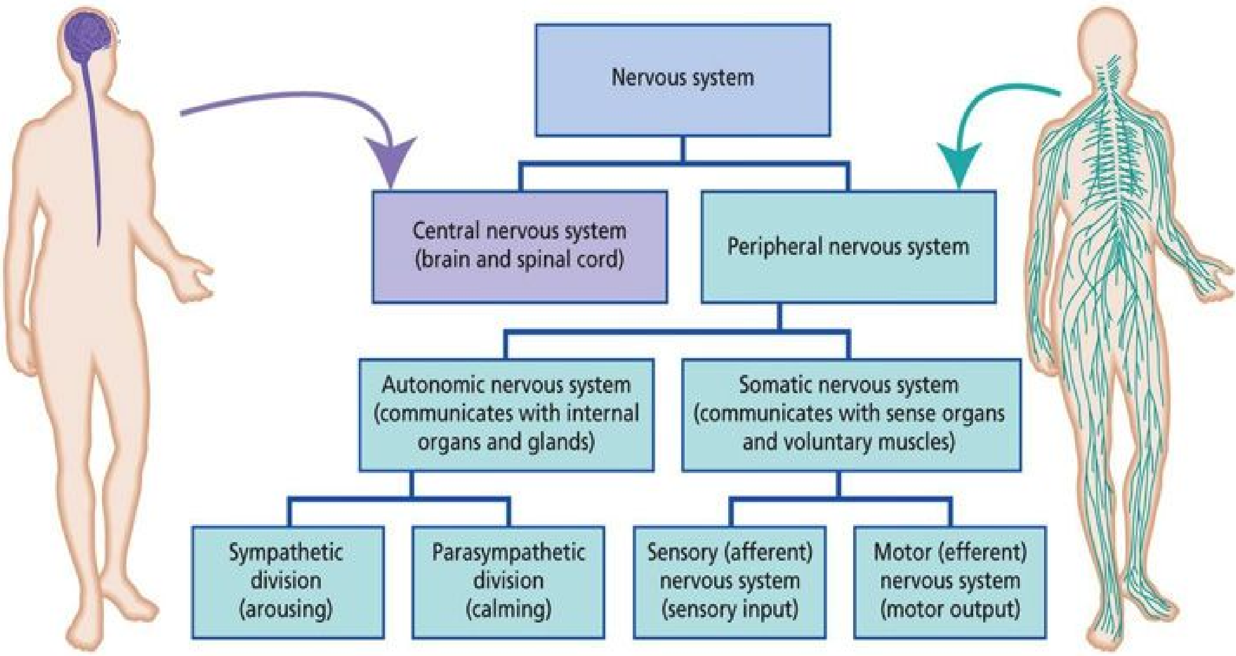
The Nervous System

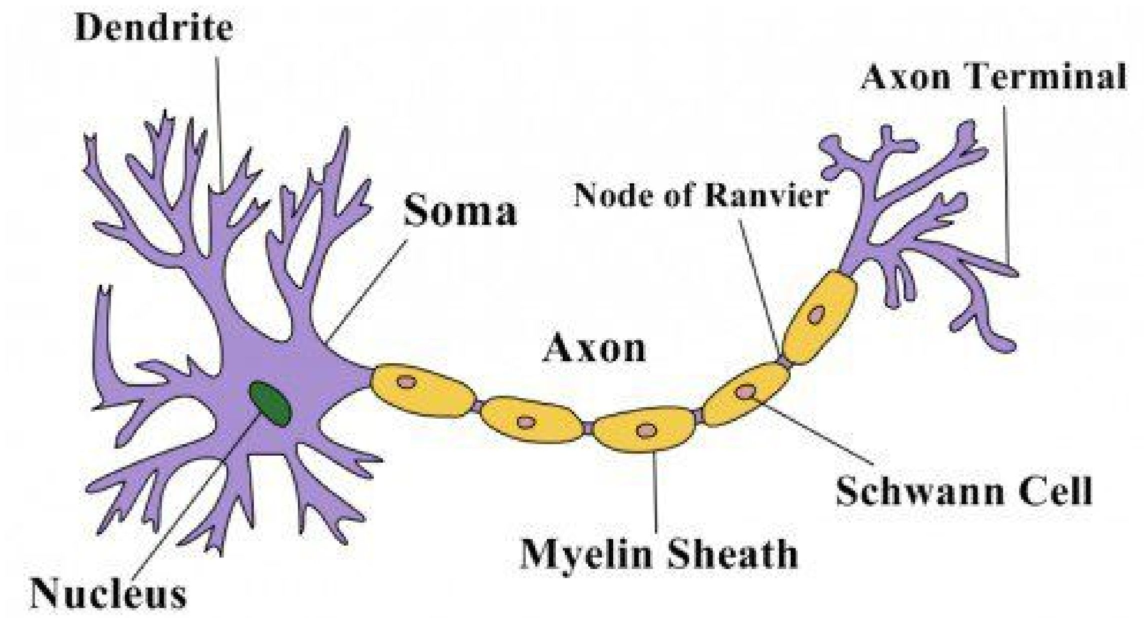
Two main forms of coordination in animals (pg 346):

