Control and coordination

A-Level Biology

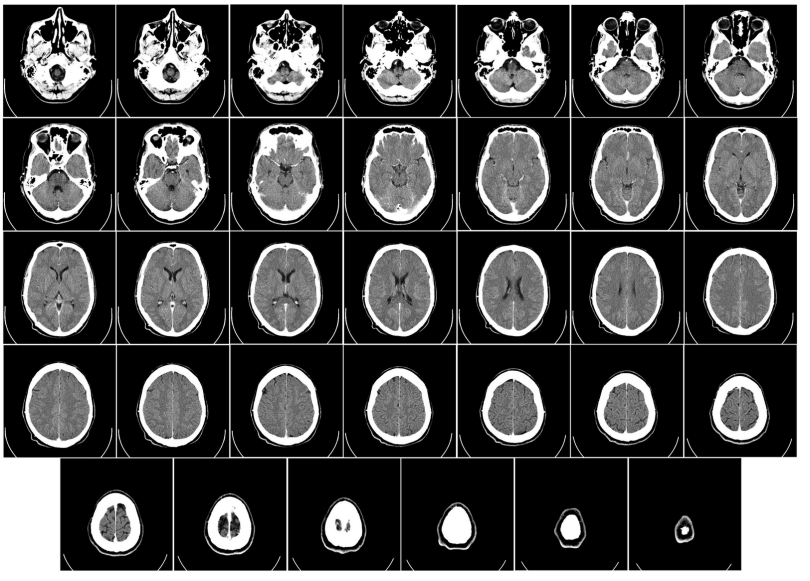
Two systems for control

The body has two coordination systems. The **endocrine system** sends chemical **hormones** (such as ADH, glucagon and insulin) in the blood. The **nervous system** sends fast electrical signals along nerve cells.

nervous system
electrical impulses
along nerves — fast, short

endocrine system
chemical hormones
in the blood — slow, lasting

Nervous control is fast and electrical; hormonal control is slow and chemical



A scan of the human brain, the control centre of the nervous system

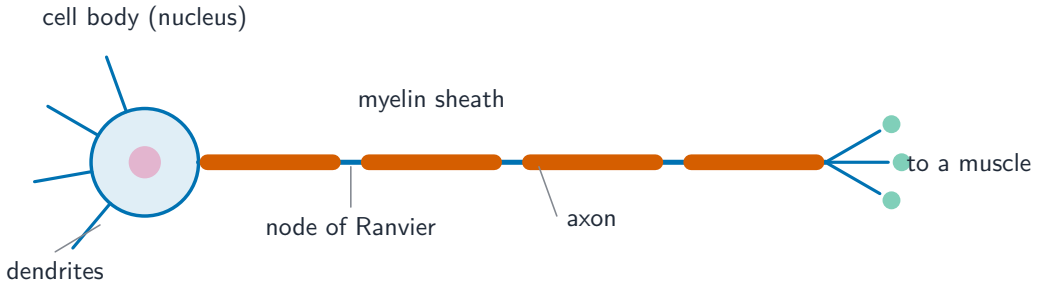
Feature	Nervous system	Endocrine system
signal	electrical **impulse**	chemical hormone
transport	along nerve cells	in the blood
speed	very fast	slower
how long it lasts	short	longer

Neurones

A **neurone** is a nerve cell. There are three kinds:

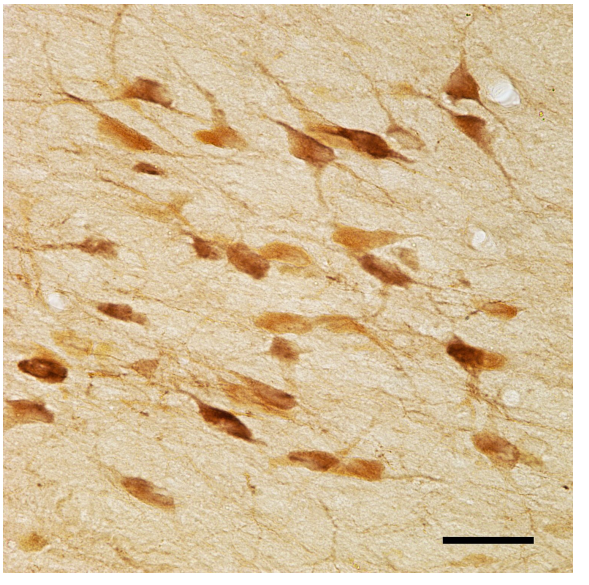
- a **sensory neurone** carries impulses from a receptor towards the brain or spinal cord.
- a **motor neurone** carries impulses out to an effector, such as a **muscle**.
- **intermediate neurones** connect sensory neurones to motor neurones.

