A-LEVEL BIOLOGY • EXERCISE SHEET

15.1 Control and coordination in mammals

Name: _____ Class: _____ Date: _____ **Total: 35 marks**

KEY WORDS neurone 神经元 • synapse 突触 • sensory neurone 感觉神经元 • action potential 动作电位 • endocrine 内分泌

Objective

Build the skills to answer exam questions on **control and coordination in mammals** — the **nervous** 神经 and **endocrine** 内分泌 systems, **neurones** 神经元, the **action potential** 动作电位, **saltatory conduction** 跳跃式传导, and the **synapse** 突触.

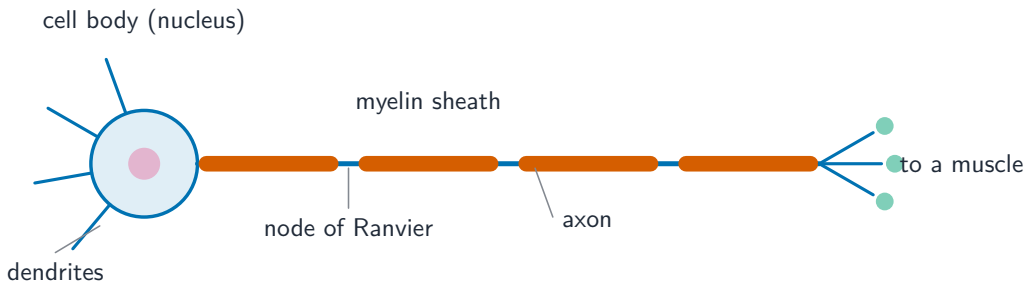
You must be able to:

- 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 Worked examples

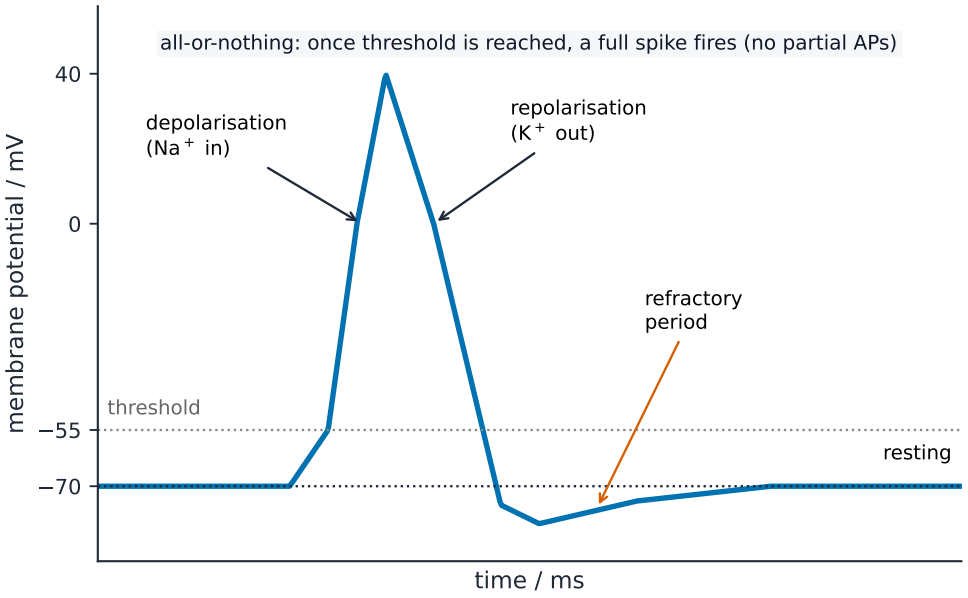
■ Nervous vs endocrine, and neurones

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



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

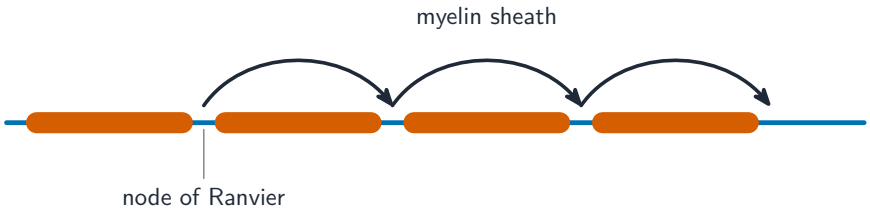
The action potential



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

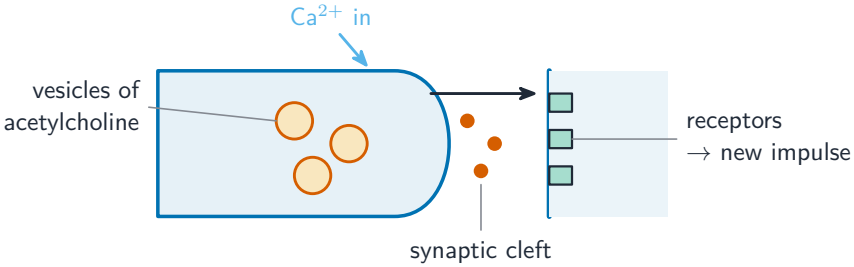
- **resting potential** 静息电位 (−70 mV): a pump moves Na^+ out and K^+ in; the membrane is more permeable to K^+.
- **depolarisation**: a stimulus opens Na^+ channels; Na^+ rushes in; inside becomes positive.
- **repolarisation**: K^+ channels open; K^+ leaves; the potential returns to negative.
- **refractory period** 不应期: 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 静息电位, 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 不应期 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** 跳跃式传导 — 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]

3.3 The graph of an action potential shows the potential difference across an axon membrane rising from −70 mV to +40 mV and back.

(a) Explain the events that produce the rise from −70 mV to +40 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

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^+).

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 speed $= \dfrac{0.60}{0.012} = 50$ m s^{-1}.

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.

3.3 (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 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.