential is reversed. It happens very quickly and is known as an **action potential (spike)** or neuron firing

After the potential

- There is a refractory period where the neuron goes to a lower voltage than its initial resting period and back to its resting membrane potential



(b) Depolarisation: If the neuron is sufficiently stimulated, sodium channels open and sodium ions flood into the axon. Note that the potassium channels are still closed.



(c) Repolarisation: Sodium channels that were open in (b) have now closed and potassium channels behind them are open, allowing potassium ions to exit and restoring the resting potential at that point. Sodium channels are opening at the next point as the action potential moves down the axon.

Learning: This is complicated so please look at the book here too – it is a very neat way of getting an electrical charge to go where it supposed to go efficiently. Evolution gives us amazing things!

How the charge moves down the axon

K+ channel   Na+ channel

Axon (Resting) negative charge

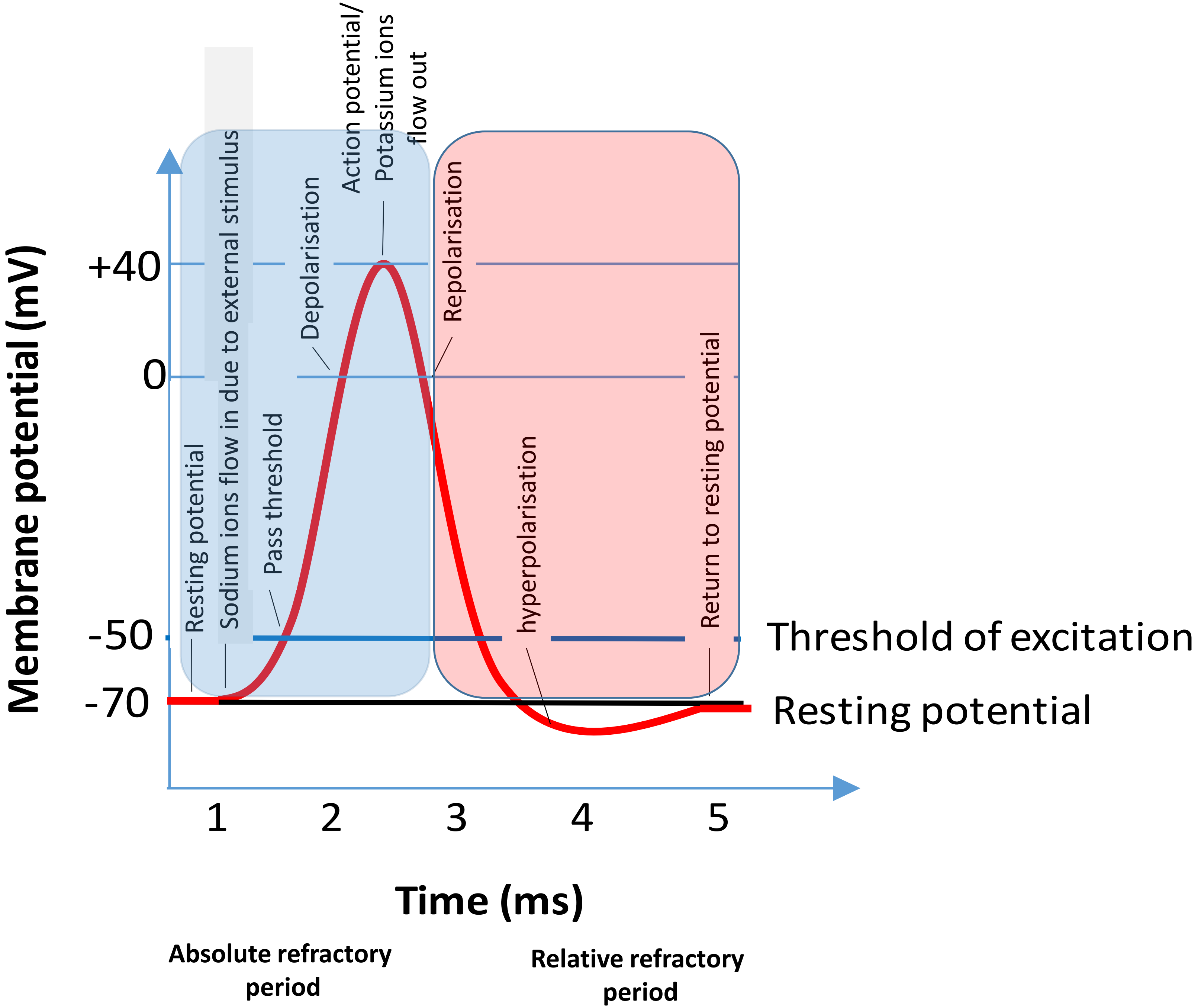
Na+ channels open. Area of axon becomes positive (depolarised)

