NAME _____ CLASS _____ DATE _____

IB BIOLOGY · C2.2

Neural signalling

Notes to fill in alongside the guide. Each numbered block matches a chapter of the guide, and of the lesson slides. Write in the gaps, answer the cues, annotate the figures, and sum up each section in your own words.

BY THE END YOU CAN

- [ ] Describe a neuron and say what its cell body, axon and dendrites are for C2.2.1
- [ ] Explain how pumping sodium and potassium ions across the membrane makes the resting potential, and why the inside is negative C2.2.2
- [ ] Explain a nerve impulse as an action potential that moves along a nerve fibre, and why that is electrical C2.2.3
- [ ] Explain how a threshold and voltage-gated sodium and potassium channels depolarize and repolarize the membrane C2.2.8
- [ ] Explain how local currents make an action potential travel along an axon C2.2.9
- [ ] Read resting potentials, action potentials and impulses per second off an oscilloscope trace C2.2.10
- [ ] Compare the speed of impulses in giant squid axons, small unmyelinated fibres and myelinated fibres, and use r and R squared on speed data C2.2.4
- [ ] Explain how saltatory conduction from node to node makes impulses faster C2.2.11
- [ ] Describe a chemical synapse and say why a signal crosses it one way only C2.2.5
- [ ] Explain how an impulse makes calcium enter a presynaptic terminal and neurotransmitter leave it C2.2.6
- [ ] Explain how acetylcholine crossing the cleft generates an excitatory postsynaptic potential C2.2.7
- [ ] Explain how neonicotinoids and cocaine change synaptic transmission C2.2.12
- [ ] Explain how an inhibitory neurotransmitter hyperpolarizes the postsynaptic membrane C2.2.13
- [ ] Explain how excitatory and inhibitory inputs add up to an all-or-nothing response C2.2.14
- [ ] Explain how free nerve endings in the skin start the signal that the brain perceives as pain C2.2.15
- [ ] Explain consciousness as a property that emerges from many interacting neurons C2.2.16

01 One cell, built to signal C2.2.1

CUES

Predict: The motor neuron that moves a toe muscle has its cell body in the lower spinal cord. Where is its axon?

What is meant by neuron?

What is meant by cell body?

What is meant by nerve fibres?

NOTES

1 A _____ is a single cell, with a nucleus and cytoplasm like any other, but drawn out into long thin threads.

2 The part with the nucleus is the _____.

3 From it run _____ of two kinds: many short, branched _____, and one long _____.

4 **Dendrites receive.** Signals from other neurons arrive on the _____ and the cell body.

What is meant by dendrites?

What is meant by axon?

What is meant by impulses?

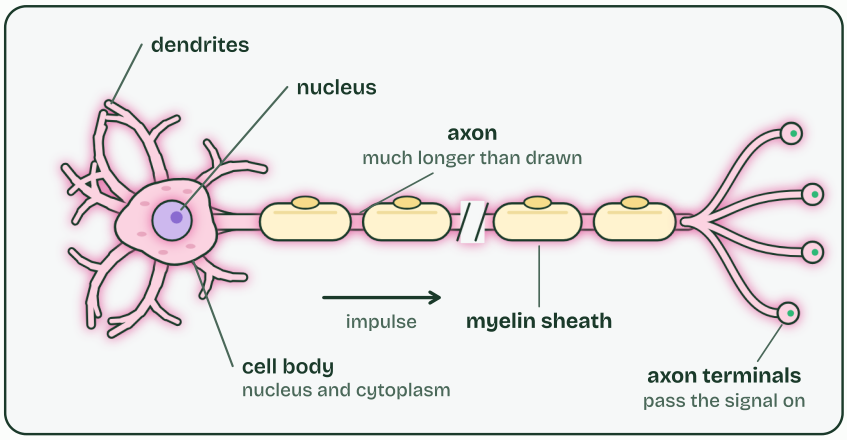
5 **The axon sends.** It carries _____ away from the cell body, as far as a metre, and branches at its end into terminals that pass the signal to the next cell.

6 **The signal is electrical.** _____ are conducted along the fibres as electrical changes in the membrane, which is what the next few chapters are about.

Your own notes

ANNOTATE THE FIGURE

Label each part and say what it does: dendrites, axon, cell body, nucleus, myelin sheath, axon terminals.



SPOT THE MISTAKE

A student writes: "A neuron is a nerve." Spot the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 01 in two or three sentences of your own.

02 A battery before any signal

C2.2.2

CUES

Predict: A neuron's pumps are all switched off and it is left alone. What happens to the voltage across its membrane over a long time?

What is meant by membrane potential?

What is meant by resting potential?

What is meant by polarized?

What is meant by sodium-potassium pump?

What is meant by concentration gradients?

NOTES

1 Across its membrane there is a voltage, the _____, of about −70 mV: the inside is 70 thousandths of a volt more negative than the outside.

2 That is the _____, and a membrane with a voltage across it is _____.

3 The _____ uses the energy of one ATP to push three sodium ions (Na^+) out and bring two potassium ions (K^+) in, both against their _____ (B2.1 has the pump's cycle).

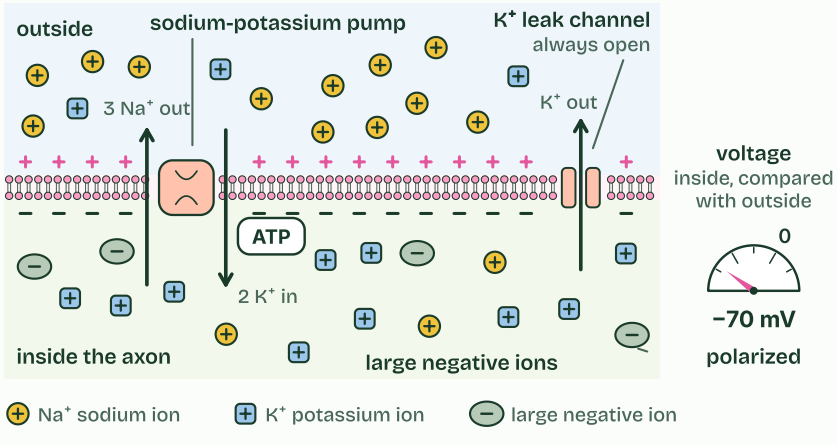
4 _____, about ten times as concentrated as inside.

5 _____, twenty to forty times as concentrated as outside.

Your own notes

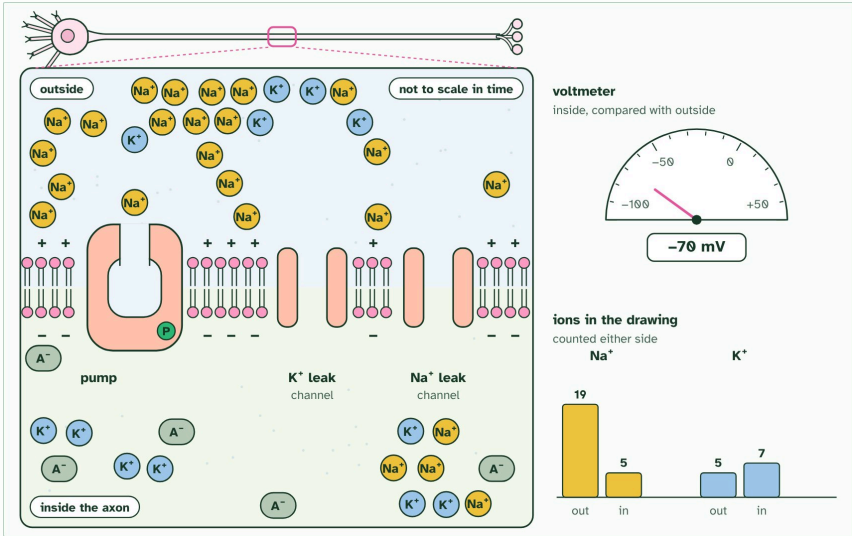
ANNOTATE THE FIGURE

Number the 5 steps on the figure and note what happens at each: 1 sodium, potassium; 2 sodium-potassium pump; 3 leaks; 4 negative ions; 5 polarized.



ANNOTATE THE FIGURE

Annotate this still from the animation (A battery before any signal): what is happening, and why?



