

Cambridge AS & A Level · Biology 9700 · Notes

Control and coordination A2

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Last checked 30 September 2026

Read first: [Cell membranes and transport](#), [Energy and respiration](#), [Homeostasis](#)

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What you need to know

By the end of this topic you should be able to:

1. **Describe the endocrine system** with ADH, glucagon and insulin as examples: hormones released into the blood act on target cells with the right receptors.
2. **Compare the nervous and endocrine systems.**
3. **Describe the structure and function of sensory and motor neurones**, and state that intermediate (relay) neurones connect them.
4. **Outline how receptor cells** detect stimuli and start impulses in sensory neurones.
5. **Describe how a chemoreceptor cell in a taste bud** leads to an action potential in a sensory neurone.
6. **Describe and explain membrane potentials**: how the resting potential is kept, the events of an action potential, and how the resting potential returns during the refractory period.
7. **Explain fast transmission in myelinated neurones** (saltatory conduction).
8. **Explain how the refractory period limits impulse frequency.**
9. **Describe a cholinergic synapse and how it works**, including the role of calcium ions.
10. **Describe the roles of the neuromuscular junction, T-tubules and sarcoplasmic reticulum** in starting contraction of striated muscle.
11. **Describe sarcomere structure** from diagrams and electron micrographs.
12. **Explain the sliding filament model**: troponin, tropomyosin, calcium ions and ATP.
13. **Describe how a Venus fly trap closes** when hairs on its lobes are touched.
14. **Explain how auxin makes cells elongate** by stimulating proton pumping that acidifies cell walls.
15. **Describe how gibberellin controls barley germination.**

Understand it

Two ways to coordinate

The **nervous system** sends electrical impulses (action potentials) along neurones. At the end of a neurone a chemical, the **neurotransmitter**, crosses a tiny gap to the next cell. Responses are fast, short-lived and go to one precise place.

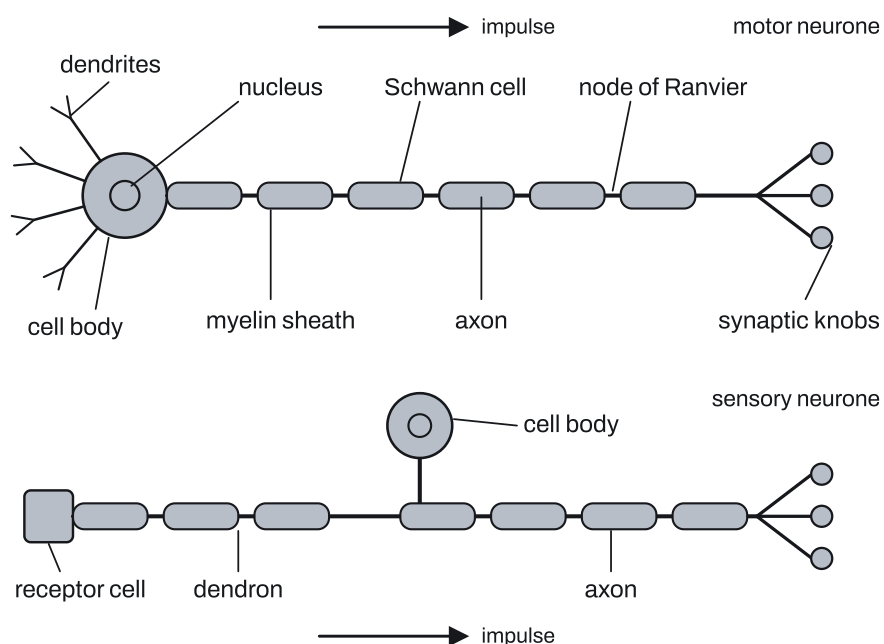
The **endocrine system** is made of **endocrine glands**, which have no ducts and secrete **hormones** straight into the blood. The blood carries a hormone all round the body, but only **target cells** with a matching **receptor** respond. Responses are slower, can be widespread and last longer. The three examples in the syllabus (see homeostasis):

- **ADH**, from the posterior pituitary gland when osmoreceptors in the hypothalamus detect a low blood water potential; collecting duct cells reabsorb more water **into the blood**.
- **Insulin**, from β cells in the islets of Langerhans (pancreas) when blood glucose is high; target cells take glucose **out of the blood**.
- **Glucagon**, from α cells in the islets when blood glucose is low; liver cells release glucose **into the blood**.

All three bind to receptors on the **cell surface membrane** of their target cells.

Neurones

A reflex runs: receptor → **sensory neurone** → **intermediate (relay) neurone** in the brain or spinal cord → **motor neurone** → effector (a muscle or gland).



- **Motor neurone**: cell body **inside** the brain or spinal cord, with many short **dendrites** that receive impulses from relay neurones; one long **axon** carries impulses **away** from the cell body to an effector.

