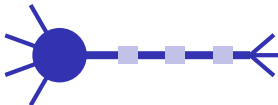


Control & Coordination

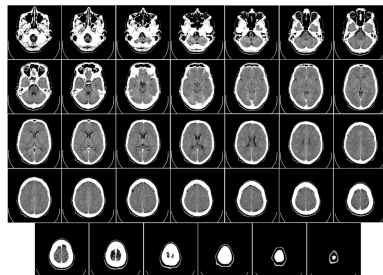
A-Level Biology ■ Topic 15

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



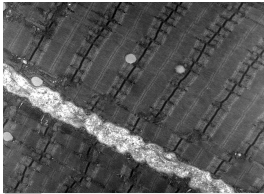
Two control systems

nervous

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

endocrine

chemical **hormones** 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.

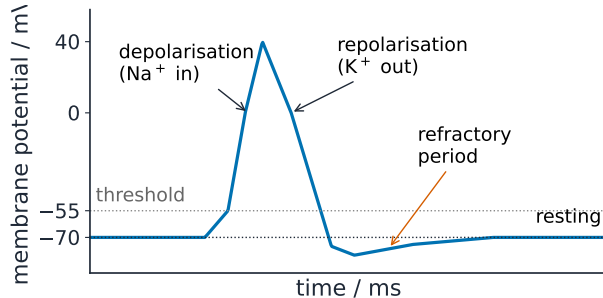
The brain is not needed, so the response is **fast** and stereotyped.



The nerve impulse

- **resting potential** – inside negative
- **action potential** – Na^+ in (**depolarisation**), then K^+ out (**repolarisation**)
- **refractory period** – limits the frequency

The nerve impulse, in detail



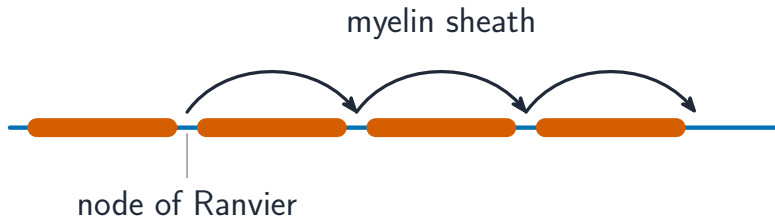
all-or-nothing: once threshold is reached, a full spike fires (no partial APs)

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

Faster impulses and the synapse

Myelin makes the impulse jump node to node (**saltatory conduction**) – much faster.

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



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

Muscles and how they contract

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

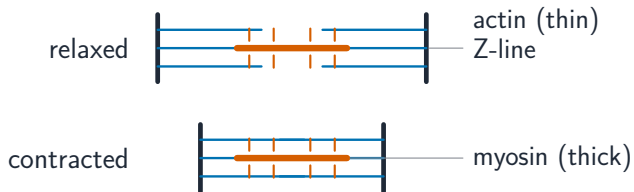
Striated muscle is made of long fibres.



Muscle contraction

The **sliding filament model** :

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



the filaments slide over each other, so the sarcomere shortens

How a muscle actually shortens

striated muscle

long fibres divided into repeating units called **sarcomeres**

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**, which moves **tropomyosin** and **uncovers the binding sites** on actin

3. the stroke

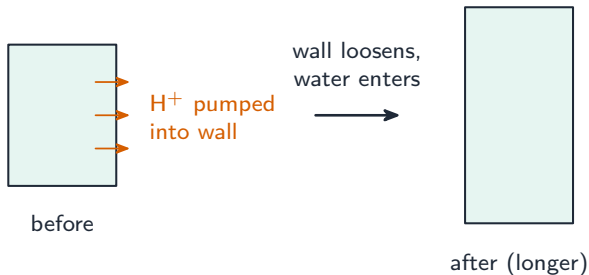
myosin heads bind, pull the actin past, then detach using ATP and reset

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 causes “acid growth”: it pumps H^+ into the wall, loosening it so the cell stretches longer. **Gibberellin** switches on amylase for **germination** ; the Venus fly trap uses fast electrical signals.

How auxin makes a cell longer

Auxin

Auxin is a plant hormone that makes cells grow longer – **elongation** growth.

Pump the protons

It makes the cell pump **protons** (hydrogen ions) out into the **cell wall**.

Acid loosens the wall

That **acidifies** 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** sends fast electrical signals along nerve cells – milliseconds, and precisely addressed.

