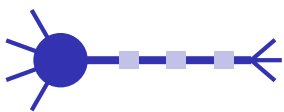
Control & Coordination

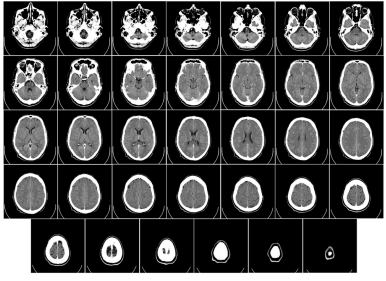
A-Level Biology ▪ Topic 15

A-Level Biology



What we will cover

1. Two control systems
2. Neurones & the reflex arc
3. The nerve impulse
4. The synapse
5. Muscle contraction
6. Plant coordination



the brain coordinates it all

1 Systems and neurones

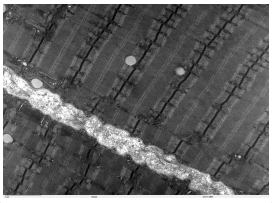
Two control systems

nervous 神经系统

electrical **impulses** 冲动
– fast, short-lived

endocrine 内分泌系统

chemical **hormones** 激素
in blood – slow, longer



Muscle striations TEM

Neurones

sensory

receptor → CNS

relay

inside the CNS

motor

CNS → effector

A motor neurone: cell body in the CNS, long axon to the muscle, many dendrites in.

The reflex arc

Receptor → sensory neurone → relay neurone (spinal cord) → motor neurone → effector.

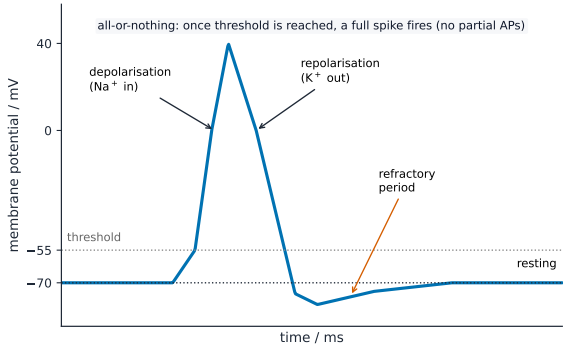
> The brain is not needed, so the response is fast and stereotyped.

2 Impulses and synapses

The nerve impulse

- **resting potential** 静息电位 – inside negative
- **action potential** 动作电位 – Na^+ in (**depolarisation** 去极化), then K^+ out (**repolarisation** 复极化)
- **refractory period** 不应期 – limits the frequency

The nerve impulse, in detail

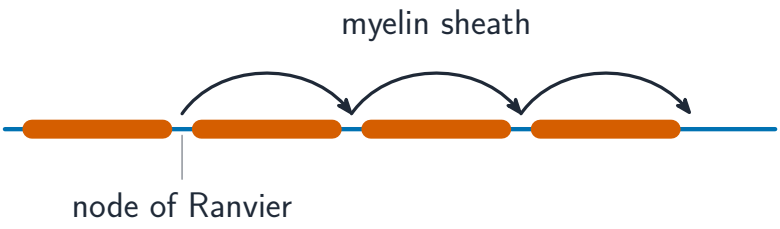


An action potential: sodium in causes depolarisation; potassium out causes repolarisation; then a refractory period

Faster impulses and the synapse

Myelin 髓鞘 makes the impulse jump node to node (**saltatory conduction** 跳跃式传导) – much faster.

> At a **synapse** 突触, Ca^{2+} triggers **acetylcholine** 乙酰胆碱 release; it crosses the gap and starts a new impulse.



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.

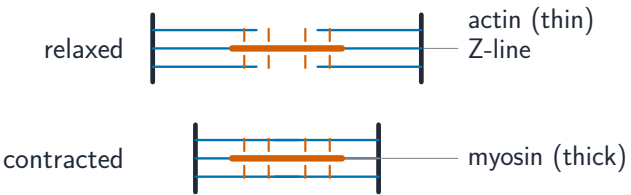
> **Striated muscle** 横纹肌 is made of long fibres.

3 Muscle and plants

Muscle contraction

The **sliding filament model** 肌丝滑动模型:

- Ca^{2+} uncovers binding sites on **actin** 肌动蛋白
- **myosin** 肌球蛋白 heads pull it in (using ATP)
- the **sarcomere** 肌节 shortens



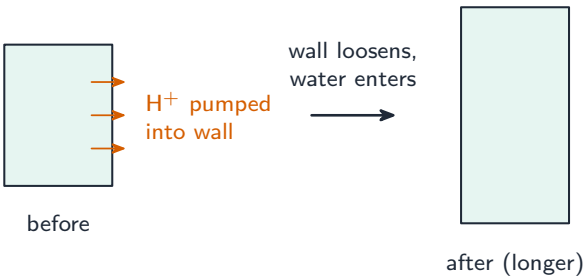
the filaments slide over each other, so the sarcomere shortens

How a muscle actually shortens

striated muscle 横纹肌	long fibres divided into repeating units called **sarcomeres** 肌节
the filaments	thick myosin and thin actin, overlapping
1. calcium released	an impulse triggers Ca^{2+} release from the sarcoplasmic reticulum
2. the switch	calcium binds **troponin** 肌钙蛋白, which moves **tropomyosin** 原肌球蛋白 and uncovers the binding sites on actin
3. the stroke	myosin heads bind, pull the actin past, then detach using ATP and reset
the result	the sarcomere shortens, though neither filament changes length

The sliding filament model: the filaments *slide*, they do not contract. Saying that explicitly is the marked point.