	Nervous System	**Endocrine System**
Mode	Electrical → Chemical	Blood borne
Messengers	Neurotransmitters	Hormones
Release	Close to cell of influence	Distant to cell of influence
Target Cells	Specific location (only at nerve supply)	More widespread
Speed	Fast	Slow
Duration	Short	Long

Organisation of the Nervous System (pg 334)



Structure of a neurone (pg 347)



Basic functions:

1. Receive signals
2. Integrate incoming signals
3. Communicate signals to target cells

Cell body: has a nucleus, organelles rich in mitochondria and RER. Continuously producing large amounts of neurotransmitter.

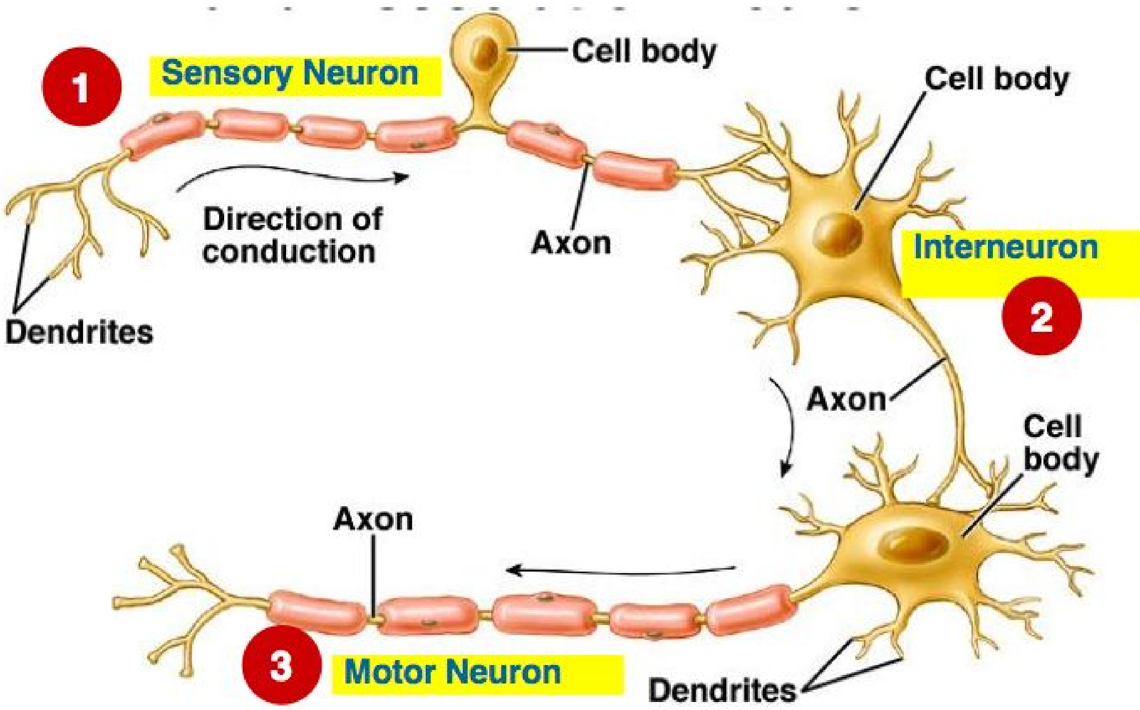
Dendrite/dendron: this carries the electrical signal (impulse) to the cell body

Axon: this carries the electrical signal away from the cell body

Terminal bulbs: store neurotransmitter, and release it when a signal is sent from the cell body

Myelin: a type of lipid produced by Schwann cells, which wrap themselves around neurones. Not all neurones are myelinated. (We will discuss this later on into the presentation)

Three Types of Neurons



Sensory: have long dendrons and transmit nerve impulses from sensory receptors all over the body to the central nervous system.

