

15.1 Control and coordination in mammals

Name: _____ Class: _____ Date: _____

Total: 35 marks

KEY WORDS neurone • synapse • sensory neurone
• action potential • endocrine

Objective

Build the skills to answer exam questions on **control and coordination in mammals** – the **nervous** and **endocrine** systems, **neurones**, the **action potential**, **saltatory conduction**, and the **synapse**.

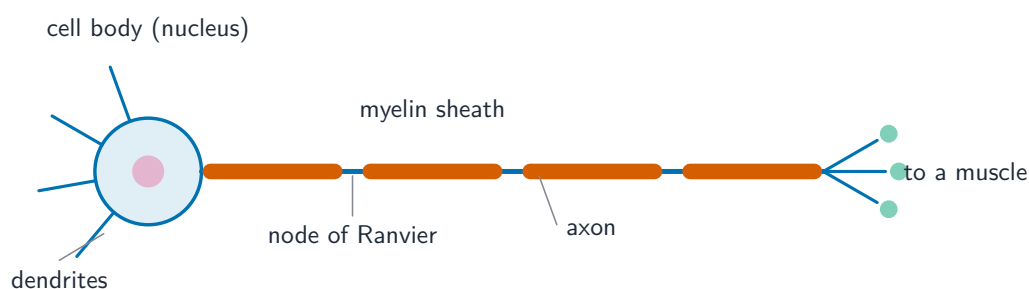
You must be able to:

- compare the nervous and endocrine systems and describe sensory and motor neurones
- describe the events of an action potential and how the resting potential is restored
- explain saltatory conduction and transmission across a cholinergic synapse

1 Key knowledge and worked examples

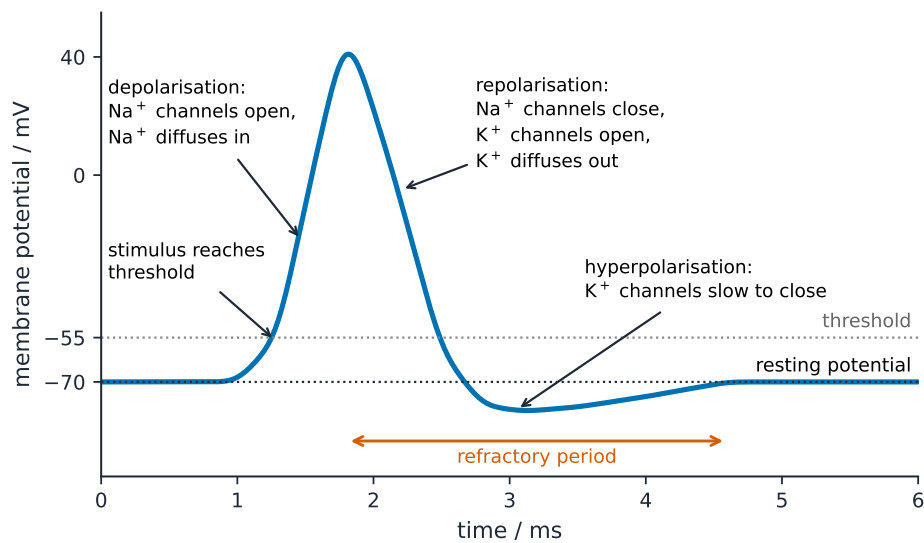
■ Nervous vs endocrine, and neurones

The **nervous system** sends fast, short-lived electrical **impulses** along neurones; the **endocrine system** sends slower, longer-lasting **hormones** in the blood.



A motor neurone carries impulses to an effector; a sensory neurone carries them from a receptor

■ The action potential

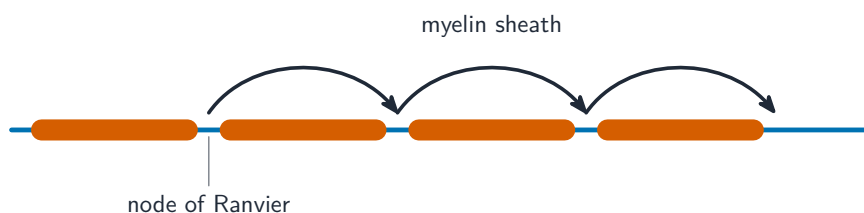


all-or-nothing: once threshold is reached, a full spike fires (no partial APs)

