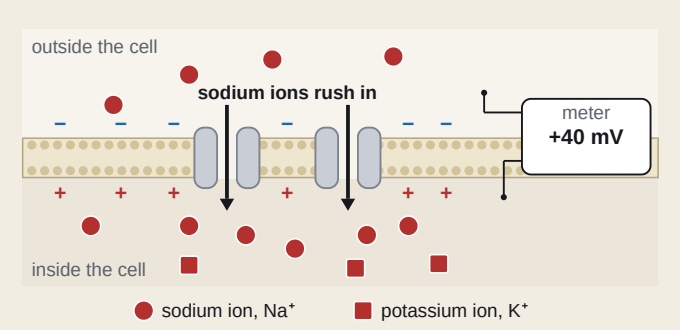
A3 · The action potential, threshold and all-or-none · Completed notes

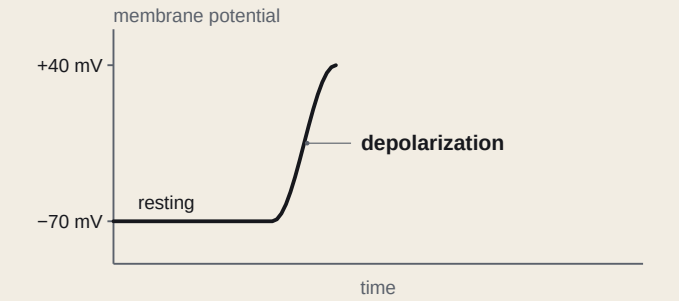
Goals: Describe depolarization and repolarization, and name the ion that moves in each. Say what the refractory period is and what the sodium-potassium pump does after an action potential. Read a graph of an action potential. Explain how an action potential moves along an axon in one direction. Explain the threshold level and the all-or-none response. Explain how the body tells a weak stimulus from a strong one.

These are the completed notes. The blanks are filled in and each question is worked.

Slide 1 of 7 · Depolarization: sodium ions rush in

In lesson A2, a resting neuron had a resting potential of −70 mV. Sodium ions were mostly outside. Today a stimulus arrives.





Key ideas

A stimulus opens **sodium channels**. Sodium ions rush in.

The inside becomes **positive**. This reversal of charge is **depolarization**.

The membrane potential rises from −70 mV to **+40 mV**.

A nerve impulse is an **action potential**.

Example

State what moves during depolarization, and which way.

1. Sodium channels open.
2. Sodium ions rush into the cell.

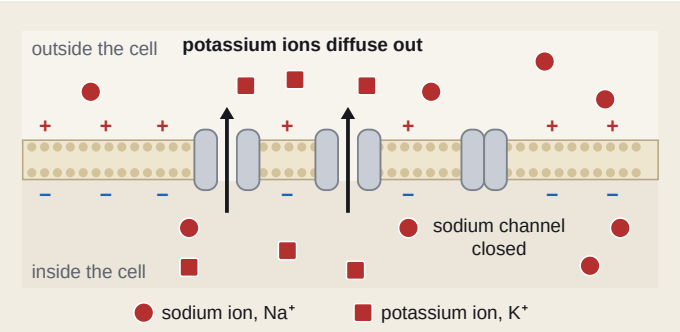
Try it

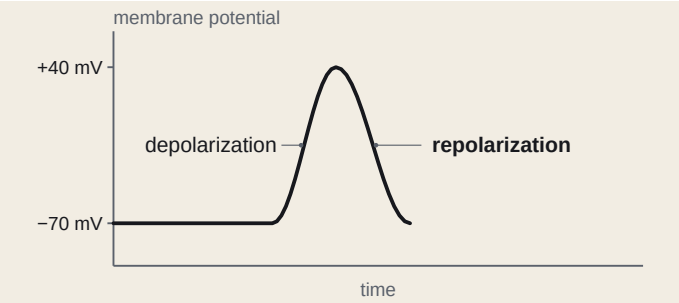
State the membrane potential at the peak of an action potential. Say what the plus sign means.

1. It is +40 mV.
2. The plus sign means the inside is now positive compared with the outside.

Slide 2 of 7 · Repolarization: potassium ions diffuse out

On the last slide, sodium ions rushed in. The membrane potential rose to +40 mV. The neuron cannot stay like that.