Motor: have long axons and transmit nerve impulses from the central nervous system to effectors (muscles and glands) all over the body.

Intermediate or Relay: are much smaller cells, with many interconnections. The majority of neurones in the CNS are relay neurones, and the help with coordination of responses

How a normal neuronal pathway works

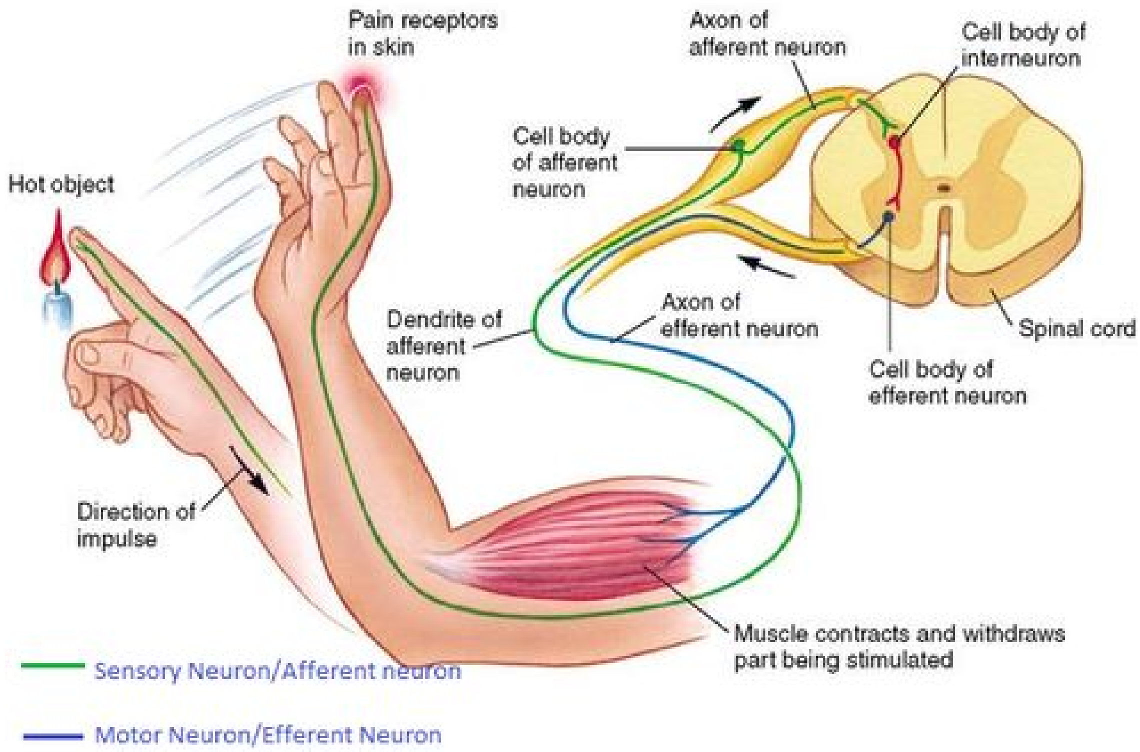
Information picked up by a **receptor** is transmitted along a **sensory neurone** to the central nervous system (brain or spinal cord)

The impulse is transmitted to a **relay neurone**, which lies entirely within the brain or spinal cord, and to several other parts of the brain (“thought”)

Once a decision has been reached, the impulse travel via a **motor neurone** to an **effector** (a muscle or gland).