SPOT THE MISTAKE

A student writes: "The pump moves ions down their gradients." Spot the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 02 in two or three sentences of your own.

03 A blip that travels

C2.2.3

CUES

Predict: An impulse sets off along an axon a metre long. Compared with where it started, how big is it when it reaches the far end?

What is meant by action potential?

What is meant by propagated?

What is meant by depolarization?

NOTES

1 A nerve impulse is an _____: for about a millisecond, one short stretch of membrane flips its voltage, the inside turning positive, then flips back.

2 While it is reversed, that stretch sets off the same reversal in the stretch next to it, and so the impulse is _____ along the fibre.

3 Turning the inside less negative is called _____.

4 A resting axon, cut along its length: _____ outside the membrane and _____ inside, all the way along.

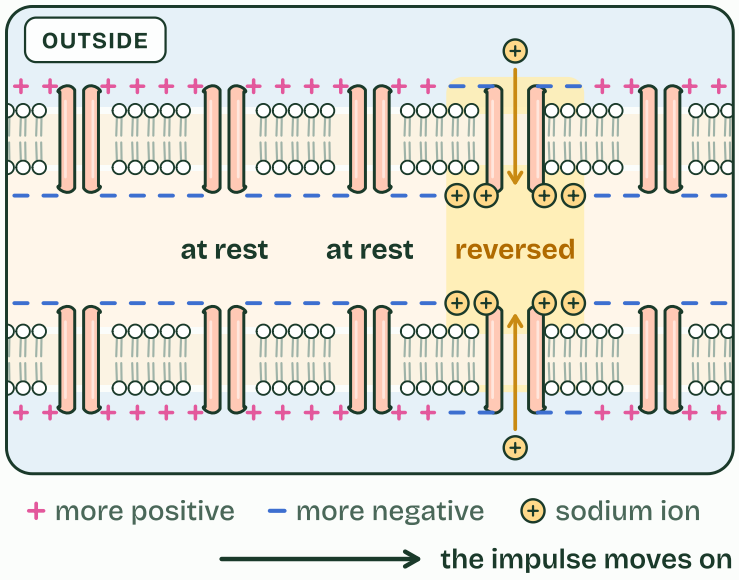
5 A stimulus: sodium ions rush _____ at one stretch, and its charge is _____, positive inside.

6 That stretch sets off the next one, and goes _____ itself. The reversal has moved on.

Your own notes

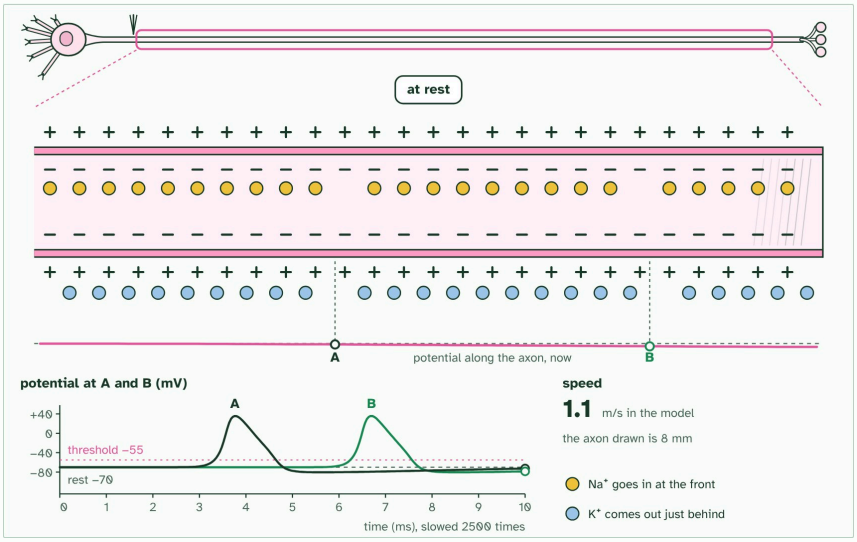
ANNOTATE THE FIGURE

Number the 4 steps on the figure and note what happens at each: 1 positive, negative; 2 in, reversed; 3 back to rest; 4 travels.



ANNOTATE THE FIGURE

Annotate this still from the animation (An impulse travels): what is happening, and why?



SPOT THE MISTAKE

A student writes: “An impulse is electrons flowing along the axon, as in a wire.” Spot the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 03 in two or three sentences of your own.

04 The shape of an action potential

C2.2.8 HL

CUES

Predict: A stimulus just strong enough fires a neuron. A second stimulus, twice as strong, then reaches the same neuron. What does its action potential look like?

What is meant by voltage-gated channels?

What is meant by threshold potential?

NOTES

1 Both are _____: they open when the membrane potential reaches a certain value, and they let only one kind of ion through.

2 **To threshold.** A stimulus makes the inside a little less negative. If it reaches the _____, about −55 mV, the voltage-gated sodium channels open. Below it they stay shut and the membrane falls back to rest.

3 At rest the inside of the axon is about −70 mV against the outside: the _____. The pump has made sodium (Na^+) many times more concentrated outside and potassium (K^+) more concentrated inside; potassium leaks out through its leak channels.

4 A stimulus opens a few voltage-gated _____. Sodium rushes in down its gradient, which opens more: the inside becomes positive, about +39 mV. This is _____.

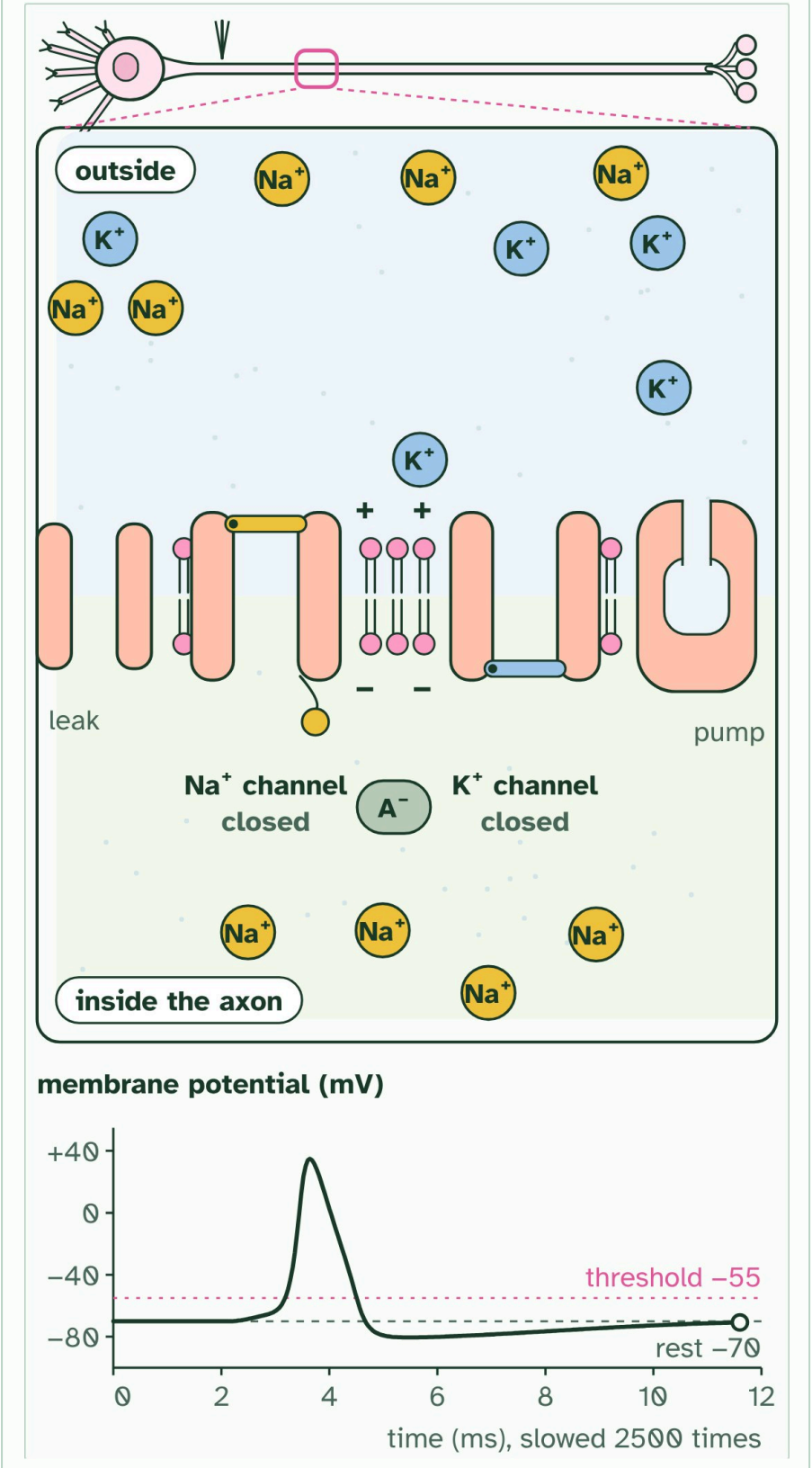
5 The sodium channels close (inactivated) and the slower voltage-gated _____ open. Potassium flows out, and the inside goes negative again: _____, overshooting to about −76 mV.