A neurone has a long fibre (the axon) along which the impulse travels.



A motor neurone: the impulse travels along the axon, jumping between the gaps (nodes of Ranvier) in the myelin sheath

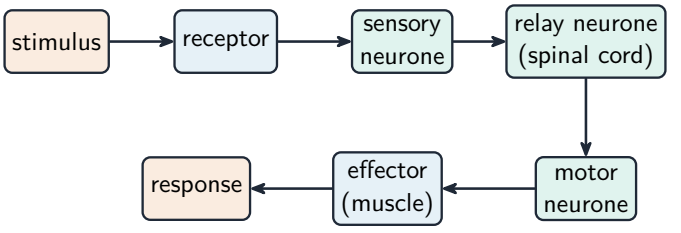
This is what real neurones look like in a stained slice of brain tissue:



*Real **neurones** stained brown: you can see the cell bodies and the thin processes that carry signals to and from each cell*

Detecting a stimulus

A **sensory receptor** cell detects a **stimulus** and starts an impulse in a sensory neurone. For example, a **chemoreceptor** cell in a **taste bud** detects chemicals in food, and this triggers an **action potential** in the sensory neurone.

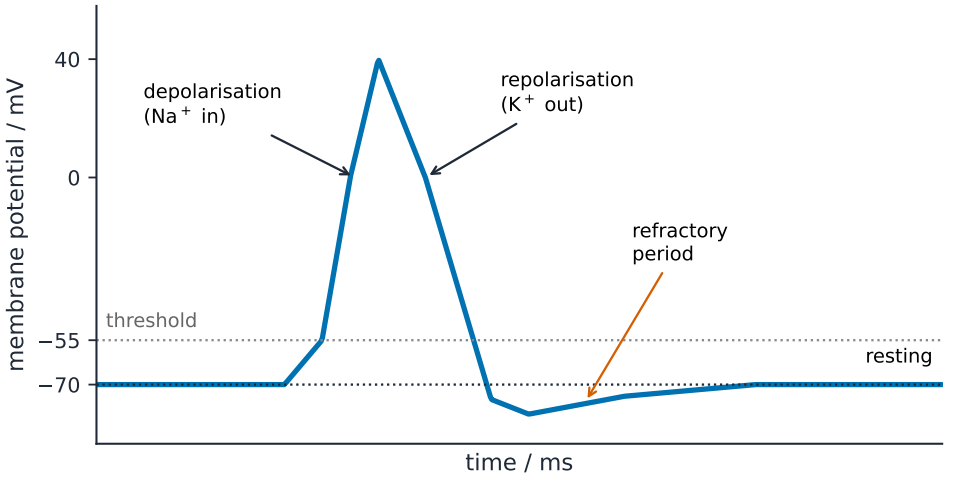


A reflex arc: stimulus → receptor → sensory neurone → relay → motor neurone → effector → response

The nerve impulse

The impulse is a change in the voltage across the neurone's membrane.

- **resting potential** – when no impulse passes, the inside is negative compared to the outside. This is maintained by a pump that moves sodium ions out and potassium ions in, and by the membrane being more permeable to potassium.
- **action potential** – a stimulus makes sodium channels open, so sodium ions rush in and the inside briefly becomes positive (depolarisation). Then potassium channels open, potassium ions leave, and the **membrane potential** returns to negative (repolarisation).
- **refractory period** – just after an action potential, the sodium channels cannot open again for a short time. This restores the resting potential and sets a limit on how often impulses can be sent (their frequency).

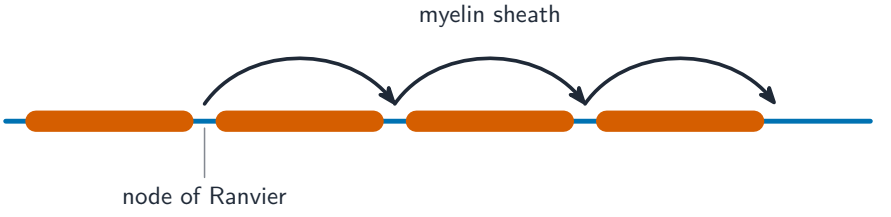


all-or-nothing: once threshold is reached, a full spike fires (no partial APs)

An action potential: sodium in causes depolarisation; potassium out causes repolarisation; then a refractory period