A motor neurone has its cell body within the central nervous system, and a long **axon** which carries the impulse all the way

The Reflex Arc (pg 334-5)



Some responses need to be very quick, as the stimulus might present a threat

The reflex response is automatic, and does not involve any decision-making by the brain

Bypasses the higher areas of thought in the brain, and often just passes through the spinal cord

Pathway is Sensory > Relay > Motor (2 connections) or Sensory > Motor (1 connection) = faster response

Examples: pupil dilation/constriction, corneal reflex, knee-jerk reflex

Types of sensory receptors

	Mechanoreceptor	Chemoreceptor	Thermoreceptor	Photoreceptor
Function	Movement	Chemicals	Temperature	Light
Stimuli	Sound waves Pressure changes Touch / stretch	Molecules / solutes Blood pH (CO_2 levels)	Heat / cold	Visible light (400 – 700 nm)
Locations	Ears, skin, arteries	Tongue, nose, tissues	Skin, hypothalamus	Eyes (retina)

Baroreceptor = blood pressure (located in the walls of the aorta and carotid artery)

Osmoreceptor = blood water potential (located in the hypothalamus)

Stretch receptor = detects degree of expansion of tissue (located in the walls of the alveoli)

Resting potential (pg 350-51)

A non-signalling (OFF state) neuron has a voltage across its membrane called the **resting potential**.

- Na+/K+ ions are actively transported against their concentration gradient - Na+ is exported out whereas K+ is transported in

- 3 Na+ ions move out for every 2 K+ that come in

- As there are more positive ions on the outside of the membrane than the inside, creating an electrochemical gradient - the charge inside starts to become more negative compared to the charge outside the membrane

- most of the gates that control Na+ diffusion are closed, so the concentration of Na+ remains high outside the membrane

- most of the gates that control K+ diffusion are open, so K+ can diffuse out along its concentration gradient

- this causes the charge inside the neurone to drop further

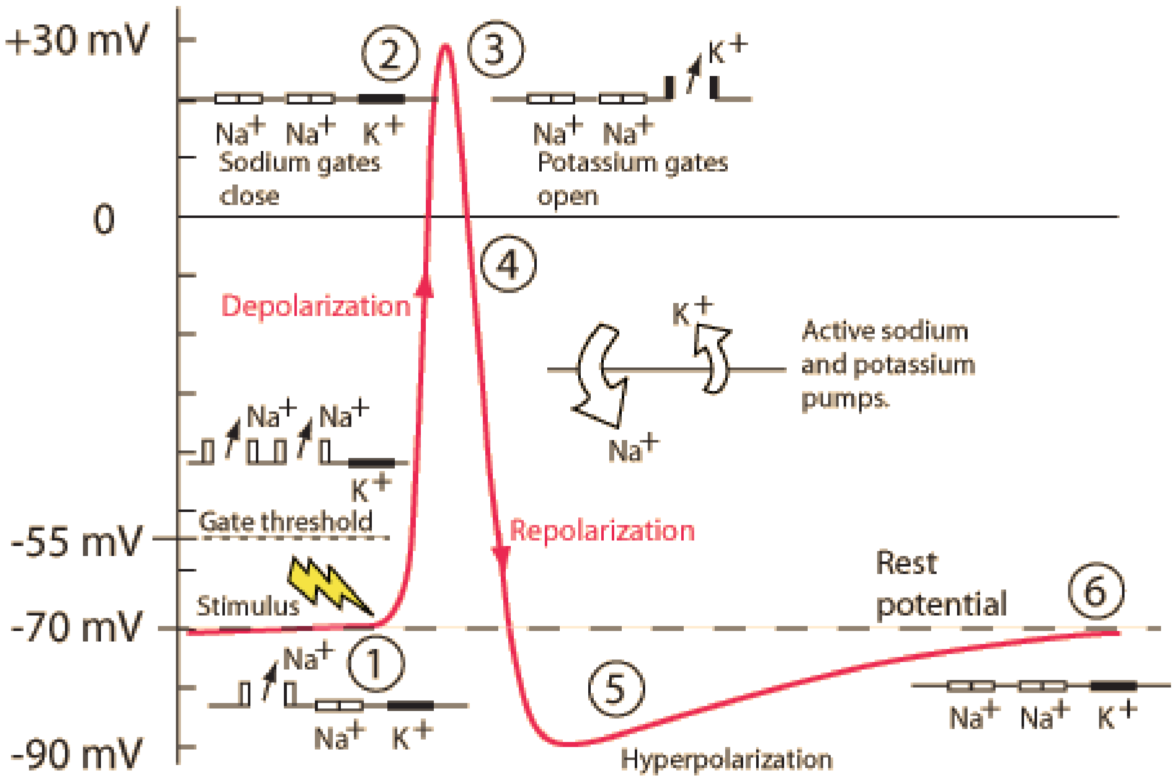
- the negative charge starts to attract the K+ back in

- at one point the rate of flow of K+ to the outside of the neurone is the same as the rate at which it diffuses back in

- there is no net movement of K+ - the membrane is said to be at REST

- this is ‘resting potential’ - the potential difference across the cell membrane is measured to be -65 mV (The neurone is said to be polarised)

Action Potential



A stimulus is received by the dendrites of a sensory neurone. This causes some of the Na^+ channels, at the tips of the sensory receptor, to open.