6 The potassium channels close and the membrane settles back to −70 mV within a few milliseconds. The _____ keeps the gradients, moving three Na^+ out for two K^+ in with each ATP.

Your own notes

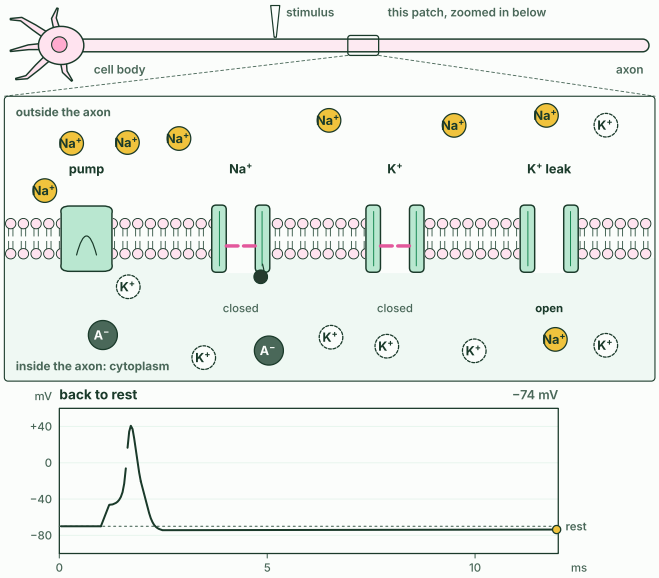
ANNOTATE THE FIGURE

Annotate this still from the animation (One action potential): what is happening, and why?



ANNOTATE THE FIGURE

Number the 4 steps on the figure and note what happens at each: 1 resting potential; 2 sodium channels, depolarization; 3 potassium channels, repolarization; 4 sodium-potassium pump.



REMEMBER IT

The order of one action potential

T Tickle	S Salty	P Pickles	D Dance
T	S	P	D

SPOT THE MISTAKE

A student writes: "Potassium rushes in at the start." Spot the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 04 in two or three sentences of your own.

05 The current that pulls the wave on

C2.2.9 HL

CUES

Predict: An axon is stimulated in its middle, not at one end. Which way does the impulse go?

What is meant by local current?

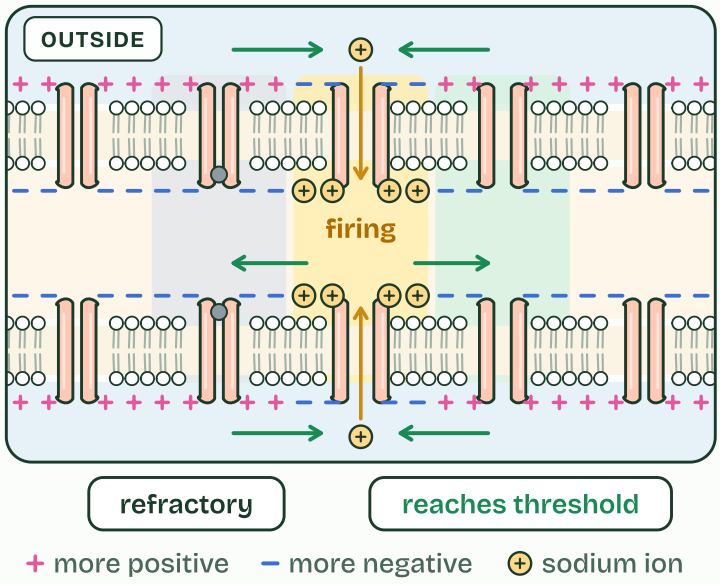
NOTES

1. **That is a local current.** Together these flows of charge make a small loop of current, a _____, which makes the resting membrane next door less negative.
2. One stretch of axon is _____: sodium ions have rushed in, and its inside is positive.
3. The sodium ions _____, both ways, and positive charge outside moves back towards the firing stretch: a _____.
4. The resting stretch ahead is depolarized by it until it _____, about −55 mV. Its sodium channels open, and it fires.
5. The stretch behind has just fired: it is _____, its sodium channels still resetting, so the impulse cannot go back.

Your own notes

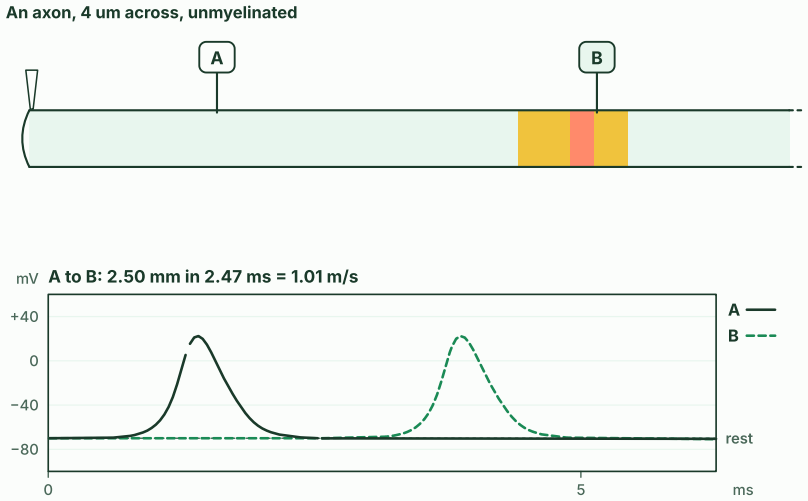
ANNOTATE THE FIGURE

Number the 4 steps on the figure and note what happens at each: 1 firing; 2 diffuse along the inside, local current; 3 reaches threshold; 4 refractory.



ANNOTATE THE FIGURE

Number the 3 steps on the figure and note what happens at each: 1 A; 2 local currents; 3 B.



SPOT THE MISTAKE

A student writes: “The impulse moves because sodium ions flow along the whole axon.” Spot the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 05 in two or three sentences of your own.

06 Reading the oscilloscope

C2.2.10 HL

CUES

Predict: A trace shows 12 identical spikes in 3 seconds. What was the rate of impulses, and what would a stronger, steady stimulus have changed?

What is meant by oscilloscope?

NOTES

1 An _____ then draws the membrane potential against time, as a line across its screen: a *trace*.

2 The _____ along the bottom gives how long one impulse lasts, and how far apart the spikes are; count the spikes in a stretch of trace and divide by its time for the _____.

3 The _____ up the side gives the resting potential, the peak and the depth of the dip.

4 One electrode inside the axon, one outside: the screen draws the membrane potential against time. Before anything happens it sits at the _____, here −68 mV.

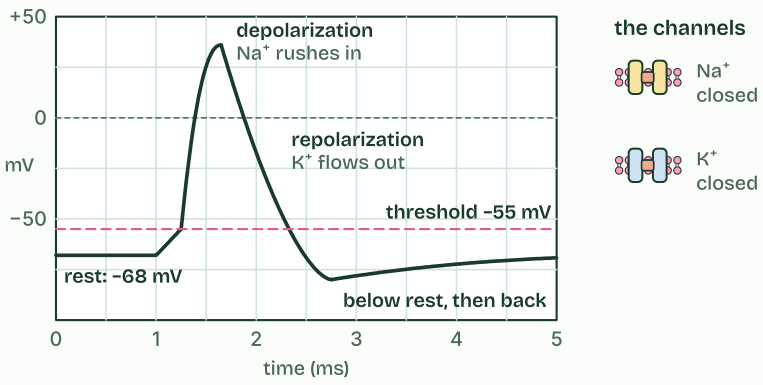
5 A stimulus takes it to threshold and the sodium channels open: Na^+ rushes in and the trace shoots up, past zero: _____.