Key ideas

After the peak, the sodium channels **close**.

Then **potassium channels** open. Potassium ions diffuse out.

The inside becomes negative again. This is **repolarization**.

Example

State what moves during repolarization, and which way.

1. Potassium channels open.
2. Potassium ions diffuse out of the cell.

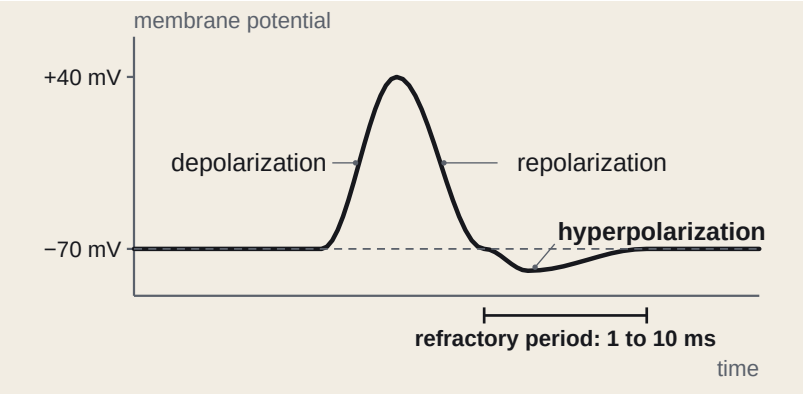
Try it

On a graph of an action potential, the line is falling. Name this part and the ion that is moving.

1. The fall is repolarization.
2. Potassium ions are diffusing out.

Slide 3 of 7 · The refractory period

On the last slide, potassium ions diffused out and the inside became negative again. The neuron is still not quite back to rest.



Key ideas

For a moment the inside is more negative than the resting potential: **hyperpolarization**.

The time to return to rest is the **refractory period**. It lasts 1 to **10** ms.

The **sodium-potassium pump** puts the ions back.

Example

State what a membrane cannot do during its refractory period.

1. It has not yet returned to the resting potential.
2. It cannot start another action potential.

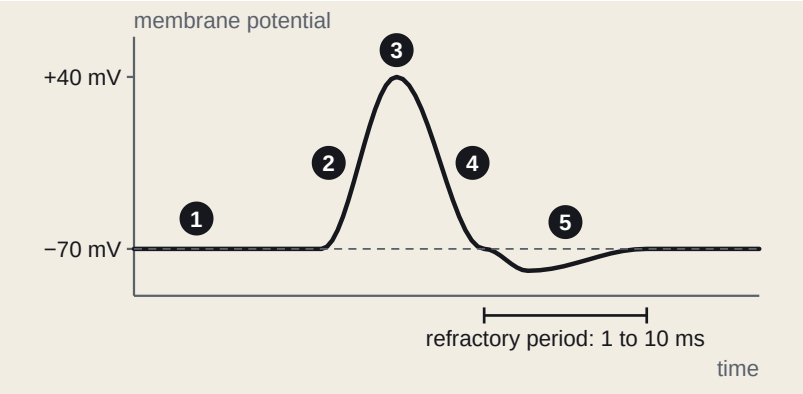
Try it

Explain why the sodium-potassium pump is needed after an action potential.

1. Sodium ions came in and potassium ions went out.
2. The pump moves them back.
3. Then the neuron is ready to fire again.

Slide 4 of 7 · Method: how to read an action potential graph

You have now seen every part of an action potential. Here the parts become five steps for reading any graph of one.



Key ideas

Step 1: the flat line at −70 mV is the neuron **resting**.

Step 2: the rise is **depolarization**. Step 3: the **peak** is +40 mV.

Step 4: the fall is **repolarization**.

Step 5: the dip and the return are the **refractory period**.

Example

Use the five steps. The line on a graph is rising steeply. Name the step and what the ions are doing.