If the opening is sufficient to drive the interior potential from -70 mV up to -55 mV, the process continues.

At threshold,more voltage-gated Na^+ channels open.

The influx of Na^+ influx increases the membrane potential difference to about +40 mV. This is called depolarization.

At +40 mV, the Na^+ channels close and the K^+ channels open.

With the K^+ channels open, the membrane begins to repolarize back toward its rest potential.

The repolarization typically overshoots the rest potential to about -90 mV. This is called hyperpolarization.

After hyperpolarization, the Na^+/K^+ pump eventually brings the membrane back to its resting state of -70 mV

Significance of Hyperpolarisation

Hyperpolarization prevents the neuron from receiving another stimulus for a time = refractory period

Hyperpolarization ensures that the action potential is proceeding only in one direction (away from the stimulus)

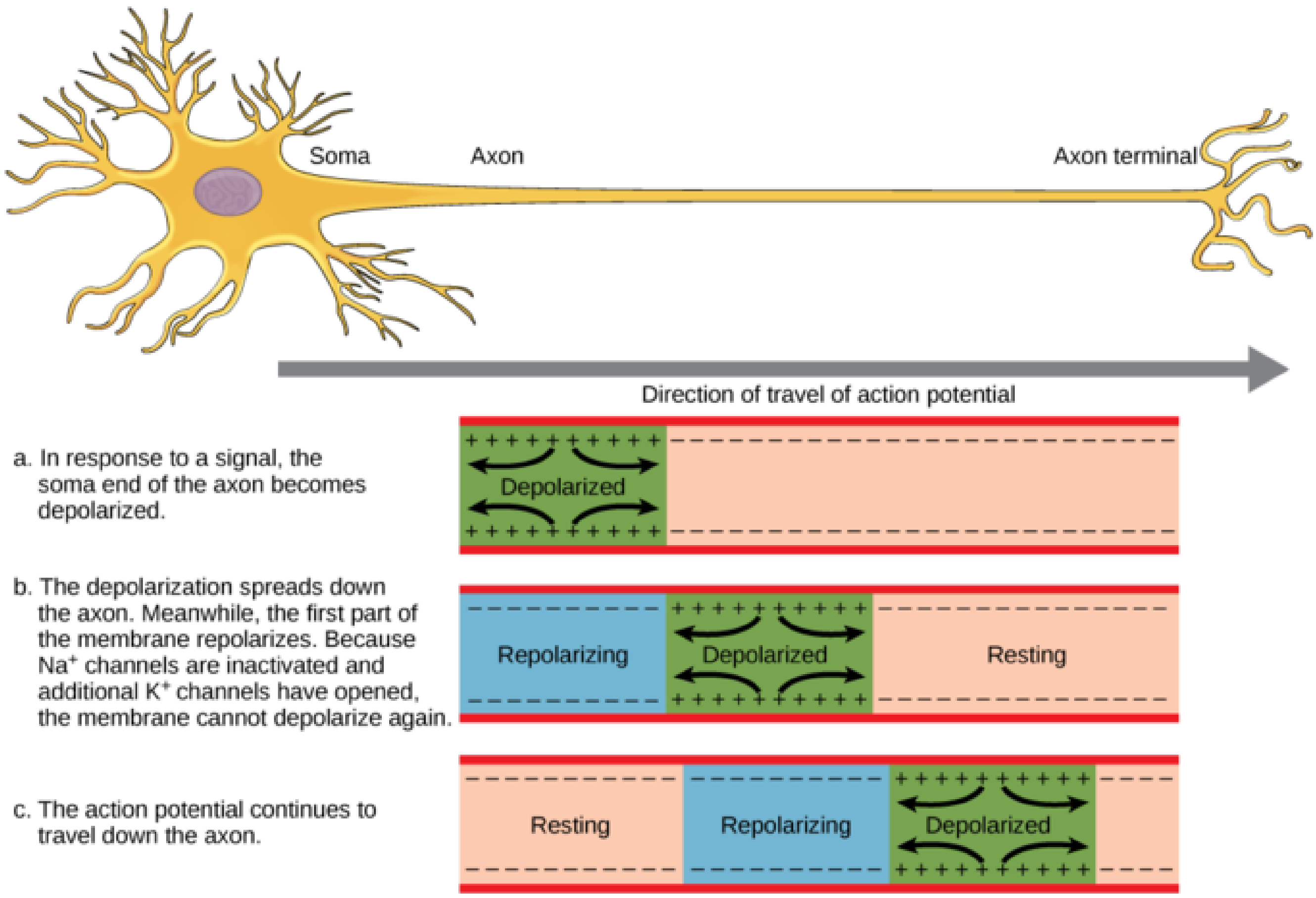
It also ensures that each action potential is discrete and separate from the next one behind it