6 At the peak the sodium channels shut and the potassium channels open: K^+ flows out and the trace falls: _____.

Your own notes

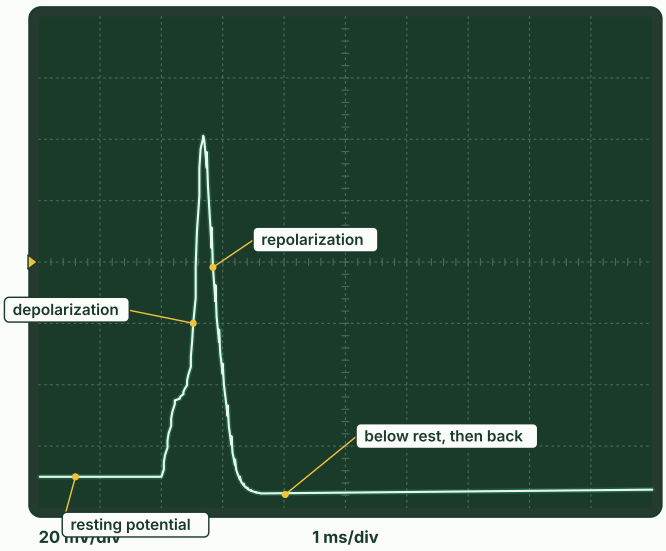
ANNOTATE THE FIGURE

Number the 5 steps on the figure and note what happens at each: 1 resting potential; 2 depolarization; 3 repolarization; 4 dips below rest; 5 threshold.



ANNOTATE THE FIGURE

Number the 3 steps on the figure and note what happens at each.



SPOT THE MISTAKE

A student writes: "The horizontal axis is distance along the axon." Spot the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 06 in two or three sentences of your own.

07 Why some impulses are quicker

C2.2.4

CUES

Predict: Two axons are the same diameter. One has a myelin sheath and the other has none. Which carries impulses faster?

What is meant by myelin sheath?

What is meant by giant axon?

What is meant by correlation coefficient?

What is meant by coefficient of determination?

NOTES

1 Many vertebrate axons are wrapped in a fatty _____, broken by short bare gaps; others are bare.

2 The _____, r, says how strong it is: +1 is a perfect straight line rising, 0 no straight-line link at all, −1 a perfect line falling.

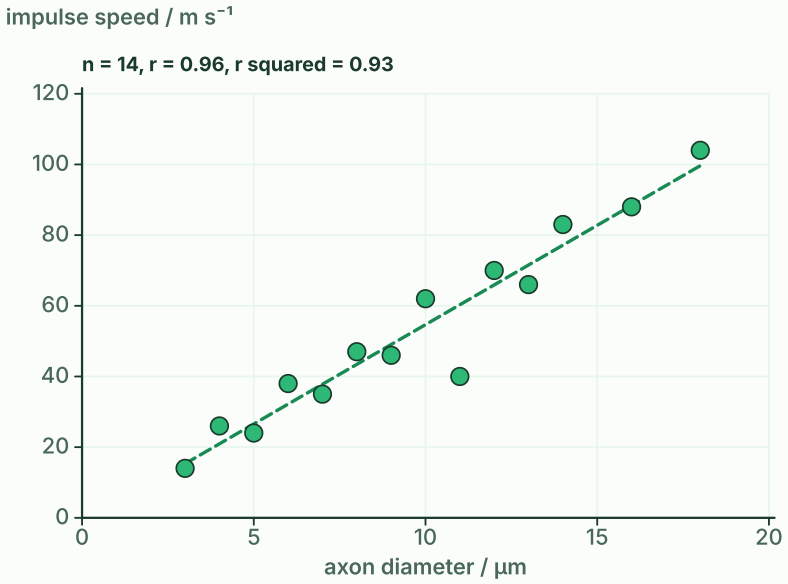
3 Square it for the _____, R^2: the share of the spread in speed that goes with diameter.

4 **A wider axon.** The wider the axon, the faster the impulse. A wide axon has more room inside for the local current to flow, so the current spreads further along it and brings the next stretch to threshold sooner. The squid's _____, up to about a millimetre across, carries an impulse at roughly 20 to 25 metres a second. That is twenty to forty times as fast as a small unmyelinated fibre a micrometre or so across, and it fires the squid's escape jet.

Your own notes

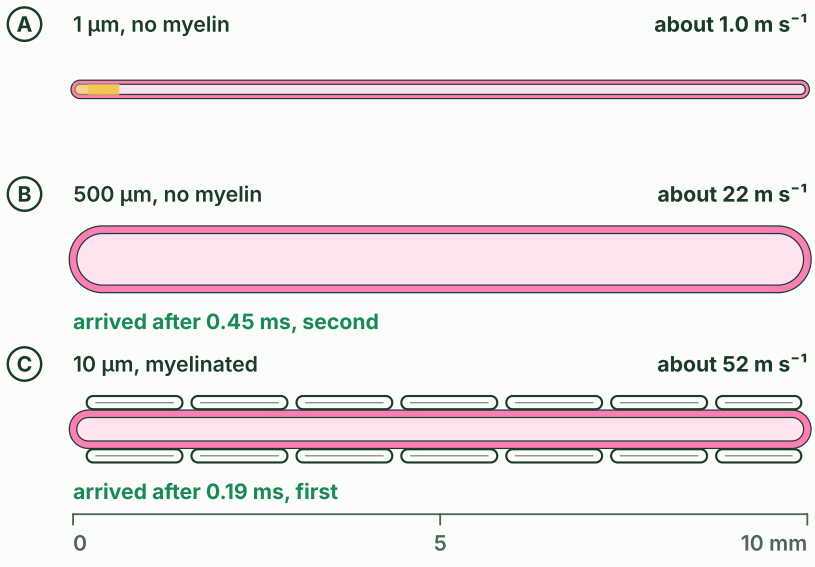
ANNOTATE THE FIGURE

Number the 2 steps on the figure and note what happens at each: 1 Invented data; 2 correlation coefficient.



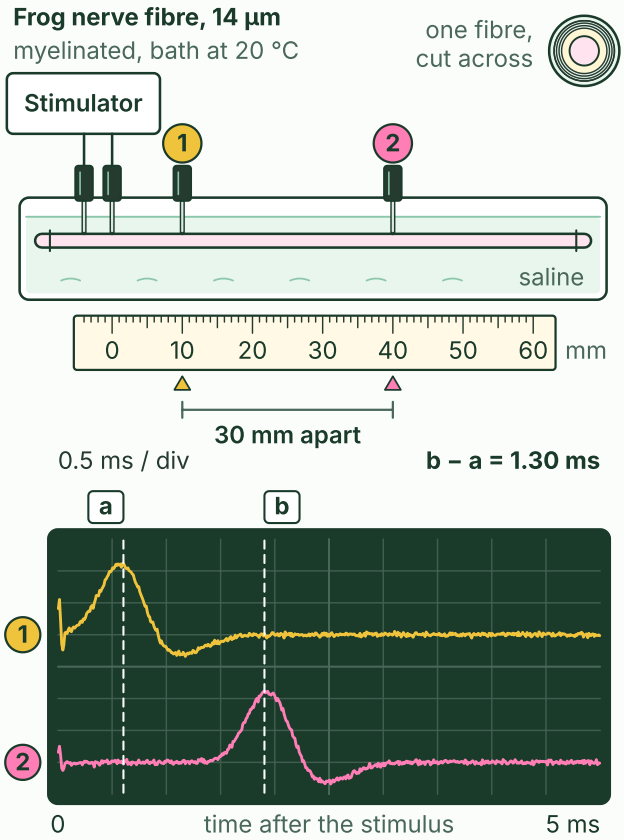
ANNOTATE THE FIGURE

Number the 2 steps on the figure and note what happens at each.



ANNOTATE THE FIGURE

Number the 3 steps on the figure and note what happens at each.