Plant coordination



Auxin 生长素 causes "acid growth": it pumps H^+ into the wall, loosening it so the cell stretches longer.

Gibberellin 赤霉素 switches on amylase for **germination** 萌发; the Venus fly trap uses fast electrical signals.

How auxin makes a cell longer

Auxin	**Auxin** 生长素 is a plant hormone that makes cells grow longer – **elongation** 伸长 growth.
Pump the protons	It makes the cell pump **protons** 质子 (hydrogen ions) out into the **cell wall** 细胞壁.
Acid loosens the wall	That **acidifies** 酸化 the wall, which loosens the links between its fibres.
Water does the rest	Water enters by osmosis and the loosened wall lets the cell stretch – so the shoot bends towards the light.

"Acid growth": the hormone does not push the cell open, it makes the wall weak enough for turgor pressure to do it.

Two systems for control

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

Two systems, two kinds of message

The nervous system	The **nervous system** 神经系统 sends fast electrical signals along nerve cells – milliseconds, and precisely addressed.
The endocrine system	The **endocrine system** 内分泌系统 sends chemical **hormones** 激素 (ADH, glucagon, insulin) in the blood – slower, everywhere at once, and longer-lasting.
Where they meet	Both are coordinated by the brain, and both end in the same place: a change in what a cell does.

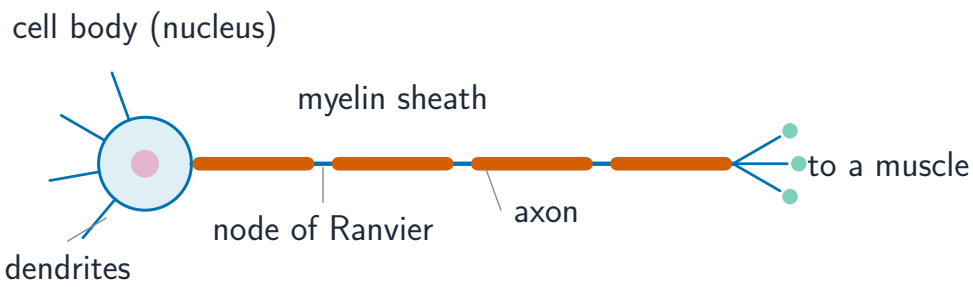
Speed, path, duration and precision – four columns that separate the two systems in any comparison question.

Nervous and endocrine control, compared

the signal	nervous: an electrical impulse along a neurone. Endocrine: a chemical in the blood
speed	nervous: very fast. Endocrine: slower
the target	nervous: a precise effector. Endocrine: any cell with the right receptor
duration	nervous: brief. Endocrine: longer-lasting
used for	nervous: rapid responses – reflexes, movement. Endocrine: sustained change – growth, metabolism, the menstrual cycle
adenylyl cyclase 腺苷酸环化酶	the enzyme many hormone receptors activate, making cyclic AMP as a second messenger inside the cell

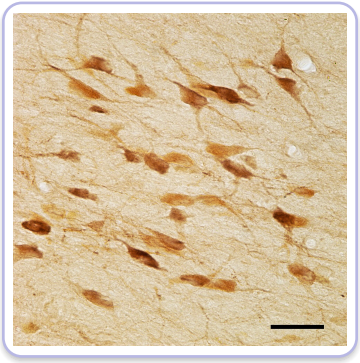
Both end in the same place: a change in a cell's behaviour. They differ in speed and precision, which is what decides which the body uses.

Neurones, continued



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

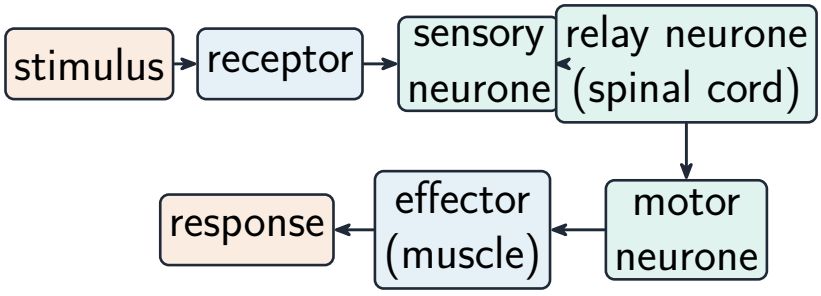
Neurones, continued (2)