All or nothing response

All action potentials have the same height of +40 mV. A neurone is either ON or OFF, there is no in-between state.

Any stimulus below the threshold value will fail to generate an action potential. Any stimulus above the threshold value will always generate an action potential.

Transmission along an unmyelinated neurone (pg 355)



The first part of the axon membrane, closest to the cell body, is depolarised

Na+ diffuses into the axon, depolarising it

It also moves down the axon, attracted by the negative charge of the region in front

This sets up a local electrical circuit between adjacent sections of the membrane

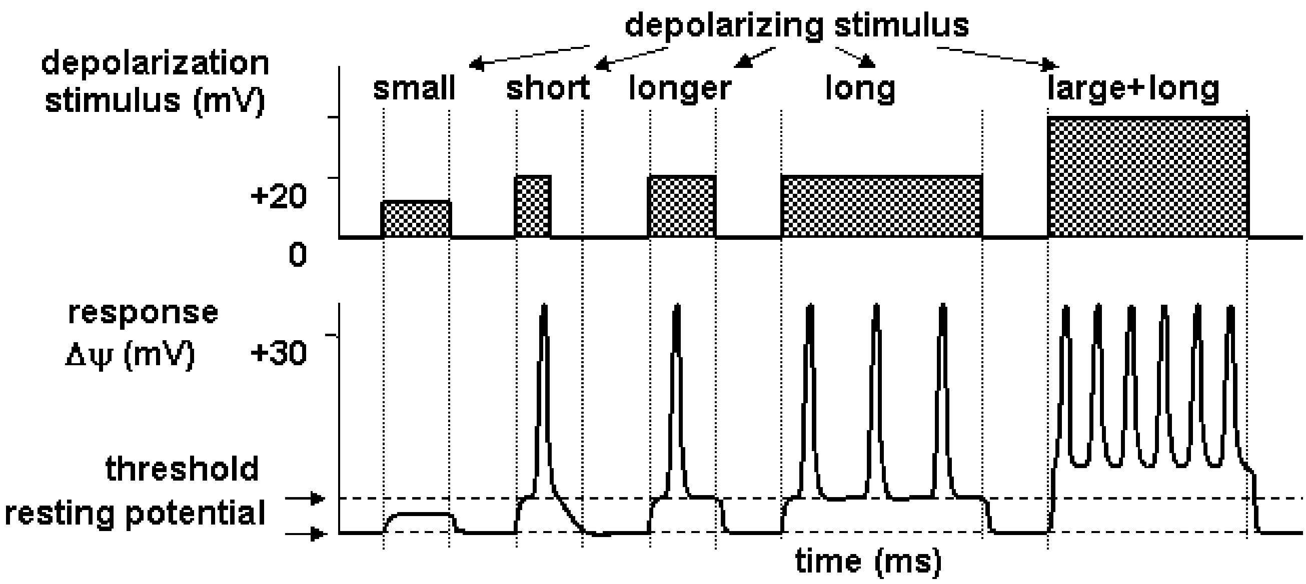
The diffusion of sodium allows the voltage-gated Na+ channels further down the membrane to open

This region enters depolarisation phase, whereas the first region (behind it) enters the hyperpolarisation phase

This polatiry ensures that only the region in front of the action potential is depolarised

The action potential travels like a wave from one end of the neurone to another

The frequency of action potentials (pg 358)