- **Sensory neurone:** impulses start at a **receptor**; a long **dendron** carries them **to** the cell body, which sits in a swelling just **outside** the spinal cord; a shorter axon carries them into the CNS.
- In mammals many axons and dendrons are wrapped in a **myelin sheath**, made by **Schwann cells** wrapping their membranes around the neurone. The gaps between Schwann cells are **nodes of Ranvier**.
- The ends of the axon swell into **synaptic knobs**, full of mitochondria and vesicles of neurotransmitter.

Receptor cells

A **receptor cell** turns the energy of a stimulus into an electrical change. The stimulus opens ion channels, Na^+ flows in, and the membrane depolarises a little. This small change is the **receptor potential** (or generator potential), and its size depends on the stimulus strength. Only if it reaches the **threshold** does an action potential start in the sensory neurone. Above threshold, a stronger stimulus does not make bigger action potentials; it makes **more of them per second**.

A chemoreceptor in a taste bud (salt as the example):

1. Na^+ from salty food diffuses into the chemoreceptor cell through **Na^+ channels** in the membrane of its microvilli.
2. The inside becomes less negative: the cell **depolarises** (a receptor potential).
3. The depolarisation opens **voltage-gated Ca^{2+} channels**; Ca^{2+} diffuses in.
4. Ca^{2+} makes **vesicles** of neurotransmitter move to the membrane and release it by **exocytosis**.
5. The transmitter diffuses across to the **sensory neurone** and binds to receptors, opening Na^+ channels.
6. Na^+ enters the sensory neurone; if the depolarisation reaches **threshold**, an **action potential** starts.

Other substances (such as sugars) instead bind a **receptor protein**, which starts a signalling pathway in the cell; from step 2 on it is the same.

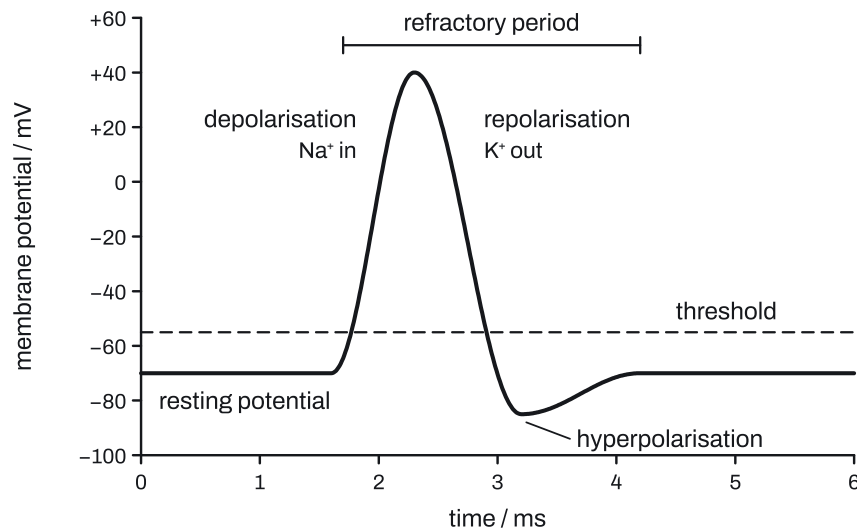
The resting potential

At rest the inside of an axon is about **-70 mV** compared with the outside. This is kept by:

- **Na^+/K^+ pumps:** carrier proteins that use **ATP** (active transport) to move **3 Na^+ out** for every **2 K^+ in**. This builds concentration gradients: more Na^+ outside, more K^+ inside.
- **Leaky K^+ channels:** the membrane is much more permeable to K^+ than to Na^+ , so K^+ diffuses **out** faster than Na^+ diffuses in.
- **Negatively charged proteins** and other anions that stay inside the cell.

The result: more positive charge outside than inside, so the inside is negative.

The action potential



1. **Depolarisation.** A stimulus opens a few **voltage-gated Na⁺ channels**; Na⁺ diffuses **in** down its electrochemical gradient. If the membrane reaches **threshold** (about -55 mV), many more Na⁺ channels open (**positive feedback**), and the inside shoots up to about **+40 mV**.
2. **Repolarisation.** The Na⁺ channels close, and **voltage-gated K⁺ channels** open; K⁺ diffuses **out**, and the inside becomes negative again.
3. **Hyperpolarisation.** The K⁺ channels are slow to close, so too much K⁺ leaves and the potential overshoots below -70 mV.
4. **Back to rest.** The K⁺ channels close, and the Na⁺/K⁺ pumps and leaky K⁺ channels restore the resting potential.

Depolarisation and repolarisation are **diffusion** through channels; they don't use ATP. Action potentials are **all-or-nothing**: they are always the same size.