Frog nerve fibre, 14 µm, 30 mm apart

Repeat	b – a / ms	Speed / m s^{-1}
1	----------	----------
2	----------	----------
3	----------	----------

REMEMBER IT

The two things that make an impulse faster

W Wide	**W** Wrapped
W	W

SPOT THE MISTAKE

A student writes: “A faster impulse is a bigger one.” Spot the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 07 in two or three sentences of your own.

08 Jumping from node to node

C2.2.11 HL

CUES

Predict: In a myelinated axon the nodes are about a millimetre apart. Imagine an axon whose nodes were ten centimetres apart instead. What would happen to an impulse?

What is meant by node of Ranvier?

What is meant by saltatory conduction?

NOTES

1 Between one wrapping cell and the next is a short bare gap, a _____, about a micrometre long and every millimetre or so along the axon.

2 **The next node fires.** It reaches threshold and fires in turn. The impulse leaps from node to node: _____, from the Latin for to leap.

3 A myelinated axon: the _____ wraps the membrane, broken every millimetre or so by a bare _____.

4 An action potential at one _____: sodium ions rush in there, where the membrane is bare.

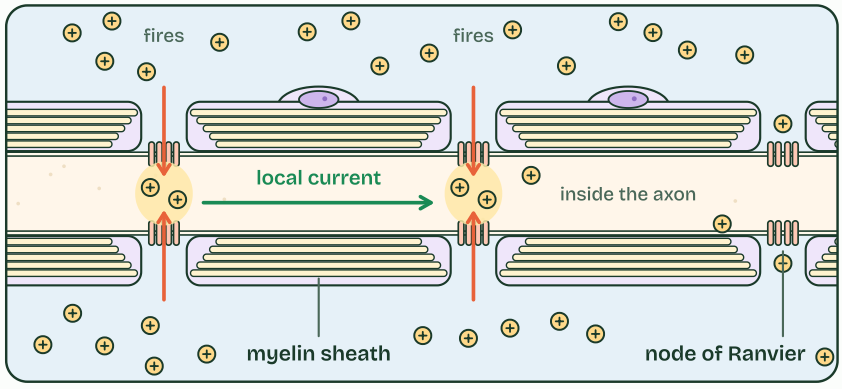
5 The _____ flows along the inside of the axon, under the sheath, without leaking out, as far as the next node.

6 The next node reaches threshold and _____. The impulse leaps from node to node: saltatory conduction.

Your own notes

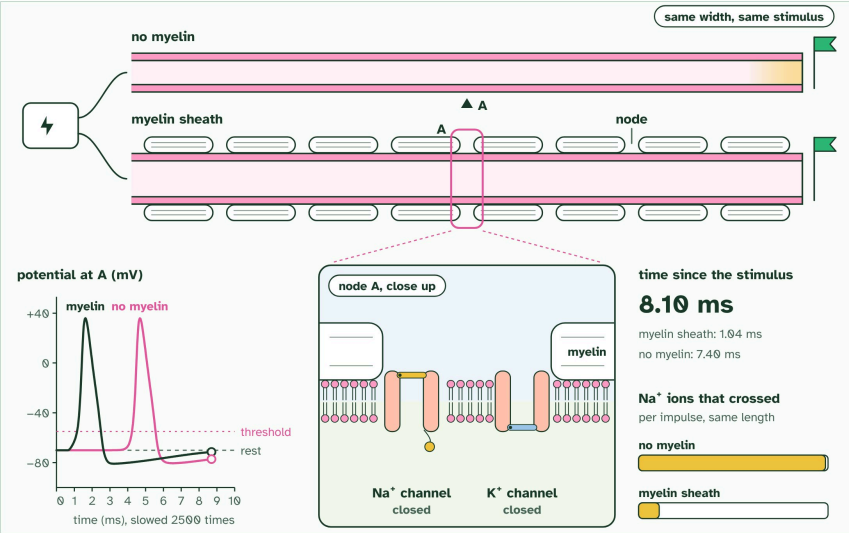
ANNOTATE THE FIGURE

Number the 4 steps on the figure and note what happens at each: 1 myelin sheath, node of Ranvier; 2 node; 3 local current; 4 fires.



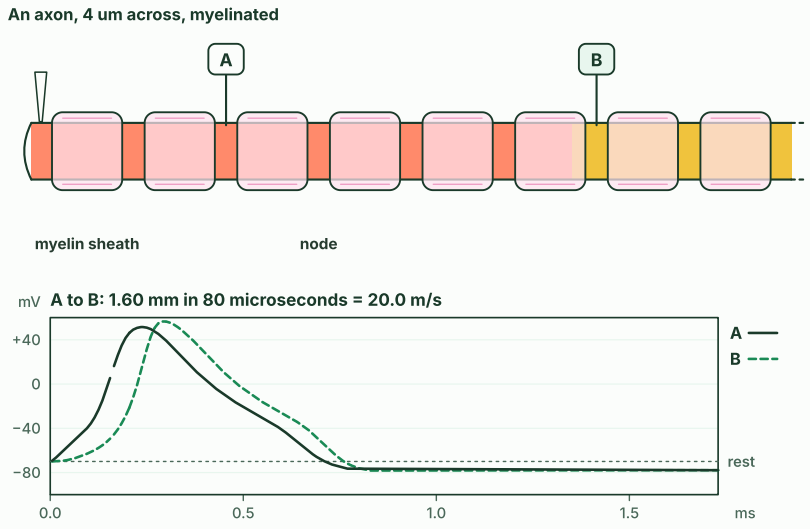
ANNOTATE THE FIGURE

Annotate this still from the animation (Node to node): what is happening, and why?



ANNOTATE THE FIGURE

Number the 3 steps on the figure and note what happens at each: 1 A; 2 node, saltatory conduction; 3 B.



SPOT THE MISTAKE

A student writes: “The impulse jumps through the air between nodes.” Spot the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 08 in two or three sentences of your own.

09 A gap that works one way

C2.2.5

CUES

Predict: A neurotransmitter carries a signal across a synapse. Why can the postsynaptic cell not send a signal back the same way?

What is meant by synapse?

What is meant by effector?

What is meant by synaptic cleft?

What is meant by presynaptic?

What is meant by postsynaptic?

What is meant by neurotransmitter?

NOTES

1 To go on, the signal has to cross to the next cell, at a _____.

2 There are synapses between one neuron and another, and between a neuron and an _____ cell: a muscle fibre that contracts, or a gland cell that secretes.

3 A gap about 20 nanometres wide, the _____, separates the end of the axon, the _____ terminal, from the _____ cell.

4 The signal crosses as a chemical, a _____, stored in tiny sacs, the vesicles, in the terminal.

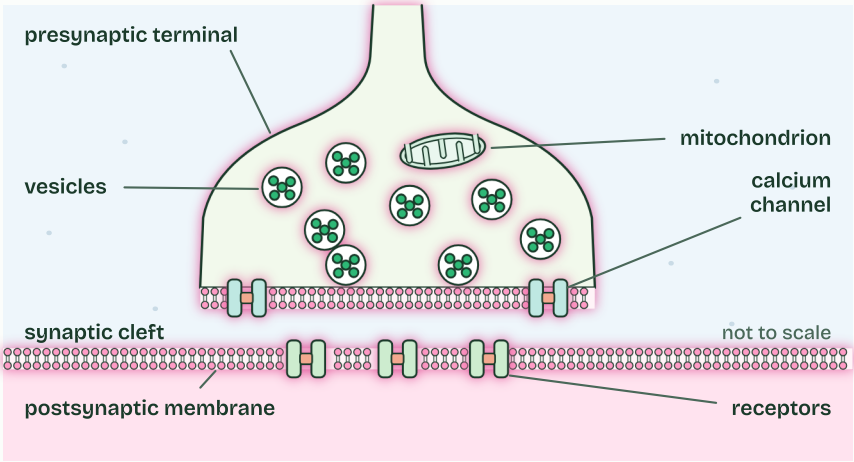
5 **Presynaptic terminal.** Vesicles full of _____, and mitochondria to make the ATP they need.

6 **Postsynaptic membrane.** Receptor proteins that bind the _____.