The endocrine system

The **endocrine system** sends chemical **hormones** (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

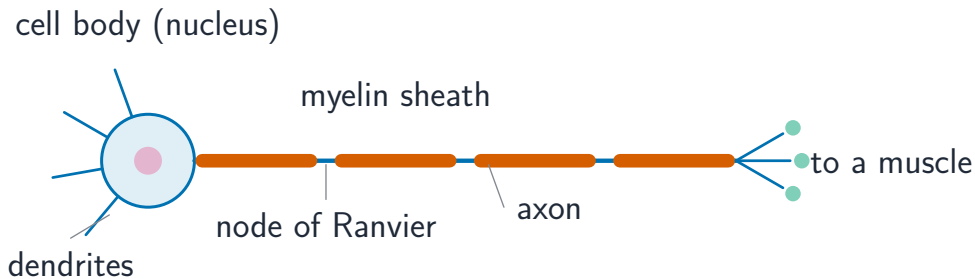
nervous: rapid responses – reflexes, movement. Endocrine: sustained change – growth, metabolism, the menstrual cycle

adenylyl cyclase

the enzyme many hormone receptors activate, making cyclic AMP as a second messenger inside the cell

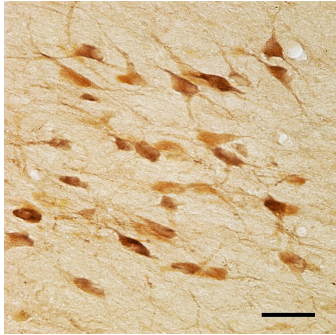
Both end in the same place: a change in a cell's behaviour. They differ in **speed and precision**, which is what decides which the body uses.

Neurones, continued



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

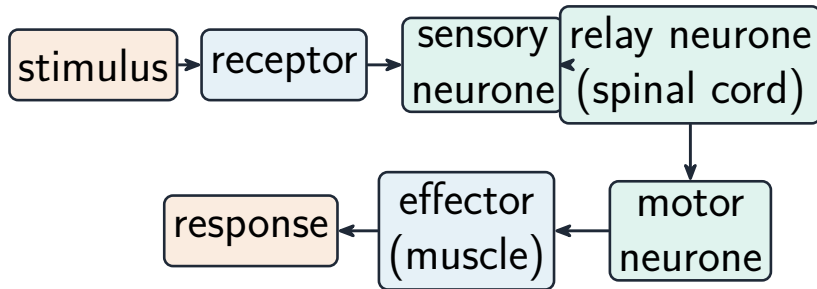
Neurones, continued (2)



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** cell detects a **stimulus** and starts an impulse in a sensory neurone.

A worked case

A **chemoreceptor** in a **taste bud** detects chemicals in food, and that triggers an **action potential** in the sensory neurone.

Membrane potential

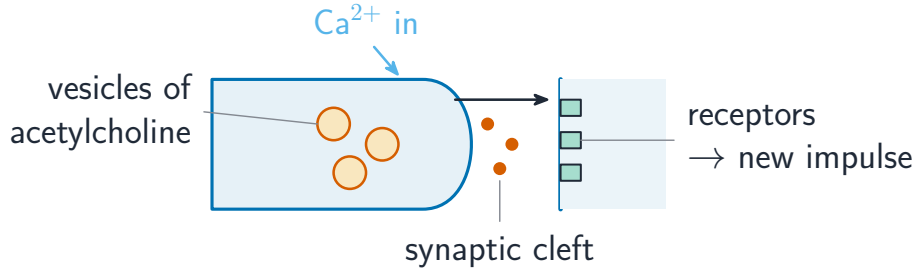
Sodium channels open and the inside goes briefly positive (depolarisation); then potassium channels open, potassium leaves, and the **membrane potential** returns to negative (repolarisation).

Intermediate neurones

In a reflex, **intermediate neurones** 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** enter the first neurone.

2. Vesicles fuse Calcium makes vesicles of **acetylcholine** 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 controls the **germination** of **barley** seeds.

What it switches on

It switches on the *genes* that make **amylase** – 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** 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 $\rightarrow$ 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: Ca^{2+} enters $\rightarrow$ vesicles fuse $\rightarrow$ neurotransmitter $\rightarrow$ receptors $\rightarrow$ new impulse.
- Muscle contraction follows the **sliding-filament** model (actin, myosin, ATP, Ca^{2+}).



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

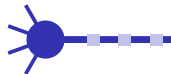
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Muscle

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)