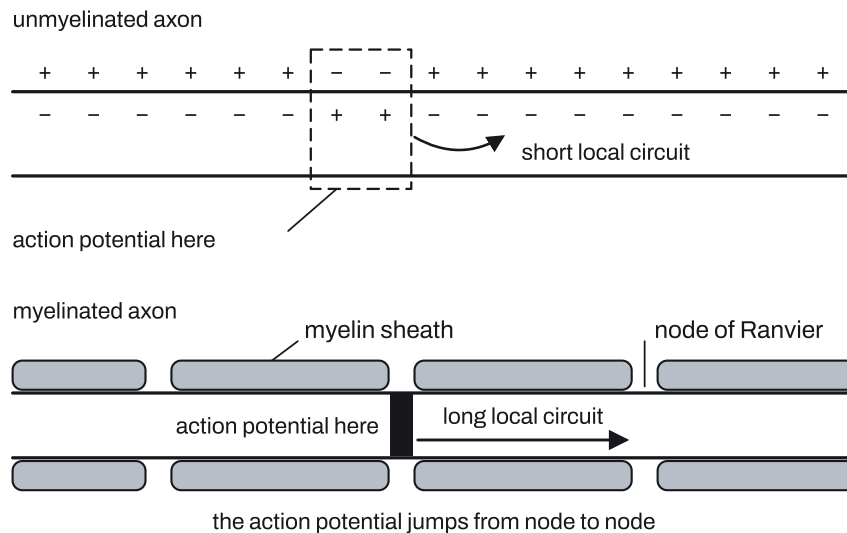
The refractory period

From the start of an action potential until the resting potential is back, that part of the membrane cannot fire again: at first the Na⁺ channels **cannot** reopen, and while the membrane is hyperpolarised only a much stronger stimulus reaches threshold. This matters because:

- action potentials are **discrete** (separate), never merging;
- they travel **one way**: the section behind the impulse is refractory, so only the section ahead can depolarise;
- it sets a **maximum frequency**: if the refractory period lasts 2 ms, at most $1 \div 0.002 = 500$ impulses per second.

How an impulse travels

An action potential in one section makes the next section fire. Na⁺ that has flooded in moves sideways inside the axon towards the negative resting region; these **local circuits** depolarise the next section to threshold.

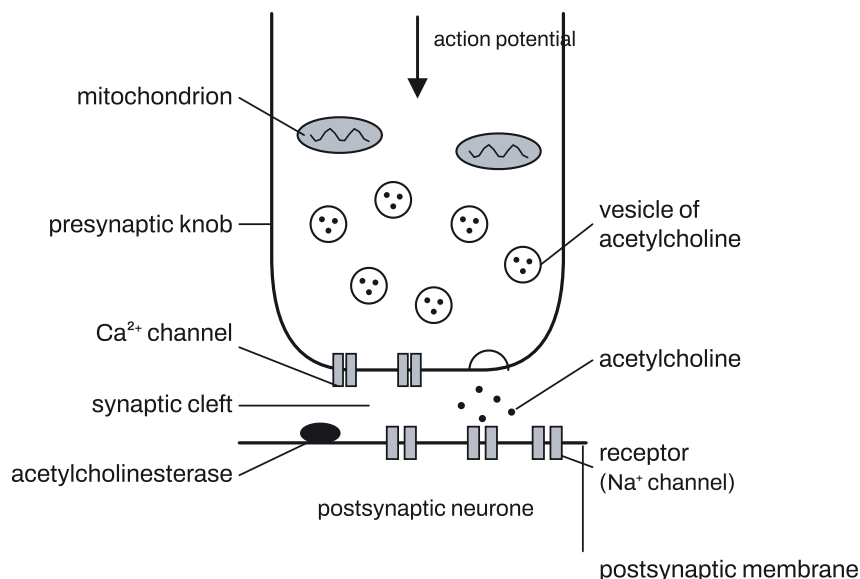


In a **myelinated** neurone the myelin **insulates** the axon: ions cannot cross the membrane there, and the voltage-gated channels are concentrated at the **nodes of Ranvier**. So depolarisation happens **only at the nodes**, the local circuits are **long** (node to node), and the action potential **jumps from node to node**: **saltatory conduction**. Speeds reach about 100 m s^{-1} , against a few m s^{-1} for thin unmyelinated axons.

Axon diameter matters too: a wider axon has less resistance to the flow of ions inside it and less leakage, so it conducts faster. Myelination has a much bigger effect than diameter.

The cholinergic synapse

A **synapse** is a junction between two neurones; a **cholinergic** synapse uses **acetylcholine (ACh)**.



1. An action potential arrives at the **presynaptic knob** and depolarises its membrane.
2. **Voltage-gated Ca^{2+} channels** open; Ca^{2+} diffuses **into** the knob.
3. Ca^{2+} makes **vesicles** of ACh move to and **fuse with** the presynaptic membrane: ACh is released by **exocytosis**.

4. ACh **diffuses** across the **synaptic cleft** (about 20 nm).
5. ACh binds to **receptor proteins** on the postsynaptic membrane. These are **ligand-gated Na⁺ channels**: they open when ACh binds.
6. Na⁺ diffuses in and **depolarises** the postsynaptic membrane. If it reaches threshold, an action potential starts.
7. **Acetylcholinesterase hydrolyses** ACh into acetate and choline, so the channels close. Choline returns to the knob, where ACh is remade using ATP.