Your own notes

ANNOTATE THE FIGURE

Label each part and say what it does: presynaptic terminal, vesicles, mitochondrion, calcium channels, synaptic cleft, postsynaptic membrane, receptors.



SPOT THE MISTAKE

A student writes: “The impulse jumps the gap.” Spot the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 09 in two or three sentences of your own.

10 Calcium opens the stores

C2.2.6

CUES

Predict: A toxin blocks the calcium channels in a presynaptic terminal. An impulse arrives. What happens at the synapse?

What is meant by exocytosis?

NOTES

1 **Vesicles fuse.** Inside the terminal calcium acts as a signal: it makes the vesicles fuse with the presynaptic membrane, and their neurotransmitter spills into the cleft by _____.

2 The terminal at rest: vesicles full of neurotransmitter, two of them _____ at the membrane, and calcium ions in the fluid outside.

3 An _____ down the axon and depolarizes the membrane of the terminal.

4 The depolarization opens voltage-gated _____. Ca^{2+}, far more concentrated outside, diffuses in.

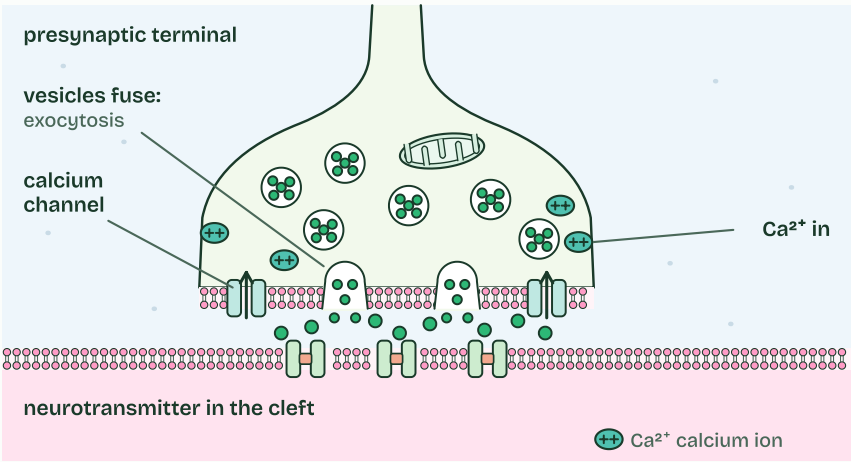
5 Calcium inside makes the docked vesicles _____ with the membrane and open into the cleft: _____.

6 The _____ spills into the cleft, ready to cross to the next cell.

Your own notes

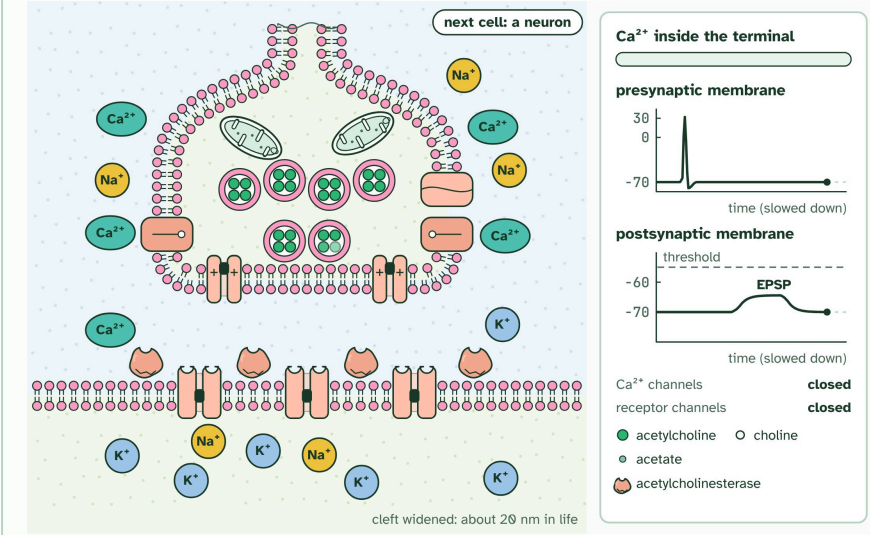
ANNOTATE THE FIGURE

Number the 5 steps on the figure and note what happens at each: 1 docked; 2 impulse arrives; 3 calcium channels; 4 fuse, exocytosis; 5 neurotransmitter.



ANNOTATE THE FIGURE

Annotate this still from the animation (Across the synapse): what is happening, and why?



REMEMBER IT

Across a synapse, in order (this chapter and the next)

A All	C Cats	V Very	R Rarely	B Bark
A	C	V	R	B

SPOT THE MISTAKE

A student writes: "The neurotransmitter is made when the impulse arrives." Spot the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 10 in two or three sentences of your own.

11 Acetylcholine across the cleft

C2.2.7

CUES

Predict: The enzyme that breaks down acetylcholine in the cleft stops working. What happens to the postsynaptic membrane after one impulse?

What is meant by acetylcholine?

What is meant by transmembrane receptors?

What is meant by excitatory postsynaptic potential?

What is meant by acetylcholinesterase?

NOTES

1 Many synapses use the same neurotransmitter, _____.

2 In the cleft is the enzyme _____, which breaks acetylcholine into choline and acetate within milliseconds.

3 **It diffuses across.** Released into the cleft, _____ diffuses across the 20 nm in a fraction of a millisecond.

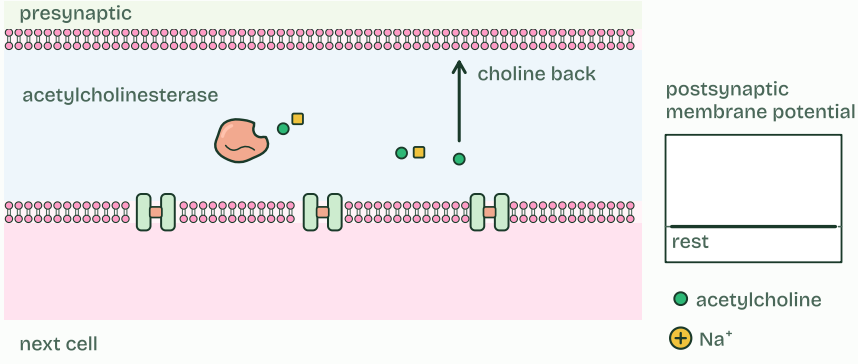
4 **It binds a receptor.** On the postsynaptic membrane are _____ that fit it. At this synapse the receptor is itself an ion channel, opened when acetylcholine binds to it (C2.1 has this receptor among its examples).

5 **An EPSP.** That small depolarization is an _____, EPSP. If it is big enough, an action potential starts in the next cell.

Your own notes

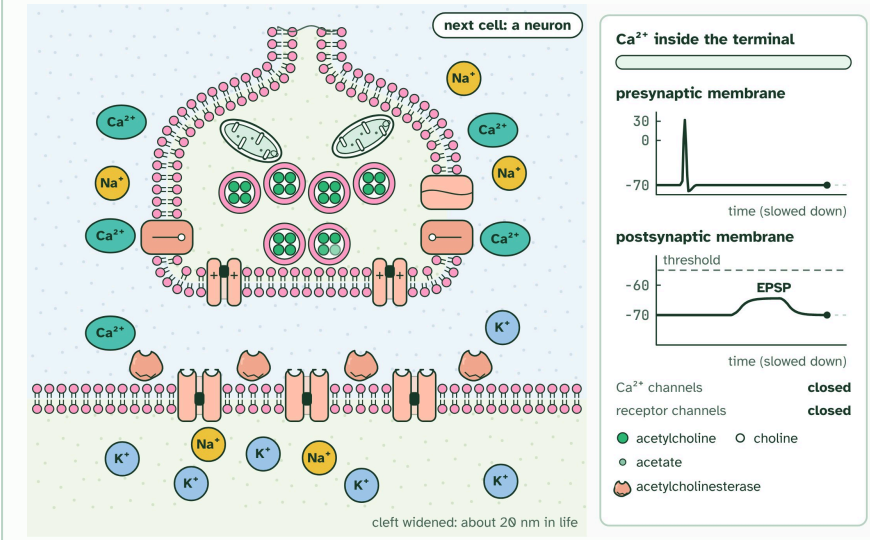
ANNOTATE THE FIGURE

Number the 4 steps on the figure and note what happens at each: 1 Acetylcholine; 2 bind; 3 opens, EPSP; 4 Acetylcholinesterase.