Real

Neurones

Detecting a stimulus



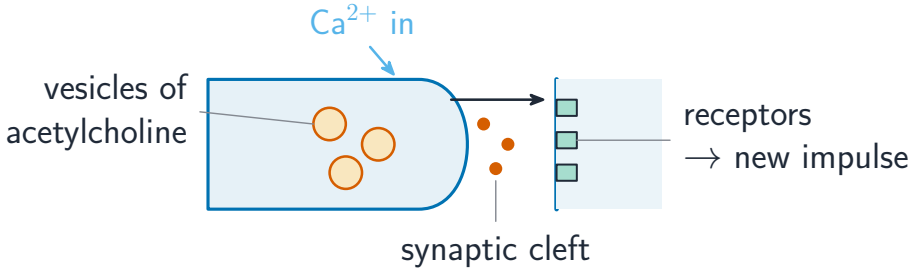
A reflex arc: stimulus → receptor → sensory neurone → relay → motor neurone → effector → response

From stimulus to impulse

Sensory receptor	A **sensory receptor** 感受器 cell detects a **stimulus** 刺激 and starts an impulse in a sensory neurone.
A worked case	A **chemoreceptor** 化学感受器 in a **taste bud** 味蕾 detects chemicals in food, and that triggers an **action potential** 动作电位 in the sensory neurone.
Membrane potential	Sodium channels open and the inside goes briefly positive (depolarisation); then potassium channels open, potassium leaves, and the **membrane potential** 膜电位 returns to negative (repolarisation).
Intermediate neurones	In a reflex, **intermediate neurones** 中间神经元 connect the sensory neurone straight to the motor neurone – which is why no decision is needed.

A receptor is a *transducer*: it converts one kind of energy – chemical, light, pressure – into the one language the nervous system speaks.

The synapse



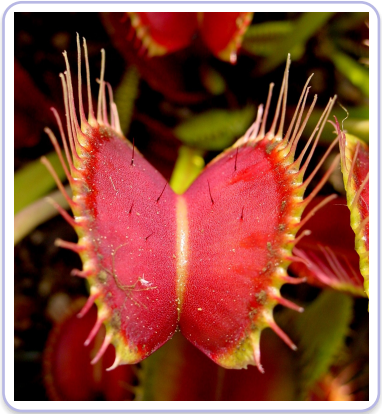
At a synapse, acetylcholine diffuses across the cleft and binds receptors to start a new impulse in the next neurone

Four steps across a synapse

1. Calcium enters	The impulse arrives and makes **calcium ions** 钙离子 enter the first neurone.
2. Vesicles fuse	Calcium makes vesicles of **acetylcholine** 乙酰胆碱 fuse with the membrane and empty into the cleft.
3. Receptors bind	The transmitter diffuses across and binds receptors on the next neurone, opening sodium channels.
4. It is removed	Enzymes break the transmitter down at once, so the next impulse starts from a clean slate.

Vesicles on one side, receptors on the other: that asymmetry is the whole reason a synapse conducts in one direction.

The Venus fly trap



The trap-like leaves carry tiny trigger hairs. When an insect touches them a fast electrical signal spreads, the cells quickly lose water and change shape, and the trap snaps shut on the insect.

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

Gibberellin and germination

The hormone	**Gibberellin** 赤霉素 controls the **germination** 萌发 of **barley** 大麦 seeds.
What it switches on	It switches on the *genes* that make **amylase** 淀粉酶 – so the effect is at the level of transcription, not of the enzyme already present.
Why that matters	Amylase breaks the seed's stored **starch** 淀粉 down into sugars, which feed the growing seedling until it can photosynthesise.

A hormone that acts on a **gene** explains a delay: nothing happens until the new enzyme has been made.

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+).

4 Recap

Worked example – across the synapse

Explain how an impulse crosses a cholinergic synapse.

- The action potential depolarises the presynaptic membrane, opening voltage-gated Ca^{2+} channels.
- Ca^{2+} enters; vesicles fuse and release acetylcholine by exocytosis.
- ACh diffuses across and binds receptors, opening Na^{+} channels $\Rightarrow$ postsynaptic depolarisation.
- Acetylcholinesterase breaks ACh down, so the synapse resets $\Rightarrow$ one-way, brief.

Vesicles are only on one side and receptors only on the other – that is what makes transmission unidirectional.

Topic 15 – key takeaways

1 Two systems

nervous fast electrical; endocrine slow chemical

2 Impulse

Na^+ in depolarises; K^+ out repolarises

3 Synapse

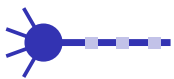
acetylcholine crosses to start a new impulse

4 Muscle

sliding filaments shorten the sarcomere

Check yourself

1. Which ion rushes in during depolarisation?
2. What is myelin's jumping conduction called?
3. Which neurotransmitter acts at a cholinergic synapse?
4. Which filament slides in muscle contraction?



Answers **1.** sodium (Na^+) **2.** saltatory conduction **3.** acetylcholine **4.** actin (thin filament)