Sodium in → depolarisation; potassium out → repolarisation; then a refractory period

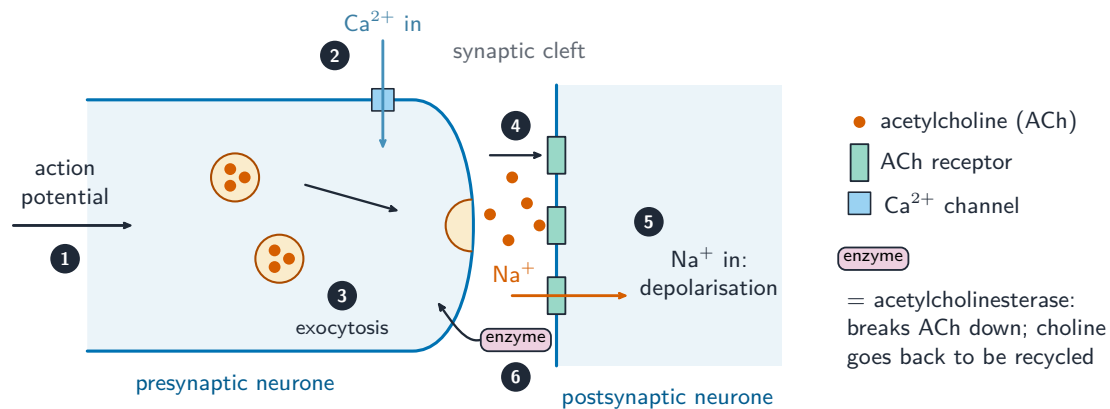
- **resting potential** (-70 mV): a pump moves Na^+ out and K^+ in; the membrane is more permeable to K^+ .
- **depolarisation:** a stimulus opens Na^+ channels; Na^+ rushes in; inside becomes positive.
- **repolarisation:** K^+ channels open; K^+ leaves; the potential returns to negative.
- **refractory period** : Na^+ channels cannot reopen for a moment, limiting impulse frequency.

■ Saltatory conduction and the synapse



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

The impulse jumps between nodes (saltatory conduction), so a myelinated neurone conducts much faster



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

■ The action potential, and why it travels one way

Resting potential, about -70 mV: the **sodium–potassium pump** actively moves 3 Na^+ out for every 2 K^+ in, and the membrane is far more permeable to K^+ than to Na^+ , so the inside is negative relative to the outside.

The action potential, in the order the marks are awarded:

1. A stimulus opens some **voltage-gated Na^+ channels**; Na^+ enters and the membrane **depolarises**.
2. If the **threshold** (about -55 mV) is reached, all the voltage-gated Na^+ channels open – positive feedback – and the potential rises to about $+40$ mV.
3. Na^+ channels close and **voltage-gated K^+ channels open**; K^+ leaves and the membrane **repolarises**.
4. K^+ channels are slow to close, so the potential briefly overshoots: **hyperpolarisation**.
5. The sodium–potassium pump restores the resting potential.

All-or-nothing. Below threshold there is no impulse at all; at or above it the action potential is always the same size. A stronger stimulus is therefore coded by a **higher frequency** of impulses, not a bigger one.

The refractory period is the short time after an action potential during which the Na^+ channels cannot reopen. It does three things the exam asks for: it makes impulses **discrete** and separated, it **limits the frequency** of impulses, and – because the region behind is still refractory – it ensures the impulse travels in **one direction only**.

Myelination. In a myelinated axon the sheath insulates the membrane, so depolarisation can only occur at the **nodes of Ranvier**. The impulse therefore jumps node to node – **saltatory conduction** – which is much faster than the continuous conduction of an unmyelinated axon. A larger axon diameter and a higher temperature also increase conduction speed.

Nervous or endocrine? Nervous: electrical along neurones, very fast, short-lived, and targeted at specific effectors. Endocrine: chemical in the blood, slower to act, longer-lasting, and reaching all cells with the right receptor.