Only the presynaptic side has vesicles and only the postsynaptic side has receptors, so a synapse passes impulses **one way**. Mitochondria supply ATP for moving vesicles, remaking ACh and pumping ions.

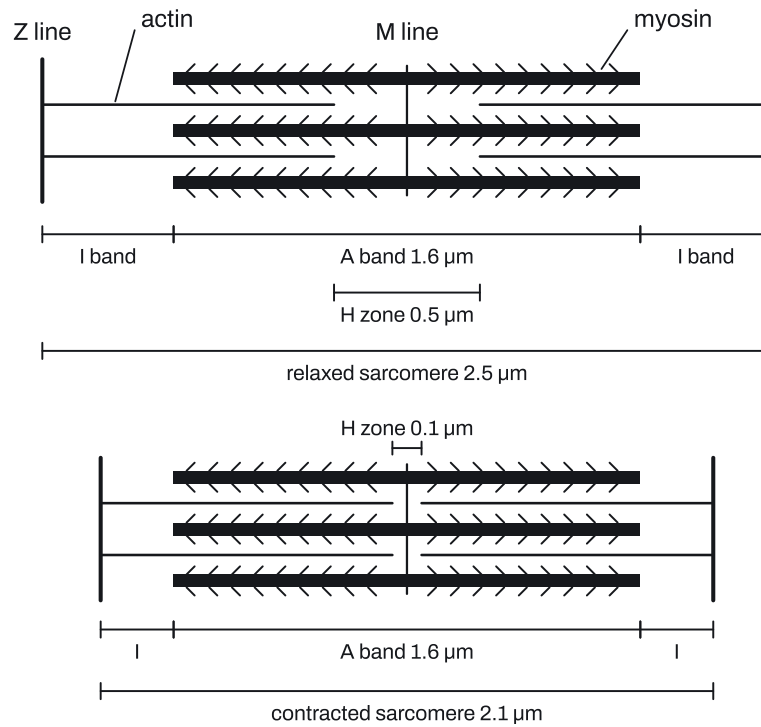
From nerve to muscle

A **neuromuscular junction** is a synapse between a motor neurone and a muscle fibre; it works the same way, and ACh binds to receptors on the **sarcolemma** (the muscle fibre's cell surface membrane).

1. Na⁺ enters, the sarcolemma **depolarises** and an action potential spreads along it.
2. It passes deep into the fibre down the **T-tubules** (infoldings of the sarcolemma).
3. The T-tubules touch the **sarcoplasmic reticulum** (SR), a store of Ca²⁺. The depolarisation opens **Ca²⁺ channels** in the SR; Ca²⁺ diffuses out into the **sarcoplasm**.
4. Ca²⁺ reaches every myofibril at once, so the whole fibre contracts together.

The sarcomere

A striated muscle fibre is packed with **myofibrils**, each a chain of **sarcomeres**, the units that shorten. A sarcomere runs from one **Z line** to the next. Thin **actin** filaments are fixed to the Z lines; thick **myosin** filaments sit in the middle, held at the **M line**, and overlap the ends of the actin.



Region	What it contains	Look in an electron micrograph	On contraction
I band	actin only (spans a Z line)	lightest	shorter
A band	the full length of the myosin	dark	same length
overlap (in the A band)	actin and myosin	darkest	longer
H zone	myosin only	medium, middle of A band	shorter (can vanish)
sarcomere	Z line to Z line	—	shorter

The filaments do not shorten; they **slide** past each other.

The sliding filament model

- At rest, **tropomyosin** lies along the actin, **covering the myosin-binding sites**. **Troponin** holds it there.
- Ca²⁺ binds to troponin**, which **changes shape** and pulls **tropomyosin** away, **exposing the binding sites** on actin.
 - Myosin heads**, already carrying ADP and P_i, **bind** to actin, forming **cross-bridges**.
 - The heads release ADP and P_i and **tilt**: the **power stroke** pulls the actin towards the M line.
 - ATP binds** to each head, which **detaches** it from actin.
 - The head is an **ATPase**: it **hydrolyses** the ATP, and the energy recocks it, ready to bind further along.

The cycle repeats as long as Ca²⁺ and ATP are present. When stimulation stops, Ca²⁺ is **actively pumped back into the SR** (using ATP), tropomyosin covers the sites again and the muscle relaxes. So ATP is needed to **detach** myosin heads, to **recock** them and to **pump Ca²⁺** back.

Control in plants

Venus fly trap. Each modified leaf has two lobes with sensitive hairs. Bending a hair opens Ca^{2+} channels, giving a receptor potential; at threshold an **action potential** spreads across the lobe. **Two** stimulations within about 20 s are needed, so no energy is wasted closing on rain or dust. Cells in the hinge region then pump **H^+ out** into their walls, loosening them; Ca^{2+} enters the cells, **water follows by osmosis** and the cells swell quickly. The lobes flip from curving outwards to curving inwards and **snap shut**. The struggling insect seals the trap, glands secrete digestive enzymes, and the plant absorbs nitrogen and mineral ions that are scarce in its soil.