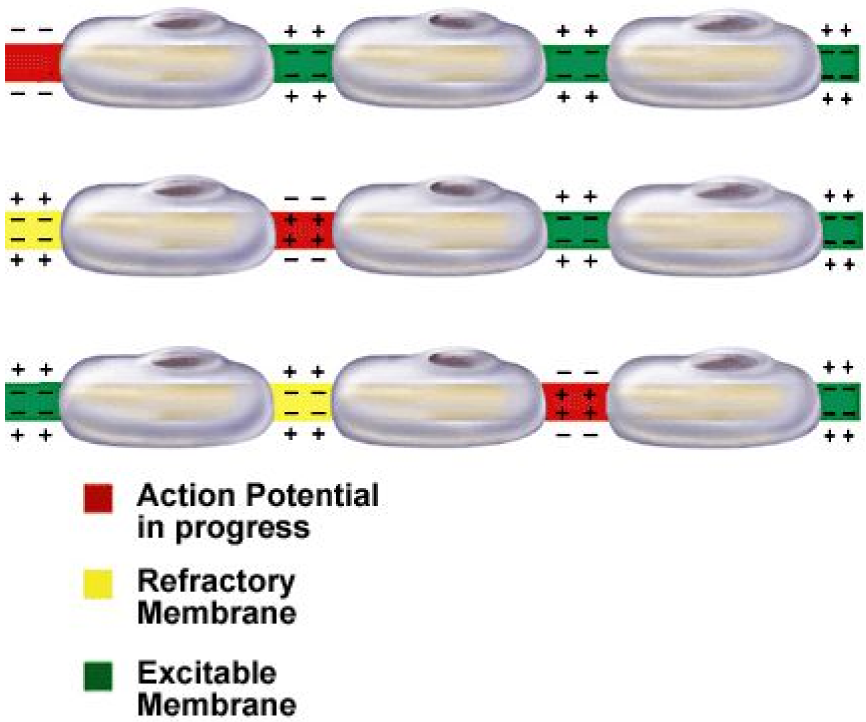


Height does not vary, only frequency varies

Stronger the stimulus, the more frequent the action potentials in a given time

Strength of the stimulus is decided by
- the frequency of action potentials
- using neurones with different threshold settings, such that only stimuli above a certain threshold can generate action potentials

Saltatory conduction in myelinated neurones (pg 356)



Myelin is produced by specialised cells called as Schwann cells, which wrap themselves around neurones

It is a type of lipid that acts as an electrical insulator and acts as a barrier for the diffusion of ions

The gaps between the myelin sheath are called the nodes of Ranvier - Na+/K+ can only diffuse in/out at the nodes

When the first node is depolarised, there is a rapid influx of Na+, changing the membrane potential to +40 mV

This Na+ is attracted to the next node of Ranvier, which is at -65 mV - this sets up localised electrical circuits between the nodes

These circuits ensure that the Na+ travels down the neurone at a faster rate than if the neurone was unmyelinated

The action potential appears to jump from node-to-node - this is called saltatory conduction

Factors affecting the speed of an action potential

1. The presence of the myelin sheath - for the same diameter, the AP travels down a myelinated neurone much faster than an unmyelinated one

2. The diameter of the axon - greater the diameter, faster the speed. A larger diameter ensures less leakage of ions from the membrane, allowing it to maintain a more efficient electrical circuit

3. Temperature - affects the kinetic energy and the rate of diffusion of the ions. Also affects the activity of enzymes involved in respiration and the speed at which the Na^+/K^+ pump operates.
Too high a temperature can denature the enzymes and proteins involved in conduction of AP