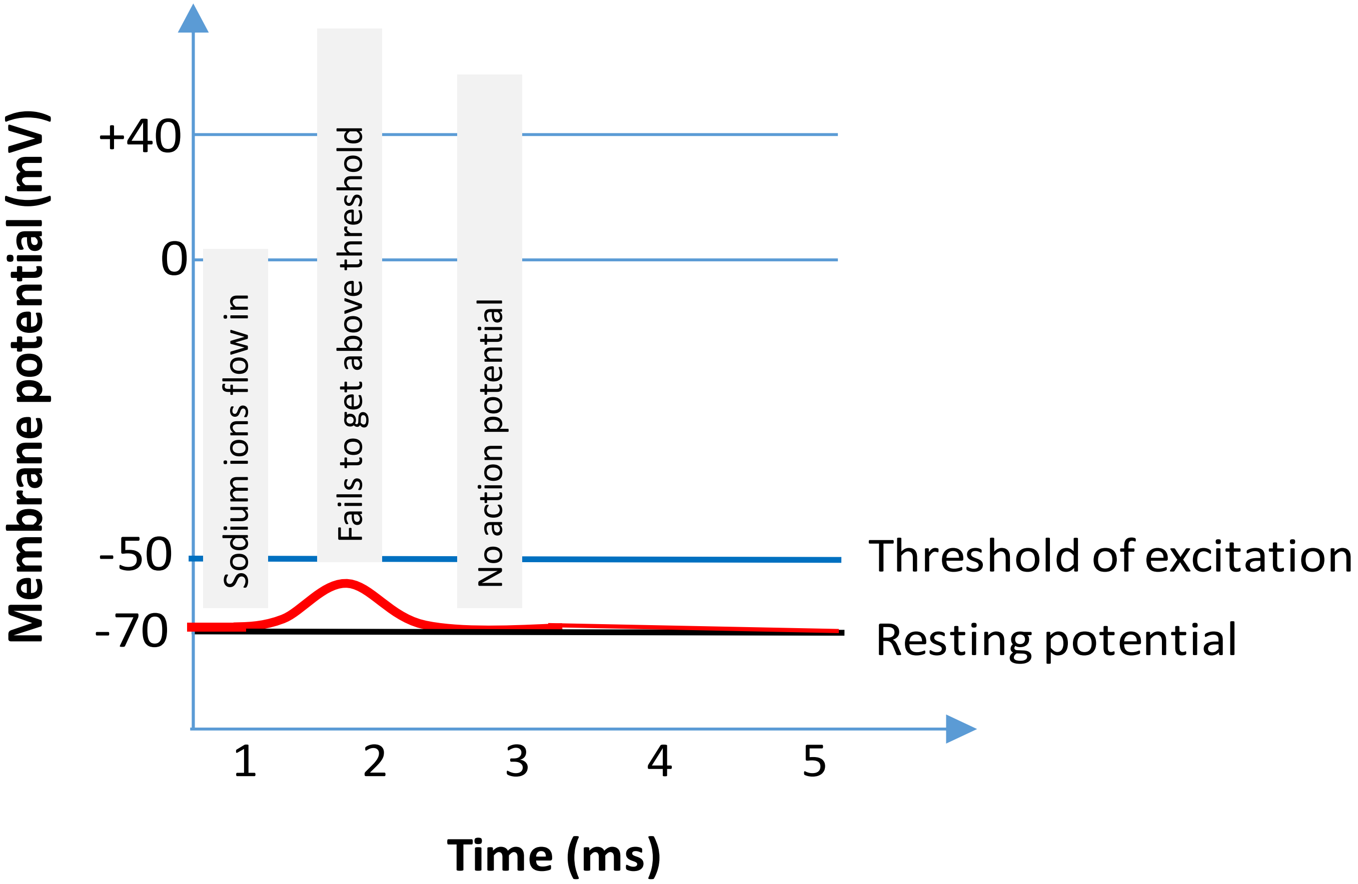
Axon hillock

More Na+ channels along the axon open, those previously open close, and K+ channels previously open causing repolarisation

Charge moves!

Charge moves!


Membrane potential (mV)
+40
0
-50
-70
Resting potential
Sodium ions flow in due to external stimulus
Pass threshold
Depolarisation
Action potential/
Potassium ions
flow out
Repolarisation
hyperpolarisation
Return to resting potential
Threshold of excitation
Resting potential
1
2
3
4
5
Time (ms)