Auxin and elongation. Auxin is made at shoot tips and moves back to the elongation zone.

1. Auxin binds to a **receptor** on the cell.
2. This stimulates **proton pumps** (ATP-driven) to pump **H^+ out** of the cytoplasm into the **cell wall**.
3. The wall's **pH falls**, activating **expansins**, proteins that break **hydrogen bonds** between cellulose microfibrils.
4. The wall loosens. K^+ enters the cell, lowering its water potential; **water enters by osmosis** and turgor pressure **stretches** the loosened wall, so the cell **elongates**.

Gibberellin and barley germination.

1. The seed absorbs water; the **embryo** makes **gibberellin**.
2. Gibberellin diffuses to the **aleurone layer** around the endosperm.
3. There it causes **DELLA proteins** to be broken down (gibberellin binds to a receptor, which leads to the DELLA being destroyed; it doesn't break them down itself). DELLA proteins normally block a transcription factor, so the gene for **amylase** can now be **transcribed** and translated.
4. Amylase is secreted into the **endosperm**, where it **hydrolyses starch** to maltose, then glucose.
5. The embryo uses the glucose for **respiration** (ATP) and growth.

Key facts and formulas

None of these are in the syllabus's list of mathematical formulae, so they are all "Learn it".

Formula	Status
Resting potential about -70 mV; inside negative	Learn it
Na^+/K^+ pump: 3 Na^+ out, 2 K^+ in, uses ATP	Learn it
Depolarisation: Na^+ in; repolarisation: K^+ out (voltage-gated channels, no ATP)	Learn it
Speed = $\frac{\text{distance}}{\text{time}}$, so time = $\frac{\text{distance}}{\text{speed}}$	Learn it
Maximum impulse frequency = $\frac{1}{\text{refractory period}}$	Learn it

Formula	Status
Percentage change = $\frac{\text{new} - \text{original}}{\text{original}} \times 100$	Learn it
Sarcomere = A band + I band; H zone = sarcomere – 2 × actin filament length	Learn it
On contraction: A band same; I band, H zone and sarcomere shorter	Learn it
Ca ²⁺ roles: vesicle release at synapses; binding troponin in muscle	Learn it
ATP roles in muscle: detach myosin head, recock it, pump Ca ²⁺ into the SR	Learn it

How to do it

In the Paper 4 questions we have tagged for this topic (57 questions, 2021–2025, including 8 repeated across variants), the types came up this often. 38 of the 57 questions mix two or more types, so the counts add up to more than 57.

Question type	Questions
Excitation and the sliding filament model	15
Myelination, axon diameter and impulse speed	14
Neurone structures	10
Chemoreceptor to action potential	9
Transmission at a synapse or neuromuscular junction	8
Effect of a drug or toxin	8
Nervous and endocrine systems	8
Sarcomere bands	7
Resting potential and action potential events	6
Comparing action potential graphs	6
Gibberellin in barley germination	5
Venus fly trap	4
Inhibitory transmitters	3
Importance of the refractory period	2
Auxin and cell elongation	2

1. Excitation and the sliding filament model (15 questions)

1. **Start where the question starts.** "From ACh release" means: ACh binds receptors on the sarcolemma → Na⁺ channels open → sarcolemma depolarised → spreads down T-tubules → Ca²⁺ channels in the SR open → Ca²⁺ into the sarcoplasm.
2. **Continue if asked** with the sliding filament steps, from Ca²⁺ binding troponin to the sarcomere shortening.
3. One mark per link, in order. Name the **binding site on actin**, not an "active site".

Variations: putting lettered events in order; explaining graphs of Ca²⁺ concentration and sarcomere width over time (Ca²⁺ rises as it leaves the SR, falls as it is pumped back; the sarcomere narrows while cross-bridges cycle and widens once they break). **Applied cases** are all about Ca²⁺ or ATP: low blood glucose, fatigue or no oxygen means less ATP, so fewer heads detach, less Ca²⁺ is pumped back, and contraction is weaker or the muscle cannot relax; anything that traps Ca²⁺ in the SR means fewer binding sites exposed and fewer power strokes.

2. Myelination, axon diameter and impulse speed (14 questions)

1. State the effect: myelinated neurones conduct **faster**.
2. Explain: myelin (Schwann cells) **insulates**; ions move and **depolarisation occurs only at nodes of Ranvier**; **longer local circuits**; the **action potential** jumps node to node: **saltatory conduction**.
3. For data: describe each trend separately (myelinated faster; for unmyelinated, wider is faster), say myelination matters **more** than diameter, and quote **paired data with units**.

Variations: loss of myelin (as in multiple sclerosis): action potentials along the whole membrane, short local circuits, slower or blocked impulses; a 9-mark "describe and explain transmission" essay, which also needs the resting potential and the events of the action potential.

