Control and coordination

A-Level Biology

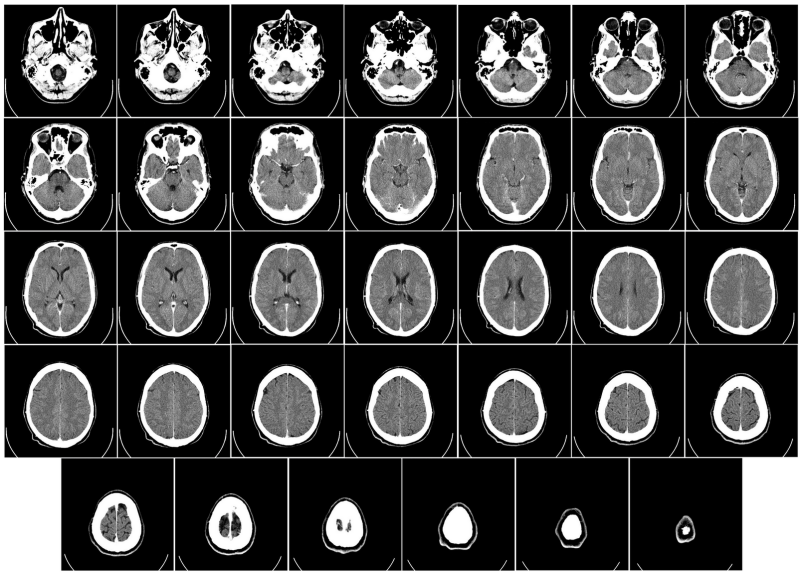
Two systems for control

The body has two coordination systems. The **endocrine system** 内分泌系统 sends chemical **hormones** 激素 (such as ADH, glucagon and insulin) in the blood. The **nervous system** 神经系统 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

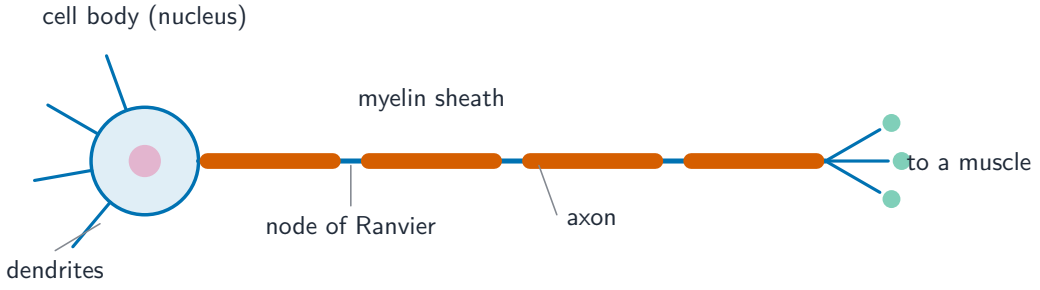
Feature	Nervous system	Endocrine system
signal	electrical **impulse** 冲动	chemical hormone
transport	along nerve cells	in the blood
speed	very fast	slower
how long it lasts	short	longer

Neurones

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

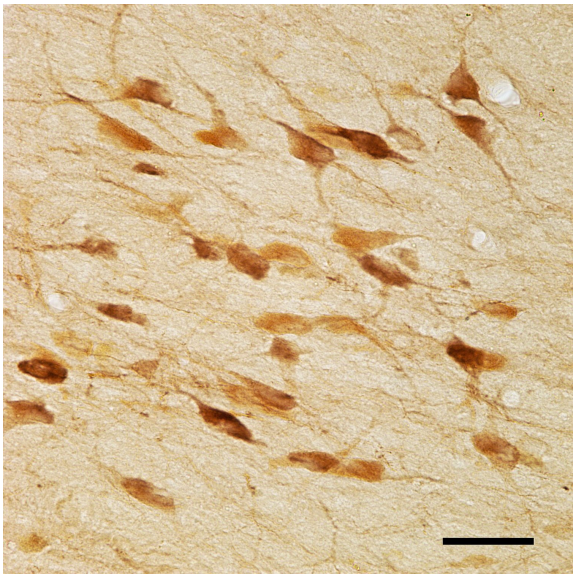
- a **sensory neurone** 感觉神经元 carries impulses from a receptor towards the brain or spinal cord.
- a **motor neurone** 运动神经元 carries impulses out to an effector, such as a **muscle** 肌肉.
- **intermediate neurones** 中间神经元 connect sensory neurones to motor neurones.

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

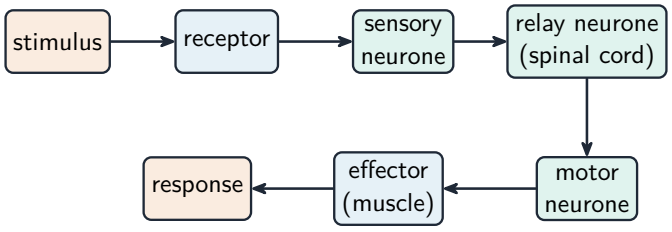
This is what real neurones look like in a stained slice of brain tissue:



*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** 感受器 cell detects a **stimulus** 刺激 and starts an impulse in a sensory neurone. For example, a **chemoreceptor** 化学感受器 cell in a **taste bud** 味蕾 detects chemicals in food, and this triggers an **action potential** 动作电位 in the sensory neurone.