ANNOTATE THE FIGURE

Annotate this still from the animation (Clearing the synapse): what is happening, and why?



SPOT THE MISTAKE

A student writes: "Acetylcholine goes back into the presynaptic neuron whole." Spot the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 11 in two or three sentences of your own.

12 When a chemical gets in the way

C2.2.12 HL

CUES

Predict: A drug blocks the carrier protein that takes a neurotransmitter back into the presynaptic neuron. What happens to the neurotransmitter?

What is meant by exogenous?

What is meant by reuptake?

NOTES

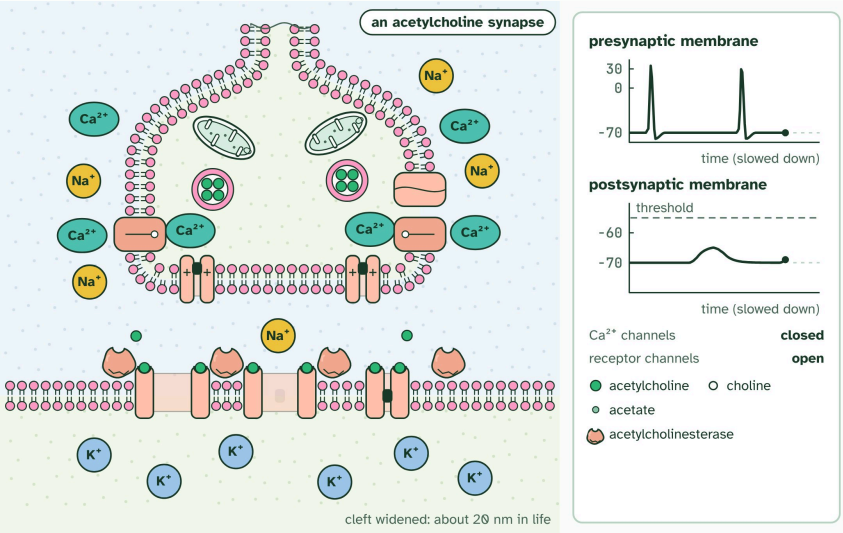
1 So a chemical from outside the body, an _____ chemical, can change what a synapse does by fitting one of those proteins.

2 **Cocaine blocks reuptake.** At some synapses in the brain the neurotransmitter is dopamine. Dopamine is cleared mainly by reuptake rather than broken down in the cleft: carrier proteins in the presynaptic membrane take it back in whole, which is _____. Cocaine binds the carrier and blocks it. Dopamine builds up in the cleft and keeps stimulating the postsynaptic neurons.

Your own notes

ANNOTATE THE FIGURE

Annotate this still from the animation (Chemicals at the synapse): what is happening, and why?



SPOT THE MISTAKE

A student writes: “Cocaine stops dopamine being made.” Spot the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 12 in two or three sentences of your own.

13 Telling a neuron not to fire

C2.2.13 HL

CUES

Predict: Acetylcholine makes a skeletal muscle fibre contract, yet the same chemical, released by a nerve onto the heart, slows it down. How can one neurotransmitter do both?

What is meant by hyperpolarized?

What is meant by inhibitory postsynaptic potential?

NOTES

1 At an inhibitory synapse the neurotransmitter makes the postsynaptic membrane more negative than at rest, further from threshold: the membrane is _____.

2 That small change is an _____, IPSP.

3 Two synapses on the same kind of cell, each named by what its receptor's channel lets through: an _____ one (acetylcholine here) and an _____ one (GABA here). Both membranes sit at rest.

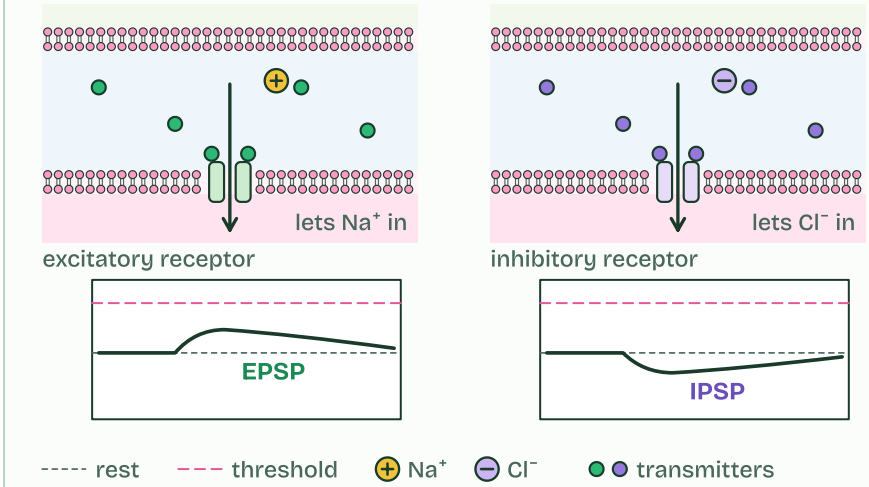
4 Acetylcholine binds: its channel lets _____ _____ _____, and the membrane moves towards threshold: an _____.

5 GABA binds: its channel lets _____ _____ _____, and the membrane moves the other way, below rest: an _____. It is _____.

Your own notes

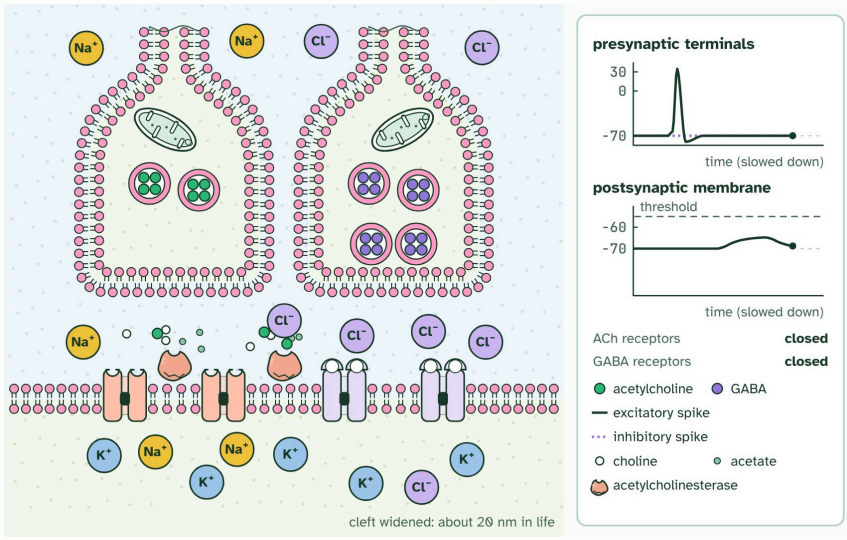
ANNOTATE THE FIGURE

Number the 3 steps on the figure and note what happens at each: 1 excitatory, inhibitory; 2 Na+ in, EPSP; 3 Cl– in, IPSP, hyperpolarized.



ANNOTATE THE FIGURE

Annotate this still from the animation (An inhibitory synapse): what is happening, and why?



SPOT THE MISTAKE

A student writes: “Inhibition stops the neurotransmitter being released.” Spot the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 13 in two or three sentences of your own.

14 Adding up the votes

C2.2.14 HL

CUES

Predict: A neuron at −70 mV fires at −55 mV, so it needs +15 mV. Three excitatory inputs give +6 mV each and one inhibitory input gives −4 mV. All four arrive together. Does it fire?

What is meant by summation?