3. Neurone structures (10 questions)

1. Name parts precisely: **dendrite, cell body, nucleus, axon, Schwann cell** (when a cell is asked for; "myelin sheath" is what it makes), **node of Ranvier, synaptic knob, receptor cell**.
2. A sensory neurone's synaptic knobs meet an **intermediate (relay) neurone**; a motor neurone's knobs meet a muscle.
3. To **contrast** sensory and motor neurones, pair each point: cell body outside vs inside the CNS; dendron vs many dendrites; from receptor to CNS vs from CNS to effector.

4. Chemoreceptor to action potential (9 questions)

Use the six steps from "Understand it" and don't stop halfway: Na⁺ in → receptor potential → **Ca²⁺ in** → exocytosis of transmitter → binds sensory neurone → Na⁺ in → **threshold** → action potential.

Variations: a new animal (a smell receptor in a dog's nose, a sugar receptor on an insect's foot): same steps, starting with the molecule **binding a receptor protein**. A table where weak stimuli give no response: the receptor potential didn't reach threshold (all-or-nothing).

5. Transmission at a synapse or neuromuscular junction (8 questions)

1. Give the seven steps from "Understand it", naming **voltage-gated Ca^{2+} channels** (presynaptic) and **ligand-gated Na^+ channels** (postsynaptic).
2. **Similarities** of a neuromuscular junction and a synapse: vesicles of ACh, many mitochondria, a cleft, receptors and Na^+ channels postsynaptic, Ca^{2+} channels presynaptic.
3. **Why so many mitochondria**: ATP for moving vesicles, remaking ACh and pumping ions; in muscle, for detaching and recocking myosin heads and pumping Ca^{2+} into the SR.

6. Effect of a drug or toxin (8 questions)

1. **Find the blocked step**. Does the drug stop Ca^{2+} entering, stop vesicles fusing, bind ACh receptors, or stop acetylcholinesterase?
2. **Follow the normal chain from that step**, one consequence per line, saying "less" or "no": less Ca^{2+} in → fewer vesicles fuse → less ACh released → less ACh binds → fewer Na^+ channels open → less depolarisation, threshold not reached → fewer action potentials (or weaker contraction).
3. **A molecule shaped like ACh** competes for the receptor: if it doesn't open the channel, no depolarisation (paralysis). **Blocked acetylcholinesterase**: ACh stays bound, so the membrane stays depolarised.

The channels on the postsynaptic membrane are **ligand-gated**, not voltage-gated; in muscle, Na^+ enters the **muscle fibre** (sarcoplasm), not a "postsynaptic neurone".

7. Nervous and endocrine systems (8 questions)

Write **paired** statements, both halves in the same sentence: impulses vs hormones; electrical (and chemical at synapses) vs chemical only; along neurones vs in the blood; to a precise place vs widespread; fast vs slow; short-lived vs long-lasting. "Both use..." earns nothing when differences are asked.

Variations: a tick table for ADH, glucagon and insulin (all bind cell-surface receptors; only ADH follows osmoreceptors; glucagon and ADH move substances into the blood, insulin out of it); why a hunting animal relies on nerves (fast detection, impulses and muscle response).

8. Sarcomere bands (7 questions)

1. Find the Z lines first; a sarcomere is Z line to Z line.
2. Lightest = I band (actin only); darkest = overlap; the medium band in the middle = H zone (myosin only); the A band = the whole dark stretch.
3. On contraction: **A band same**; I band, H zone and sarcomere shorter.
4. For lengths, use: sarcomere = A band + I band, and H zone = sarcomere – 2 × actin length.

9. Resting potential and action potential events (6 questions)

1. **Resting:** give all three causes from "Understand it" (pump with its 3:2 ratio and ATP, K^+ leaking out, anions inside), then "inside negative, about -70 mV".
2. **Action potential:** name the channel, the ion and its direction for each phase, and the words depolarisation, threshold, repolarisation, hyperpolarisation.
3. For values at points on a trace (such as -70 , $+40$, -90 mV), match each to the ion movement causing it.

10. Comparing action potential graphs (6 questions)

1. Read the same features on both: **resting potential, peak, size of depolarisation** (peak minus resting), **duration, depth and length of hyperpolarisation, time to return to rest** (refractory period).
2. Write comparative sentences with **paired data and units**, such as "the peak is $+40$ mV in A but $+60$ mV in B".
3. Then apply: a more negative resting potential or longer hyperpolarisation makes threshold harder to reach; a longer refractory period means fewer impulses per second.

11. Gibberellin in barley germination (5 questions)

Use the five steps from "Understand it", naming the **places**: gibberellin from the **embryo** to the **aleurone layer**; amylase from the aleurone layer to the **endosperm**. Say the amylase gene is **transcribed**, then translated.

Data variants: if something lowers germination (such as a substance that blocks gibberellin), link it to less amylase, less starch broken down, less glucose for respiration.