1. Rising is step 2, depolarization.
2. Sodium ions are rushing into the cell.

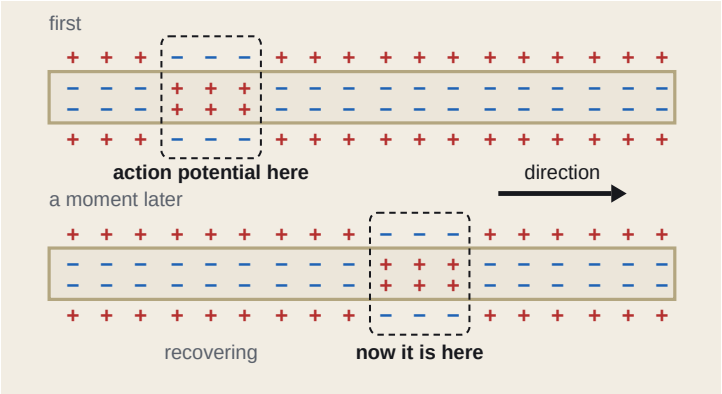
Try it

Use the five steps. The line dips below −70 mV and comes back. Name the step.

1. The dip and the return are step 5.
2. This is the refractory period.

Slide 5 of 7 · How an action potential moves along the axon

So far you watched one small part of the membrane. An axon is long. Now you see how the action potential gets from one end to the other.



Key ideas

Each action potential starts the **next** one along the axon.

The part behind is in its **refractory period**. So the action potential moves **forward** only.

With a myelin sheath, the ion channels are at the **nodes**.

Example

Explain why an action potential does not travel backward along an axon.

1. The part of the membrane behind it is in its refractory period.
2. That part cannot start another action potential yet.

Try it

State where an action potential can happen on an axon with a myelin sheath.

1. The ion channels are at the nodes of Ranvier.
2. So it can happen only at a node.

Slide 6 of 7 · Threshold and the all-or-none response

On the last slide, one action potential started the next. Now we go back to the start. Not every stimulus starts an action potential.

One neuron, five stimuli

Strength of stimulus (units)	Action potential?	Peak
1	no	none
2	no	none
3	yes	+40 mV
6	yes	+40 mV
12	yes	+40 mV

Key ideas

The smallest stimulus that starts an action potential is the **threshold level**.

A stimulus **below** the threshold level gives no action potential.

A neuron fires **fully** or not at all. This is the **all-or-none response**.

Example

A neuron has a threshold level of 3 units. Predict the result of a stimulus of 2 units.

1. 2 is below 3.
2. There is no action potential.

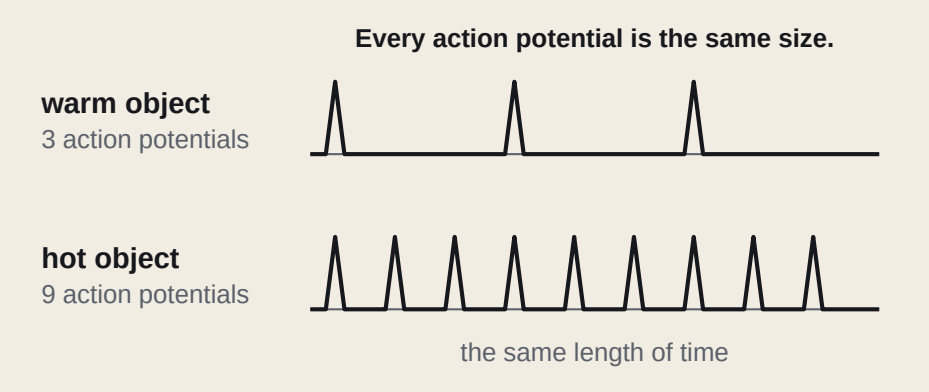
Try it

The same neuron gets a stimulus of 12 units. Predict the peak of the action potential.

1. 12 is above the threshold level of 3.
2. Every action potential is the same size.
3. The peak is +40 mV.

Slide 7 of 7 · Telling a weak stimulus from a strong one

On the last slide, every action potential was the same size. Yet you can tell a warm object from a hot one. Here is how.



Key ideas

A stronger stimulus makes a neuron fire more **often**.

The number of action potentials in a given time is the **frequency**.

A stronger stimulus also makes **more neurons** fire.

Example

A hot object and a warm object touch your hand. Compare the action potentials they cause in one neuron.

1. Each action potential is the same size.
2. The hot object gives a higher frequency.

Try it

Give the two ways the brain can tell that a stimulus is strong.

1. The frequency of action potentials is higher.
2. More neurons fire.