IB BIOLOGY | C2.2 | SL AND HL

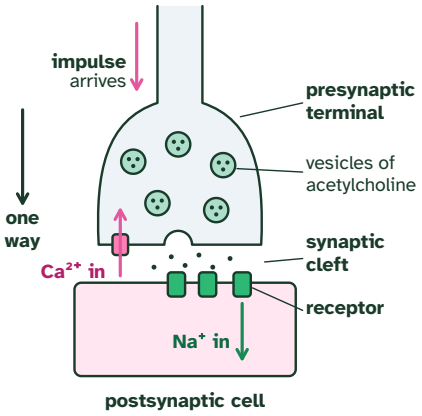
REVISION ON TWO PAGES

How neurons *signal*

What to know, what to draw and what to say. Nothing else.

THE ONE IDEA

Pumps build ion gradients and channels let ions rush down them. An impulse is that rush; a synapse passes it on as a chemical.



Draw it like this. Vesicles above, receptors below, the cleft between; arrows for Ca^{2+} in and Na^{+} in.

C2.2.5 to 7 START HERE

A *synapse* passes it on as a chemical

- A synapse joins a neuron to another neuron or to an **effector cell**, a muscle fibre or gland. A **synaptic cleft** about 20 nm wide keeps them apart.
- Vesicles are in the presynaptic terminal and receptors on the postsynaptic membrane, so the signal crosses **one way only**.
- An impulse depolarises the terminal, **calcium channels open** and Ca^{2+} diffuses in. Inside, calcium is the signal that makes vesicles fuse and release their neurotransmitter.
- Acetylcholine, at every neuromuscular junction and many other synapses, diffuses across and binds **transmembrane receptors**. Na^{+} flows in: an **excitatory postsynaptic potential** (EPSP).

ACROSS A SYNAPSE, IN ORDER — *All Cats Very Rarely Bark*

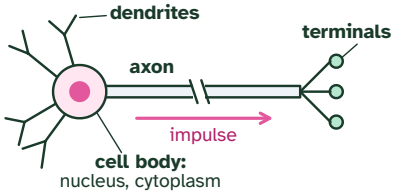
ALL	CATS	VERY	RARELY	BARK
Action potential arrives at the terminal.	**Calcium** channels open, Ca^{2+} in.	**Vesicles** fuse and release.	**Receptors** bind it, Na^{+} in.	**Breakdown** an enzyme clears it.

C2.2.1

One cell, long *fibres*

- The **cell body** holds the nucleus and cytoplasm; nerve fibres of varying length run from it.
- **Dendrites:** many short fibres that receive signals.
- **Axon: one long fibre**, up to a metre, carrying impulses away. Impulses are conducted along the fibres.

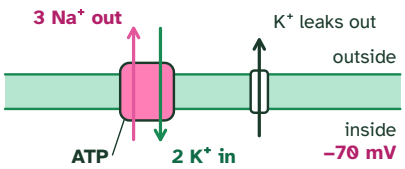
A nerve is a bundle of fibres from many neurons; a neuron is one cell.



C2.2.2

The *resting* potential

- The **sodium-potassium pump** uses ATP to move **3 Na^{+} out and 2 K^{+} in**, both against their gradients.
- Na^{+} is left high outside, K^{+} high inside. The voltage across is a **membrane potential**: the membrane is polarised.
- The inside is **negative, about −70 mV**: K^{+} leaks out more easily than Na^{+} leaks in, and large negative molecules cannot leave.



C2.2.3

An impulse is an *action potential*

- For about a millisecond a stretch of membrane **reverses its voltage**, the inside turning positive, then flips back.
- Each stretch sets off the next, so the impulse is **propagated** along the fibre without fading.
- It is electrical because **positively charged ions** move across the membrane. No electrons flow along it, as in a wire.

1 ms	Na^{+}, K^{+}
one impulse lasts	cross in an impulse

C2.2.4 SKILLS: CORRELATION

Why some impulses are *faster*

FIBRE	WIDTH	SPEED
Small, unmyelinated	about 1 µm	**about 1 m/s**
Squid giant axon unmyelinated	up to 1 mm	**20 to 25 m/s**
Mammal, myelinated	about 10 µm	**50 to 60 m/s**

Myelin wins in a fibre 100 times thinner.

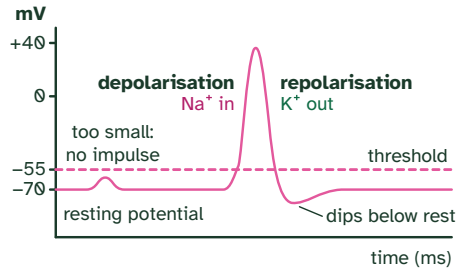
Faster if *Wide* or *Wrapped*

- Speed is **positively correlated** with axon diameter, and **negatively** with animal size.
- **r** runs from −1 to +1: its sign is the direction, its size the strength. Near 0, no straight-line link.
- **R^2** is the share of the variation in speed that goes with diameter: r = 0.9 gives **R^2 = 0.81**, or 81%.
- A correlation **does not show cause**: that needs a mechanism or an experiment.