12. Venus fly trap (4 questions)

1. Give the closure chain from "Understand it": two touches, action potential, H^+ out of hinge cells, Ca^{2+} and **water in**, cells **expand**, lobes snap shut.
2. Adaptation parts: insects supply **nitrogen and mineral ions** scarce in its soil; two touches avoid **wasting energy**; it stays shut for **digestion and absorption**; enzymes are secreted by **exocytosis**.

A contrasting plant in which cells **lose** water and turgor to fold a leaf: say which cells gain water in the fly trap and which lose it in the other plant.

13. Inhibitory transmitters (3 questions)

1. A transmitter that lets **Cl^- in** (or **K^+ out**) makes the inside **more negative**: the postsynaptic membrane is **hyperpolarised**.
2. So it is **harder to reach threshold**, and an action potential is less likely.
3. When excitatory and inhibitory inputs arrive together, their effects add up: the result depends on whether the combined depolarisation reaches threshold.

14. Importance of the refractory period (2 questions)

Three points: action potentials are **discrete**; they travel **one way**; the refractory period **limits the frequency** (maximum frequency = $1 \div$ refractory period).

15. Auxin and cell elongation (2 questions)

Write every link of the four steps in "Understand it" (worth up to 7 marks): receptor, proton pumps, low wall pH, expansins breaking hydrogen bonds, K⁺ and water in, turgor stretching the wall.

Worked examples

The bold codes show where marks are earned, as in Cambridge mark schemes. The number is how many marks.

- **M1** method mark: for a correct method, even if the numbers slip.
- **A1** accuracy mark: for a correct answer; it needs the M mark before it.
- **B1** mark for a correct result on its own, with no method needed.

Example 1

(a) State **three** ways in which the endocrine system differs from the nervous system, other than speed of transmission. **[3]**

(b) An impulse travels 0.84 m along a myelinated motor neurone at 70 m s⁻¹. Calculate the time it takes, in ms. **[2]**

(c) Explain why this neurone conducts impulses faster than an unmyelinated neurone of the same diameter. **[3]**

(a) Any three paired points: the endocrine system uses **hormones**, the nervous system **impulses**; hormones travel **in the blood**, impulses **along neurones**; endocrine effects are **widespread**, nervous effects **localised**; endocrine effects **last longer**. **B1 B1 B1**

(b) time = $0.84 \div 70 = 0.012$ s **M1** = 12 ms **A1**

(c) The **myelin sheath insulates** the axon, so ions cannot move across the membrane there. **B1**
Depolarisation only happens at the **nodes of Ranvier**, with **long local circuits** between nodes. **B1** The action potential **jumps from node to node (saltatory conduction)**. **B1**

Example 2

An axon is moved into a solution with a lower Na^+ concentration than normal tissue fluid. Its resting potential stays at -70 mV, but the peak of its action potential falls from $+35$ mV to $+15$ mV.

(a) Describe how the resting potential is maintained. [4]

(b) Calculate the percentage decrease in the size of the depolarisation (from resting potential to peak). [2]

(c) Explain why the peak is lower. [2]

(d) The refractory period of this axon is 2.5 ms. Calculate the maximum frequency of impulses. [2]

(a) Na^+/K^+ pumps move **3 Na^+ out and 2 K^+ in B1** by **active transport using ATP. B1** The membrane is **more permeable to K^+** , so K^+ **diffuses out** through open channels. **B1** Anions stay inside, so the **inside is negative** relative to outside. **B1**

(b) Normal: $35 - (-70) = 105$ mV. Low Na^+ : $15 - (-70) = 85$ mV. **M1**

Percentage decrease = $\frac{105 - 85}{105} \times 100 = 19.0\%$ **A1**

(c) The Na^+ concentration gradient into the axon is **less steep B1**, so when the voltage-gated Na^+ channels open, **fewer Na^+ diffuse in** and the inside becomes less positive. **B1**

(d) $1 \div 0.0025$ **M1** = 400 impulses per second. **A1**

Example 3

A relaxed sarcomere is 2.4 μm long. Its A band is 1.6 μm and its H zone is 0.4 μm .

(a) Calculate the length of one actin filament, measured from its Z line. [2]

(b) The sarcomere contracts to 2.0 μm . State the new lengths of the A band, the total I band and the H zone. [3]

(c) A drug blocks the Ca^{2+} channels in the membrane of the sarcoplasmic reticulum. Explain why the muscle fibre does not contract when its motor neurone is stimulated. [4]

(a) The actin from both Z lines fills everything outside the H zone: $2.4 - 0.4 = 2.0$ μm **M1**, so each actin filament is $2.0 \div 2 = 1.0$ μm . **A1**

(b) A band = 1.6 μm (myosin does not change length). **B1** I band = $2.0 - 1.6 = 0.4$ μm . **B1** H zone = $2.0 - 2 \times 1.0 = 0$ μm : the actin filaments now meet at the M line. **B1**