■ Faster impulses: myelin

Some neurones are wrapped in a fatty **myelin sheath** . The impulse cannot cross the sheath, so it jumps from one gap to the next. This jumping, called **saltatory conduction** , makes the impulse travel much faster.



the impulse jumps from node to node (saltatory conduction) → faster

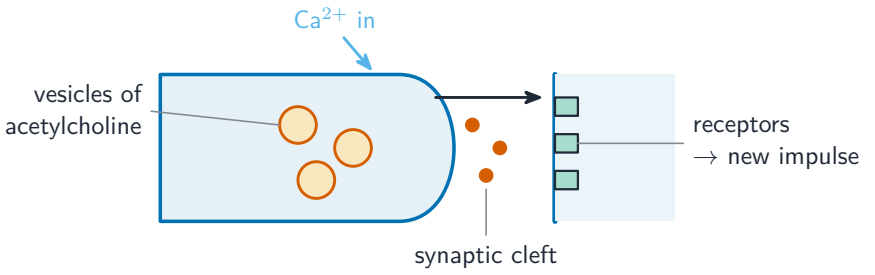
The impulse jumps node to node – saltatory conduction – so a myelinated neurone conducts much faster

The synapse

A **synapse** is a tiny gap between two neurones. A **cholinergic synapse** passes the signal like this:

1. the impulse arrives and makes **calcium ions** enter the first neurone.

2. this makes vesicles release a **neurotransmitter** called **acetylcholine** .
3. the acetylcholine diffuses across the gap and binds to receptors on the next neurone.
4. this starts a new impulse in the next neurone.

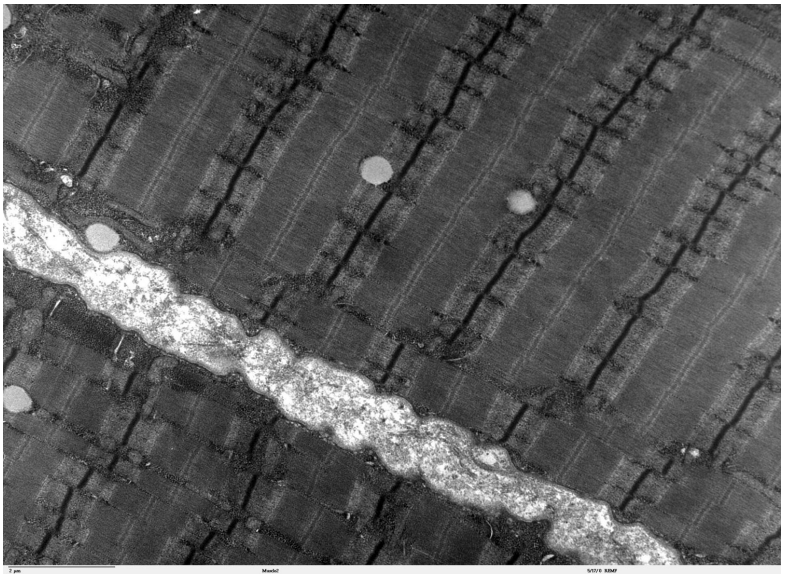


At a synapse, acetylcholine diffuses across the cleft and binds receptors to start a new impulse in the next neurone

Muscles and how they contract

A **neuromuscular junction** is like a synapse, but between a motor neurone and a muscle.

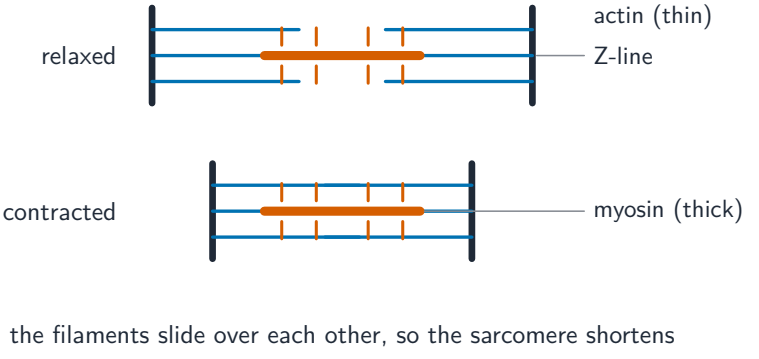
Striated muscle is made of long fibres. Each fibre is divided into repeating units called **sarcomeres** . Inside are two kinds of **filament** : thick ones (myosin) and thin ones (actin). The **T-tubule** T system carries the impulse deep into the fibre, and the **sarcoplasmic reticulum** stores and releases calcium ions.