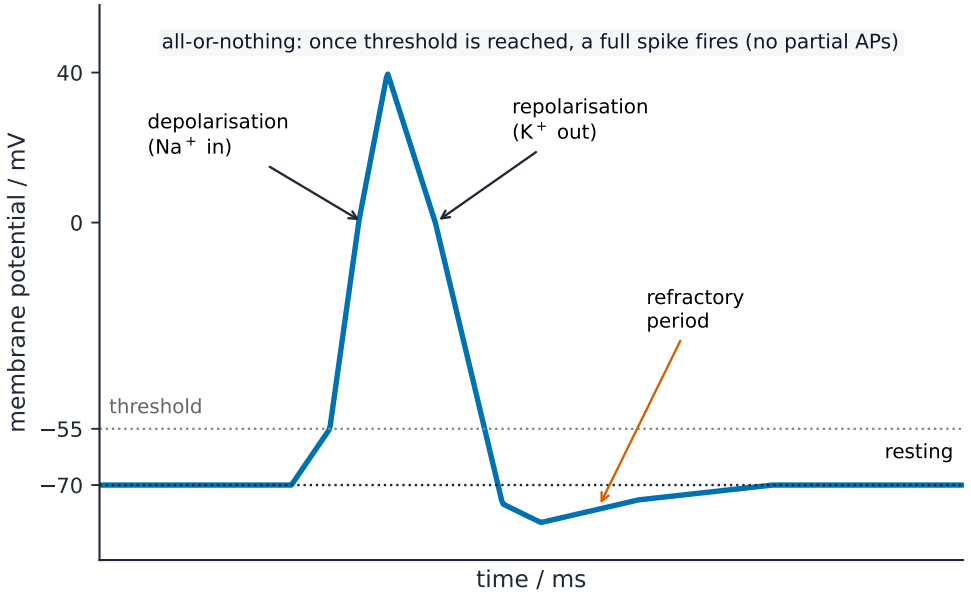


A reflex arc: stimulus → receptor → sensory neurone → relay → motor neurone → effector → response

The nerve impulse

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

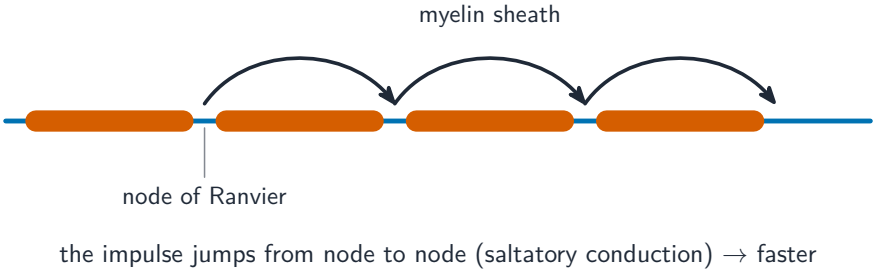
- **resting potential** 静息电位 — when no impulse passes, the inside is negative compared to the outside. This is maintained by a pump that moves sodium ions out and potassium ions in, and by the membrane being more permeable to potassium.
- **action potential** — a stimulus makes sodium channels open, so sodium ions rush in and the inside briefly becomes positive (depolarisation). Then potassium channels open, potassium ions leave, and the **membrane potential** 膜电位 returns to negative (repolarisation).
- **refractory period** 不应期 — 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).



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** 髓鞘. The impulse cannot cross the sheath, so it jumps from one gap to the next. This jumping, called **saltatory conduction** 跳跃式传导, makes the impulse travel much faster.

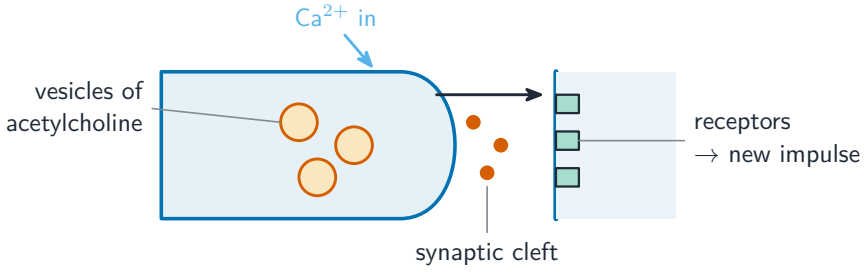


The impulse jumps node to node — saltatory conduction — so a myelinated neurone conducts much faster

The synapse

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

1. the impulse arrives and makes **calcium ions** 钙离子 enter the first neurone.
2. this makes vesicles release a **neurotransmitter** 神经递质 called **acetylcholine** 乙酰胆碱.
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.