Absolute refractory period
Relative refractory period



Neurons work on an all-or-nothing bases (like a switch)
If there is not enough change there will be no action-potential

Like a light switched on and off, action potentials tend to reach a similar level – you don't have big and small ones

Neuron communication

The action potential travels along the axon

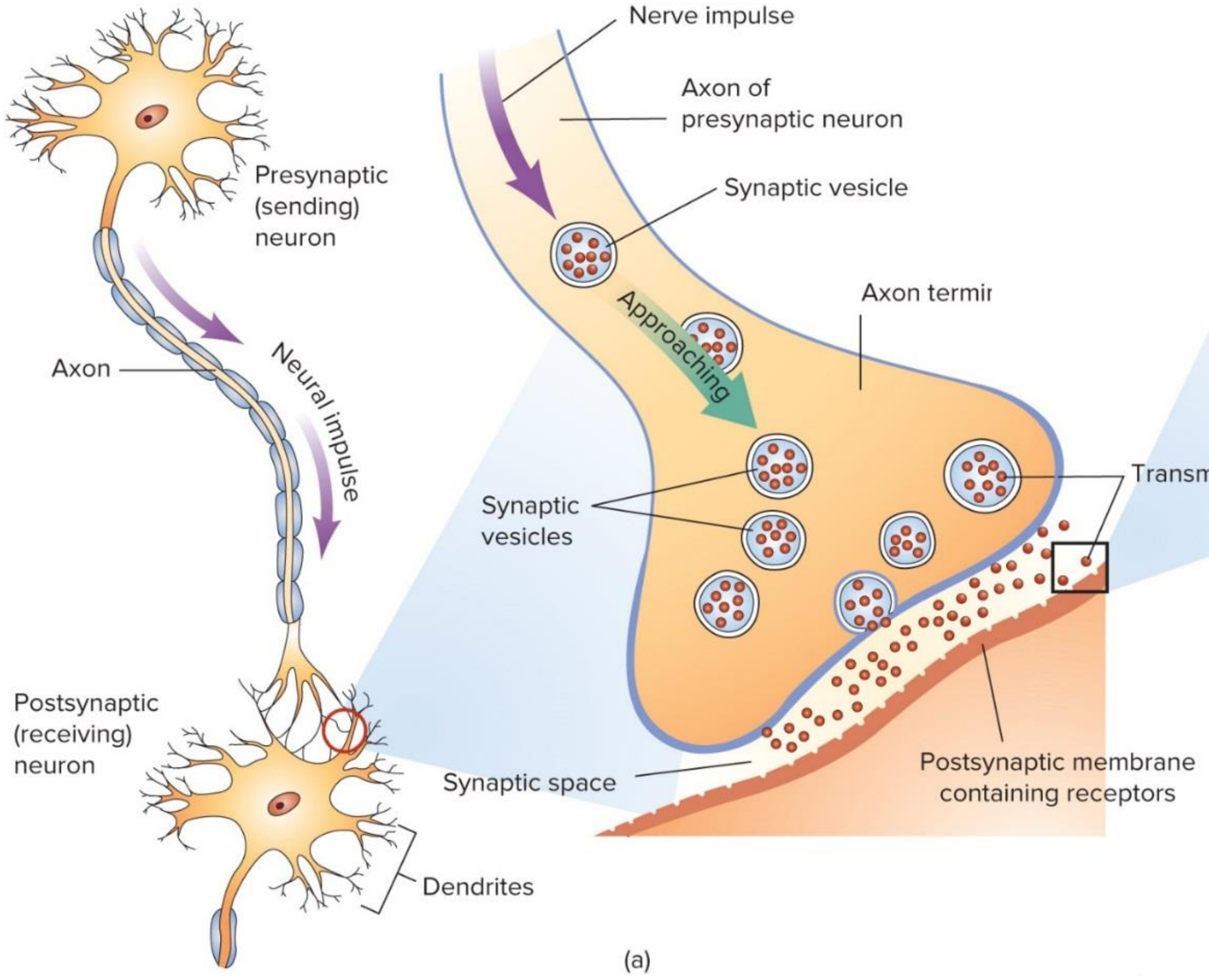
- In ‘jumps’ from one node of Ranvier to another when myelinated
- In a flow when not myelinated