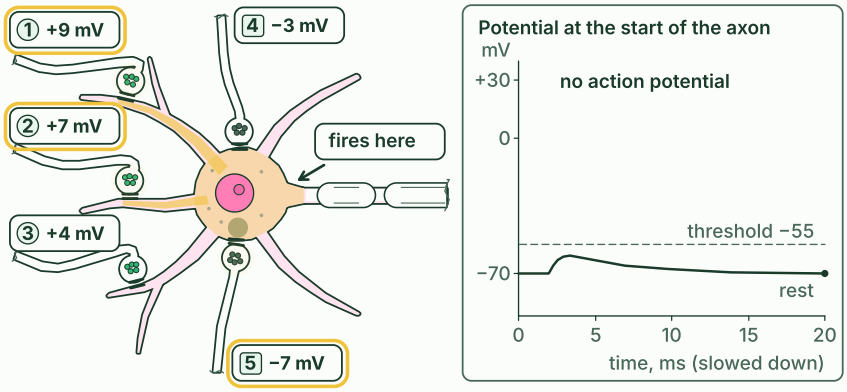
NOTES

1 Each one moves the membrane a little: an EPSP up, an IPSP down. They spread to where the axon leaves the cell body, and there they add together: _____.

Your own notes

ANNOTATE THE FIGURE

Number the 3 steps on the figure and note what happens at each.



SPOT THE MISTAKE

A student writes: "The biggest input decides." Spot the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 14 in two or three sentences of your own.

15 A burning hand

C2.2.15 HL

CUES

Predict: Chilli on a person's tongue feels hot, though nothing in their mouth is any warmer. Why?

What is meant by free nerve ending?

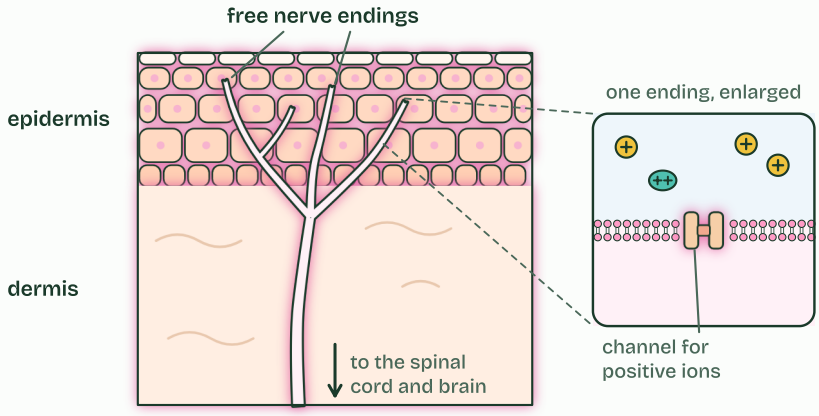
NOTES

1 A _____ is just that: the neuron's fibre branching among the cells of the skin, with no special structure round it.

Your own notes

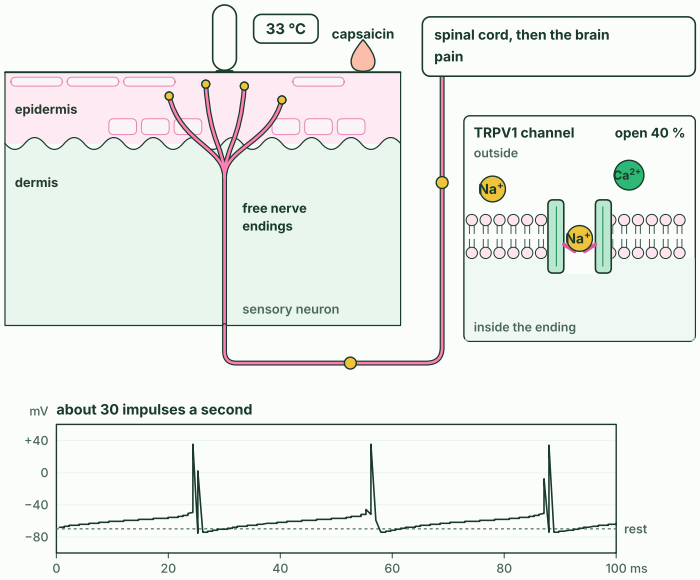
ANNOTATE THE FIGURE

Label each part and say what it does: epidermis, dermis, free nerve endings, a channel for positive ions.



ANNOTATE THE FIGURE

Number the 3 steps on the figure and note what happens at each: 1 free nerve ending; 2 threshold, pain; 3 capsaicin.



SPOT THE MISTAKE

A student writes: "Pain is felt in the hand." Spot the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 15 in two or three sentences of your own.

16 More than the sum of its cells

C2.2.16 HL

CUES

Predict: Could you find the one neuron in a person's brain that holds their consciousness?

What is meant by consciousness?

What is meant by emergent property?

NOTES

1 That awareness, _____, is not in any single neuron.

2 It is an _____: something the system has that none of its parts has, which arises from how the parts interact.

3 _____ does something simple: it adds its inputs and fires, or it does not (chapter 14).

4 Neurons linked by synapses make a _____. A network can do what no single neuron can, such as pick out a pattern in its inputs.

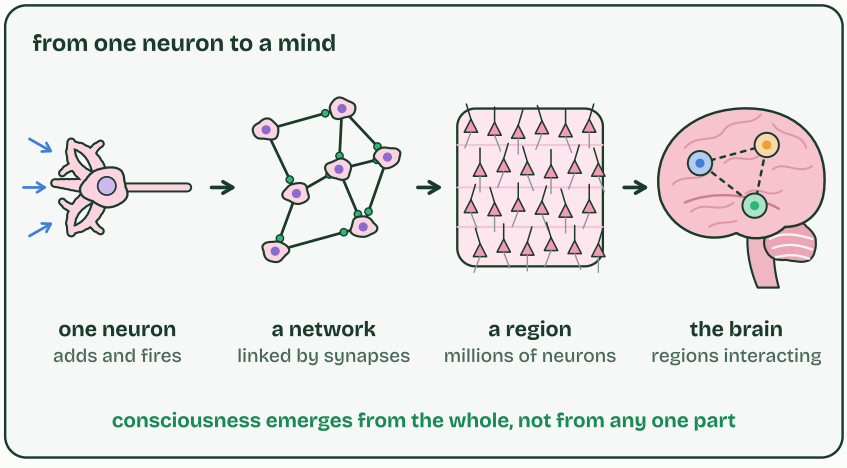
5 Millions of neurons and their networks make a _____ of the brain, which handles one kind of task, such as vision or movement.

6 Regions _____ make a brain that is aware of itself and its surroundings. Consciousness emerges from the interactions; it is in no one part.

Your own notes

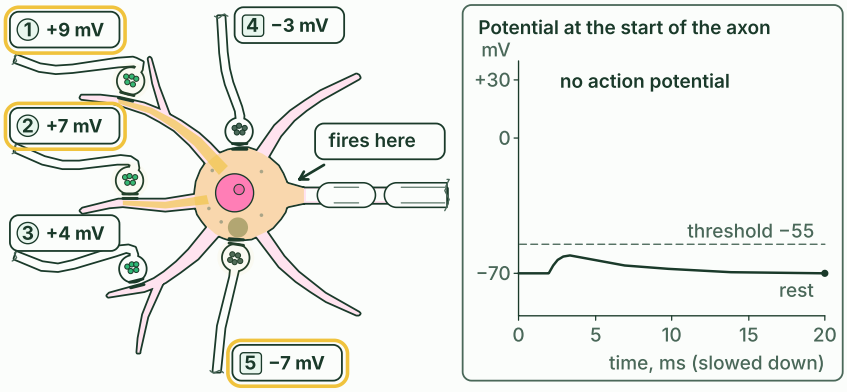
ANNOTATE THE FIGURE

Number the 4 steps on the figure and note what happens at each: 1 One neuron; 2 network; 3 region; 4 interacting.



ANNOTATE THE FIGURE

Number the 3 steps on the figure and note what happens at each.



SPOT THE MISTAKE

A student writes: "Consciousness is in one place in the brain." Spot the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 16 in two or three sentences of your own.

17 Three big ideas, point by point

CUES

NOTES

Your own notes

SUMMARY

Sum up section 17 in two or three sentences of your own.

Check yourself

The check for this guide is online: a fresh paper of past-paper style questions from the exam bank on C2.2 each time, marked as you go, and saved to your Exam practice progress when you are signed in. Scan the code, or type the link.

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How this was made. The course structure, the activities and the teaching choices come from my own classroom, my presentations and my years of teaching IB and AP Biology. I use Claude, an AI, to help write and build the interactive guides, lesson plans, slides and practice questions, and to draw the diagrams and code the interactives. I direct the work and review it against the IB and AP specifications before it goes live.