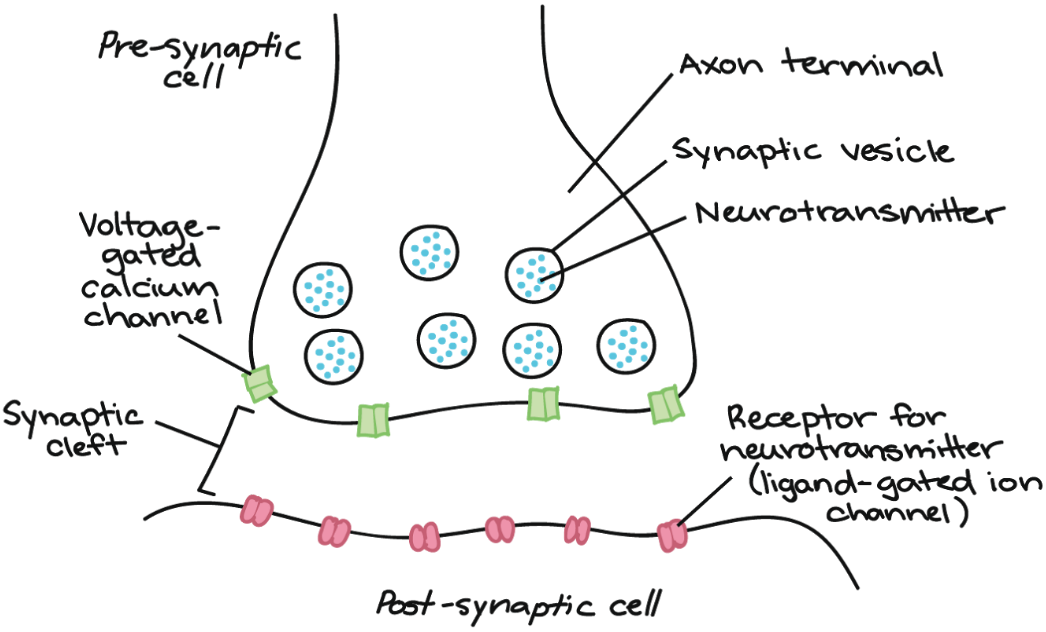
The Synapse

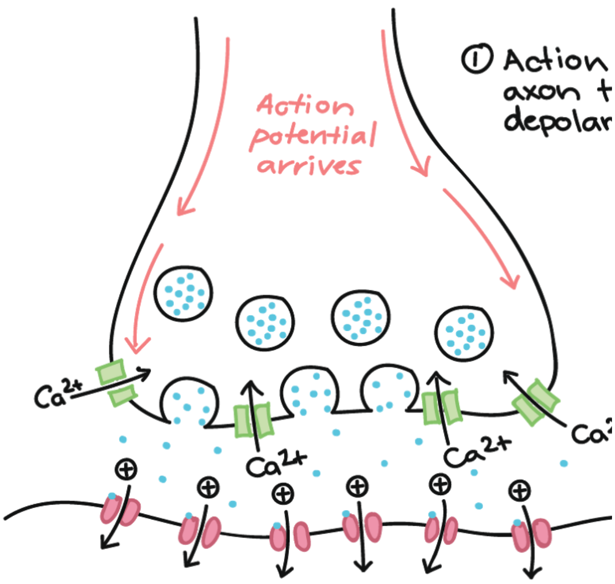
Neurons communicate with one another at junctions called synapses. At a synapse, one neuron sends a message to a target neuron or another cell (eg. muscle) .

At a synapse the electrical signal is converted to a chemical signal, then back to an electrical signal

At a synapse, an action potential triggers the presynaptic neuron to release **neurotransmitters**. These molecules bind to receptors on the postsynaptic cell and make it more or less likely to fire an action potential.

How a synapse works (pg 360)





When an action potential, or nerve impulse, arrives at the axon terminal, it activates voltage-gated calcium channels in the cell membrane.

Ca2+ enters the cell, which allows the synaptic vesicles to fuse with the presynaptic membrane, releasing neurotransmitter into the synaptic cleft.

The molecules of neurotransmitter diffuse down their concentration gradient, across the synaptic cleft, and bind to receptor proteins on the postsynaptic cell.

Receptors sites are located on Na+ (or Cl-) channel proteins

Binding of the neurotransmitters allows the Na+ channels to open, and Na+ rushes into the postsynaptic membrane, depolarising it. This generates an AP in the postsynaptic membrane

Excitatory and Inhibitory neurotransmitters

Excitatory:

- allows can action potential to pass across the synapse

- binding of the receptors leads opening Na+ channels in the postsynaptic membrane. This depolarizes the membrane

Eg. acetylcholine, serotonin, dopamine

Inhibitory (pg 362):

- prevents an action potential from passing across the synapse

- binding of the receptors leads opening Cl- channels in the postsynaptic membrane. This hyperpolarises the membrane

Eg. GABA, glutamate

Summation - the integration of signals (pg 361)

Spatial summation

The integration of postsynaptic potentials that occur in different locations—but at about the same time—is known as spatial summation