This pushes vesicles towards the synaptic space

- Vesicles contain neurotransmitters

This causes the release of some of the neurotransmitters stored in the axon terminals into synaptic space

- Neurotransmitters can then be picked up by dendrites of other neurons
    - Neurons do not touch, so this is their communication space
- Not all neurotransmitters go to other neurons
    - The neuron takes some back – **reuptake**
    - Some get broken apart by enzymes
- Glial cells regulate the amount



Excitatory versus inhibitory effects

Not all ion channels are the same

The opening of some ion channels causes neurons to be *less* likely to have an action potential

- We call this an *inhibitory* effect

Ion channels

- Some can let NA+ ions in which cause an action potential
- Some let in Cl- (chloride) ions in -- this causes the neuron to become more negatively charged so the chance of reaching the threshold to have an action potential is less

The channels are *not* distributed on the neuron in the same way

- Inhibitory channels tend to be on the cell body
- Excitatory ones tend to be on the dendrite tree

There are many other types of ion channels

Leaning: I *don't* expect you to remember the dynamics of inhibitory and excitatory neurons.

I **do** want you to understand you can have inhibitory and excitatory effects from ion channels.

Interesting stuff

Interesting Stuff

Humans do not have the largest brains nor the most neurons

- Sperm whales have brains of about 8 kilos and more than twice the neurons

The ratio of brain weight to total weight is much larger in humans than other mammals (about 1/50 vs ~= 1/200)

Some birds have a similar brain weight to total weight as humans

- Birds have much more densely packed brains than humans
- The smartest birds (ravens and parrots) have as many neurons as lower primates
- A macaw (an especially smart bird) has more neurons in its forebrain than a macaque (quite a smart primate)

Interesting Stuff

Number of neurons is not everything

- The octopus is a famous example of an animal that does smart stuff (tool use, problem solving)… with a mere 500 million neurons
- Some really important functions in your brain use tiny numbers of neurons
  - The suprachiasmatic nucleus or nuclei (SCN), part of your hypothalamus, regulates your circadian rhythm
    - It is the ‘ticker’
    - If it gets damaged, you will not have a standard circadian rhythm, which is really bad news for your sleep!
    - It is about 0.244 mm^3 in adults