This is where the name "striated" comes from. Each repeating dark-light block is one sarcomere; the bands are the thick and thin filaments overlapping by different amounts. When the muscle contracts, the filaments slide past each other and each sarcomere gets shorter

The **sliding filament model** explains contraction:

1. an impulse causes the sarcoplasmic reticulum to release calcium ions.
2. the calcium ions bind to **troponin** , which makes **tropomyosin** move and uncover the binding sites on the actin.
3. the myosin heads attach to the actin and pull it inwards, using energy from ATP.
4. the thin filaments slide over the thick ones, so each sarcomere gets shorter and the muscle contracts.



Sliding filament model: thin actin slides over thick myosin, so the sarcomere shortens

Control and coordination in plants

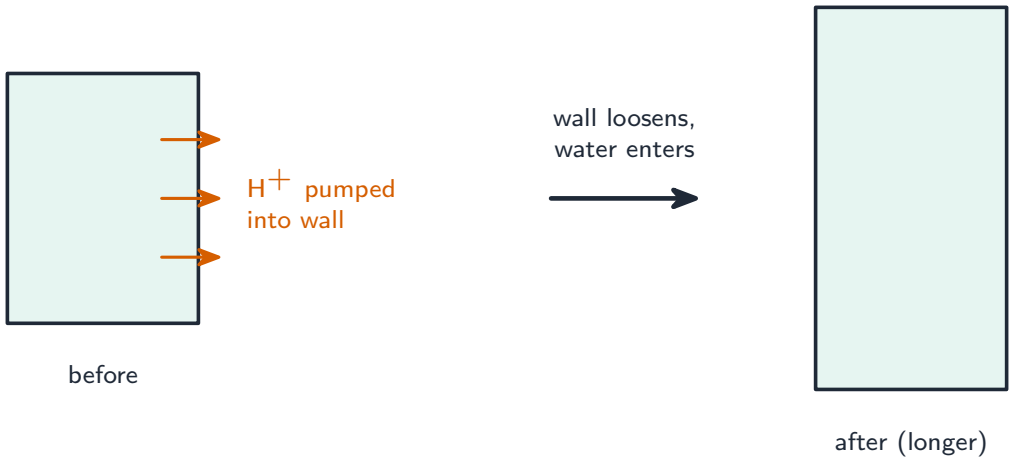
The Venus fly trap

The **Venus fly trap** has tiny hairs on its trap-like leaves. When an insect touches the hairs, a fast electrical signal spreads, the cells quickly lose water and change shape, and the trap snaps shut to catch the insect.

An open trap. The long spikes around the edge only cage the insect – it is the few short, stiff trigger hairs standing on the red surface that must be touched to fire the signal

Auxin and growth

Auxin is a plant hormone that makes cells grow longer (**elongation** growth). It does this by making the cell pump **protons** (hydrogen ions) into the **cell wall** . This **acidifies** the wall, which loosens it, so the cell can stretch as water enters.



Auxin's "acid growth": H^+ pumped into the wall loosens it, so the cell stretches longer as water enters

Gibberellin and germination

Gibberellin controls the **germination** of **barley** seeds. It switches on the genes that make amylase, which then breaks down stored starch into sugars to feed the growing seedling.

> **Worked example.** Explain why a nerve impulse crosses a synapse in **one direction only**, and why myelination speeds it up along an axon. At a synapse the **vesicles** of neurotransmitter are found only in the **presynaptic** neurone, and the **receptors** only on the **postsynaptic** membrane - so transmitter can only ever cross one way, which makes the synapse a one-way valve. Along a **myelinated** axon the myelin sheath **insulates** the membrane, so ions can only cross at the **nodes of Ranvier**; the impulse therefore jumps from node to node (**saltatory conduction**) instead of depolarising every part of the membrane in turn, which is far faster and uses less ATP. Locate the **structure** responsible for each effect: vesicles and receptors give the direction, insulation and nodes give the speed.

Exam tips

- Explain the **resting potential** (Na+/K+ pump; more negative inside) then the **action potential** (depolarisation → repolarisation) as all-or-nothing.
- **Saltatory conduction** (myelin, nodes of Ranvier) speeds the impulse; the refractory period makes it one-way and discrete.
- Describe the **synapse** in order: Ca2+ enters → vesicles fuse → neurotransmitter → receptors → new impulse.

- Muscle contraction follows the **sliding-filament** model (actin, myosin, ATP, Ca2+).