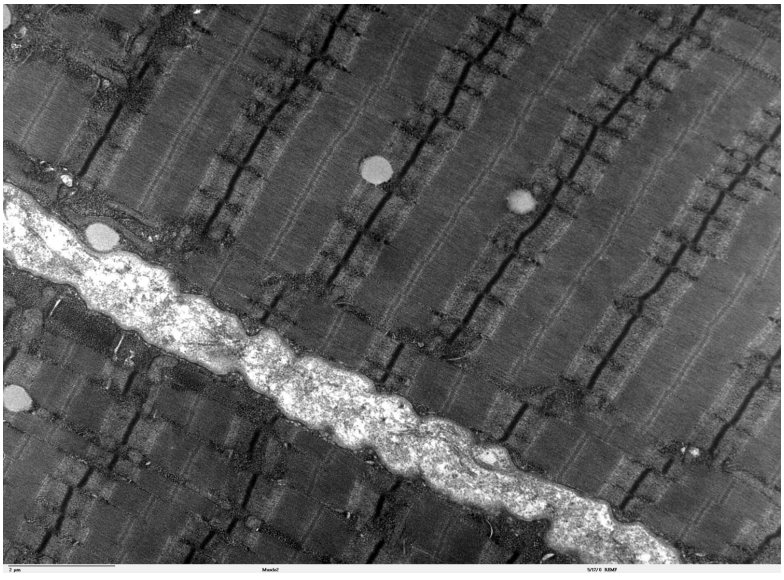


At a synapse, acetylcholine diffuses across the cleft and binds receptors to start a new impulse in the next neurone

Muscles and how they contract

A **neuromuscular junction** 神经肌肉接头 is like a synapse, but between a motor neurone and a muscle.

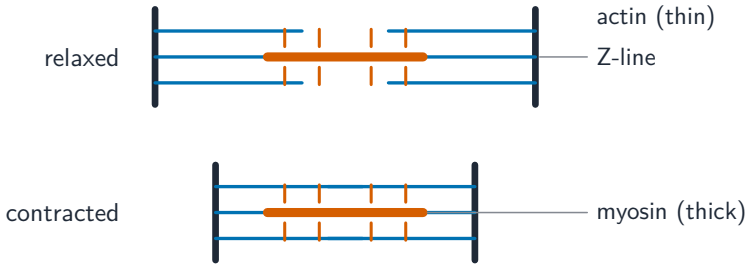
Striated muscle 横纹肌 is made of long fibres. Each fibre is divided into repeating units called **sarcomeres** 肌节. Inside are two kinds of **filament** 肌丝: thick ones (myosin) and thin ones (actin). The **T-tubule** T 小管 system carries the impulse deep into the fibre, and the **sarcoplasmic reticulum** 肌质网 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** 肌丝滑动模型 explains contraction:

1. an impulse causes the sarcoplasmic reticulum to release calcium ions.
2. the calcium ions bind to **troponin** 肌钙蛋白, which makes **tropomyosin** 原肌球蛋白 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

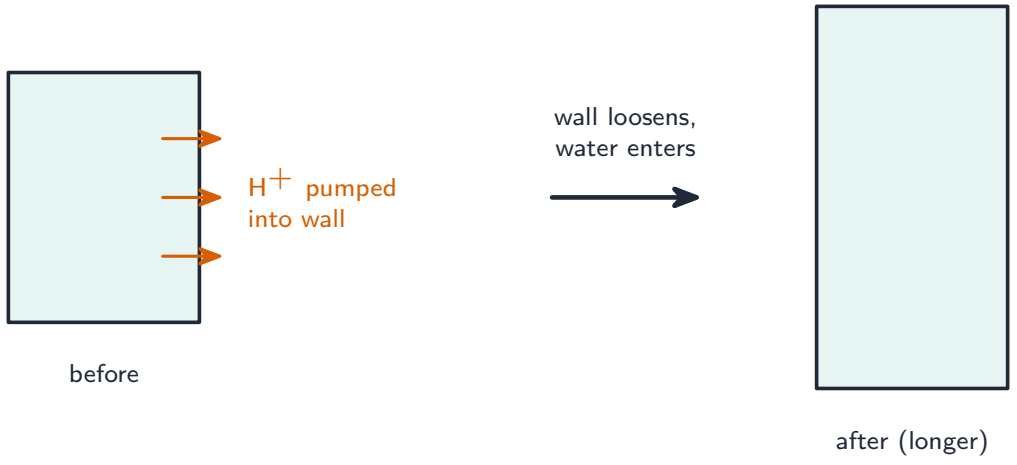
The Venus fly trap

The **Venus fly trap** 捕蝇草 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 生长素 is a plant hormone that makes cells grow longer (**elongation** 伸长 growth). It does this by making the cell pump **protons** 质子 (hydrogen ions) into the **cell wall** 细胞壁. This **acidifies** 酸化 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 赤霉素 controls the **germination** 萌发 of **barley** 大麦 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+).