Inside the *action potential*, and how synapses decide

C2.2.8 and 10 HIGHER LEVEL

One *action potential*, read off a trace



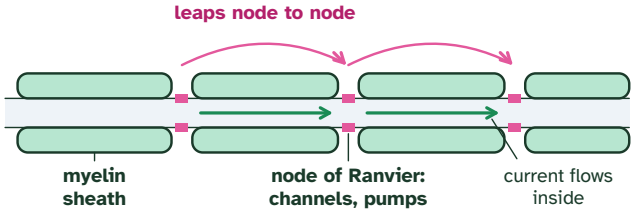
- At the **threshold potential**, about −55 mV, **voltage-gated Na⁺ channels** open. Below it, nothing.
- **Depolarisation:** Na⁺ diffuses in and the inside reaches about +30 to +40 mV.
- **Repolarisation:** Na⁺ channels shut, **voltage-gated K⁺ channels** open and K⁺ diffuses out; they close slowly, so it dips below rest.
- **A trace** is voltage against time at one place. **Impulses per second** = spikes ÷ seconds: 12 in 3 s is 4 a second.

In order: *Tickle Salty Pickles Dance* (threshold, sodium in, potassium out, dip).

C2.2.9 and 11 HIGHER LEVEL

Passing it *along*

- **Local currents:** Na⁺ **diffuses along inside** the axon while positive ions outside move the other way: the next stretch reaches **threshold**.
- **Myelin** insulates; channels and pumps are **clustered at nodes of Ranvier**. The impulse leaps node to node: **saltatory conduction**, faster and using less ATP.



C2.2.12 HIGHER LEVEL

Chemicals from *outside*

- An **exogenous chemical** changes a synapse by fitting one of its proteins.

Neonicotinoids a pesticide
Bind insect acetylcholine receptors and are not broken down, so **synaptic transmission is blocked**.

Cocaine a drug
Binds the carrier that takes dopamine back into the presynaptic neuron: it **blocks reuptake**, so dopamine builds up.

One silences a synapse; the other turns it up.

C2.2.13 and 14 HIGHER LEVEL

Inhibition and summation

- An inhibitory neurotransmitter lets Cl^- in or K^+ out: the membrane is **hyperpolarised** (an IPSP).
- EPSPs and IPSPs from many neurons add up (**summation**), with an **all or nothing** result: a full impulse or none.

C2.2.15 HIGHER LEVEL

Pain at *free* nerve endings

- Free nerve endings in the skin have **channels for positive ions** that open to heat, acid or **capsaicin** in chilli.
- Positive ions enter; at threshold, impulses pass to the **brain**, where pain is perceived.

C2.2.16 HIGHER LEVEL

Consciousness emerges

- Each neuron only adds its inputs and fires or does not.
- Consciousness is an **emergent property**: it arises from neurons **interacting**, not from any one of them.

WATCH OUT

Six mistakes that *cost marks*

- ✕ **The pump does not make the impulse.** Channels do, Na⁺ in then K⁺ out; the pump keeps the gradients.
- ✕ **Ions through channels diffuse.** No ATP is used: never write "Na⁺ is pumped in".
- ✕ **A stronger stimulus gives more impulses, not bigger ones.** Every impulse is the same size.
- ✕ **The impulse does not jump the cleft.** A chemical crosses; calcium only triggers its release.
- ✕ **Acetylcholine is not taken back whole.** It is broken down in the cleft; only the choline returns.
- ✕ **Hyperpolarised means more negative than rest.** It is not a large depolarisation.

COVER THE SHEET

Can you *answer these?*

1. Draw and label a neuron.
2. Explain how the resting potential is generated.
3. State why a nerve impulse is electrical.
4. Compare squid giant and small unmyelinated axons.
5. Explain how acetylcholine causes an EPSP.
6. Describe an action potential on a trace. HL
7. Explain saltatory conduction. HL
8. Distinguish neonicotinoids from cocaine. HL
9. Explain summation of EPSPs and IPSPs. HL
10. Outline how chilli causes pain. HL
11. Explain why consciousness is emergent. HL

IN THE EXAM

Each long answer is a **sequence**: one step per sentence, and **name the ion and its direction** every time (Na^+ in, K^+ out, Ca^{2+} in).

GO FURTHER

Animated figures, a dry lab and a marked Check are in the full guide online.