2 Practice

2.1 State **two** differences between the nervous and the endocrine systems. [2]

2.2 Name the ion that (a) rushes in during depolarisation and (b) leaves during repolarisation. [2]

2.3 State the value of the resting potential and explain how the sodium–potassium pump helps establish it. [3]

2.4 Explain what is meant by the all-or-nothing principle, and state how a stronger stimulus is represented. [3]

2.5 Name the gaps in the myelin sheath and state the term for the conduction they allow. [2]

3 Exam-style questions

3.1 During the refractory period, a neurone cannot send another impulse because: [1]

☐

- A** there is no stimulus
- B** the sodium channels cannot reopen for a short time
- C** the myelin sheath blocks it
- D** acetylcholine is not made

3.2 Why does a myelinated neurone conduct impulses faster than an unmyelinated one? [1]

☐

- A** it has a larger cell body
- B** the impulse jumps between nodes of Ranvier
- C** it has more synapses
- D** it uses hormones

3.3 (a) Describe how the resting potential is maintained in a neurone. [2]

(b) Describe how an action potential is produced when the neurone is stimulated. [3]

3.4 An impulse travels along an axon a distance of 0.60 m in 0.012 s. Calculate the speed of conduction, in m s^{-1} . [2]

3.5 The graph of an action potential shows the potential difference across an axon membrane rising from -70 mV to $+40\text{ mV}$ and back.

(a) Explain the events that produce the rise from -70 mV to $+40\text{ mV}$. [3]

(b) Explain the events that return the membrane to its resting potential, including the brief undershoot below -70 mV . [3]

(c) Explain two consequences of the refractory period. [2]

(d) A myelinated axon conducts at 100 m s^{-1} and an unmyelinated axon of the same diameter at 1 m s^{-1} . Explain this difference. [3]

(e) Compare nervous and hormonal coordination, giving three differences. [3]

Solutions

Each answer shows the steps, then the **result**.

2.1

- any two: nervous uses electrical impulses vs hormones; along neurones vs in the blood; fast vs slow; short-lived vs longer-lasting

2.2

(a)

- sodium (Na^+)

(b)

- potassium (K^+)

2.3

- About -70 mV; the pump actively transports 3 Na^+ out for every 2 K^+ in, so more positive ions leave than enter and the inside becomes negative relative to the outside

2.4

- Below the threshold potential no action potential is produced at all; at or above it the action potential is always the same size, however strong the stimulus; a stronger stimulus is represented by a higher frequency of impulses

2.5

- The nodes of Ranvier; saltatory conduction

3.1 B

- The sodium channels are temporarily unable to reopen

3.2 B

- The impulse jumps between nodes of Ranvier (saltatory conduction)

3.3

(a)

- a pump moves sodium ions out and potassium ions in; the membrane is more permeable to potassium, so the inside is negative

(b)

- sodium channels open and Na^+ rushes in, depolarising the membrane to about $+40$ mV; then K^+ channels open and K^+ leaves, repolarising it

3.4

- $\text{speed} = \frac{0.60}{0.012} = 50 \text{ m s}^{-1}$

3.5

(a)

- The stimulus opens voltage-gated sodium channels and Na^+ enters, depolarising the membrane; once the threshold of about -55 mV is reached, all the voltage-gated Na^+ channels open; the rapid influx of Na^+ raises the potential to about $+40 \text{ mV}$

(b)

- The Na^+ channels close and voltage-gated K^+ channels open; K^+ leaves the axon, repolarising the membrane; the K^+ channels are slow to close, so the potential briefly falls below the resting value – hyperpolarisation – before the sodium–potassium pump restores it

(c)

- Any two of: impulses are kept discrete and separate; the maximum frequency of impulses is limited; the impulse can only travel in one direction, because the region behind is still refractory

(d)

- The myelin sheath insulates the axon, so depolarisation can only occur at the nodes of Ranvier; the impulse jumps from node to node, which is saltatory conduction; this is much faster than the continuous depolarisation of the whole membrane in an unmyelinated axon

(e)

- Any three of: nervous is electrical along neurones, hormonal is chemical in the blood; nervous is very fast, hormonal slower; nervous effects are short-lived, hormonal longer-lasting; nervous is targeted at specific effectors, hormonal reaches all cells with the right receptor