(c) The sarcolemma and T-tubules still depolarise, but **Ca^{2+} is not released** from the SR into the sarcoplasm. **B1** So **no Ca^{2+} binds to troponin**, which does not change shape **B1**; **tropomyosin still covers** the binding sites on actin **B1**; so **myosin heads cannot bind** to actin, no cross-bridges form and there is no power stroke. **B1**

Common mistakes

- **"Impulses jump from node to node."** Say the **action potential** (or depolarisation) jumps, and name **saltatory conduction**. Don't link speed to "more action potentials".
- **Giving ATP a role in depolarisation or repolarisation.** These are diffusion through voltage-gated channels. ATP runs the Na^+/K^+ pump that keeps the resting potential.
- **"Voltage-gated" receptors on the postsynaptic membrane.** ACh receptors are **ligand-gated**. At a neuromuscular junction, Na^+ enters the **muscle fibre**, not a neurone.
- **Skipping the Ca^{2+} step.** In both a synapse and a taste cell, depolarisation → **Ca^{2+} enters** → vesicles fuse. Leaving it out loses a mark every time.
- **Confusing troponin and tropomyosin.** Ca^{2+} binds **troponin**; **tropomyosin** moves off the binding sites. Say the myosin **head** binds a **binding site** on actin.
- **Saying the A band shortens.** It stays the same; the I band and H zone shorten.
- **Vague words:** "message" or "signal" instead of impulse or action potential; "gibberellin breaks down DELLA" instead of gibberellin leading to DELLA being broken down.
- **Writing that hormones "diffuse through the blood".** They are carried in the blood by **mass flow**.
- **Data quotes with no description.** Say the pattern in words first, then quote paired data with units.

How to get the marks

- **"Describe the sequence"** means every link in order. Mark schemes reward each step (Ca^{2+} in, vesicles fuse, exocytosis, ACh binds, Na^+ in, depolarisation, threshold) separately, so small steps you skip are marks lost.
- **"Explain"** needs the reason: "faster **because** depolarisation occurs only at nodes".
- **"Suggest"** (drugs, diseases, new organisms) means apply the normal chain to the new case. Use "less", "fewer" or "no" at each step.
- **"Compare" or "contrast"** needs paired statements; for graphs, paired values with units.
- **Label lines** on diagrams must touch the right structure: the lightest band for actin only, the middle band of the A band for myosin only.
- **Calculations:** show the working and give units (ms, μm , impulses per second).

Quick check

1. Put these events at a taste bud in the correct order: **A** vesicles fuse with the membrane; **B** Na^+ enters the chemoreceptor cell; **C** Ca^{2+} channels open; **D** transmitter binds to the sensory neurone; **E** the receptor cell depolarises; **F** threshold is reached in the sensory neurone.
2. An axon has a refractory period of 4 ms. (a) Calculate its maximum frequency of impulses. (b) Explain why a stronger stimulus does not produce larger action potentials.
3. A sarcomere shortens from 2.6 μm to 2.2 μm . Its I band was 1.0 μm when relaxed. Calculate (a) the length of its A band, (b) its new I band, (c) the percentage decrease in sarcomere length (1 d.p.).

4. Barley grains are cut in half and the halves without the embryo are placed on starch agar. After two days, starch around the halves has not been broken down. When gibberellin is added to the agar, clear zones appear around the halves. Explain these results.

Answers

1. **B, E, C, A, D, F.** Na^+ in depolarises the cell (receptor potential), which opens Ca^{2+} channels; Ca^{2+} makes vesicles fuse and release transmitter; it binds to the sensory neurone, Na^+ enters it and, at threshold, an action potential starts.
2. (a) $1 \div 0.004 = 250$ impulses per second. (b) Action potentials are all-or-nothing: once threshold is reached, the same number of Na^+ channels open each time. A stronger stimulus instead gives a higher **frequency** of action potentials.
3. (a) $A \text{ band} = 2.6 - 1.0 = 1.6 \mu\text{m}$. (b) The A band stays $1.6 \mu\text{m}$, so I band $= 2.2 - 1.6 = 0.6 \mu\text{m}$. (c) $\frac{2.6 - 2.2}{2.6} \times 100 = 15.4\%$.
4. Without the embryo, no gibberellin is made, so the aleurone layer makes no amylase and starch stays. Added gibberellin reaches the aleurone layer; DELLA proteins are broken down, the amylase gene is transcribed and translated, and amylase is secreted and hydrolyses the starch, giving clear zones.

Past questions to try

- **9700/42/O/N/23 Q7:** mitochondria at synapses and in muscle, an inhibitory transmitter, and loss of myelin.
- **9700/42/M/J/22 Q6:** gibberellin in a barley seed, with arrows on a diagram.
- **9700/43/O/N/24 Q4:** how a Venus fly trap closes, against a plant whose leaves fold by losing turgor.
- **9700/41/M/J/24 Q10:** a chemoreceptor in a new animal, from sucrose to an action potential.