

Properties of Excitable Cells and Membrane Ion Channels

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SYSTEMS BIOLOGY
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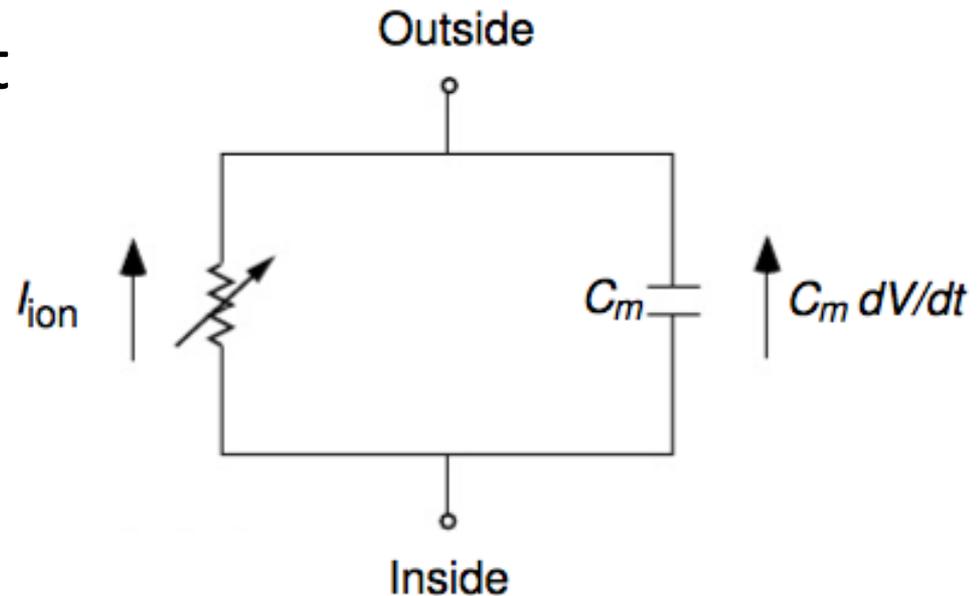
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Excitable Cells

- An excitable cell is one which has the ability to become activated
- They are able to produce and respond to electrical signals
- Excitable cells are able to transmit signals without loss of amplitude

Cell Membranes

- A cell can be considered to act like a simple electrical circuit
- The cell membrane acts like a capacitor
- The capacitive properties result in a potential difference/membrane potential

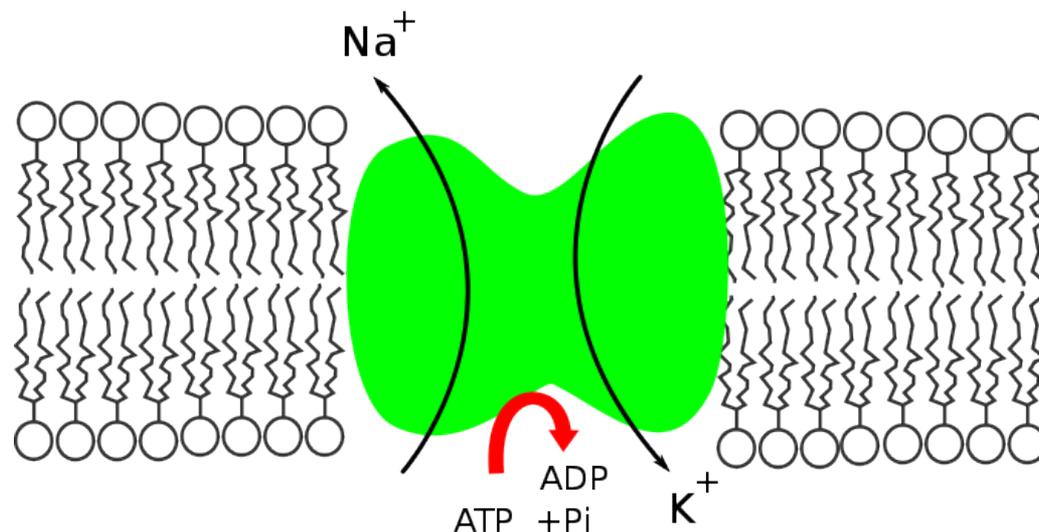


Resting Membrane Potential

- At rest, the cell is **not** in equilibrium – the inside of the cell is more negatively charged than the outside
- The potential difference arises from separation of charges across the membrane
- The unequal distribution of ions is due to:
 - Ion transporters (in particular: Na-K pump)
 - Different membrane permeability for sodium, potassium, calcium, chloride ions

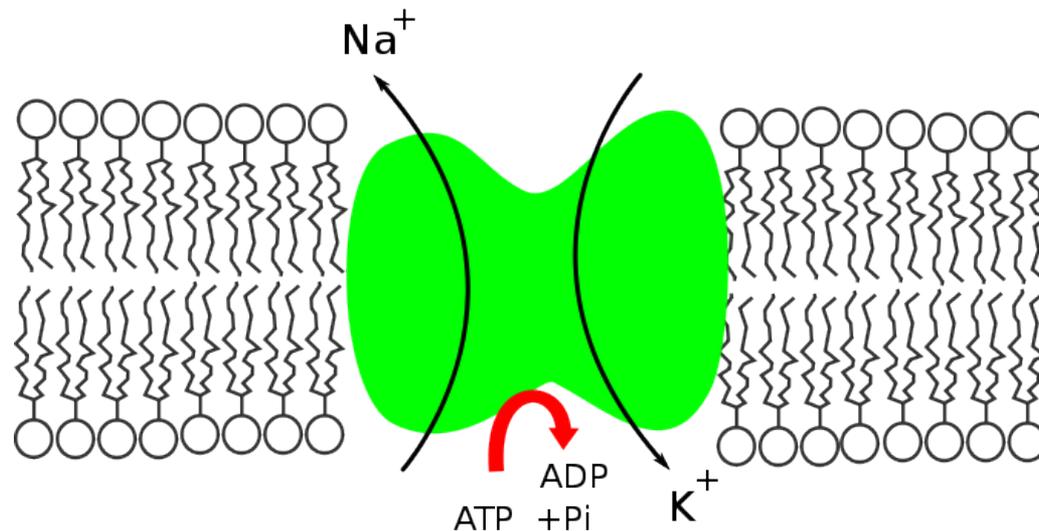
Ion Transporters

- A transporter moves ions against their electrochemical gradient to maintain a non-equilibrium steady state (i.e. resting membrane potential)
- The pump binds 3 intracellular Na ions
- ATP is hydrolysed, leading to phosphorylation of the pump and release of ADP



Ion Transporters

- Na ions are released outside, and the pump binds 2 extracellular K ions
- This causes dephosphorylation of the pump, transporting the K ions into the cell
- The pump therefore generates a small, net current out of the cell, keeping the cell polarised

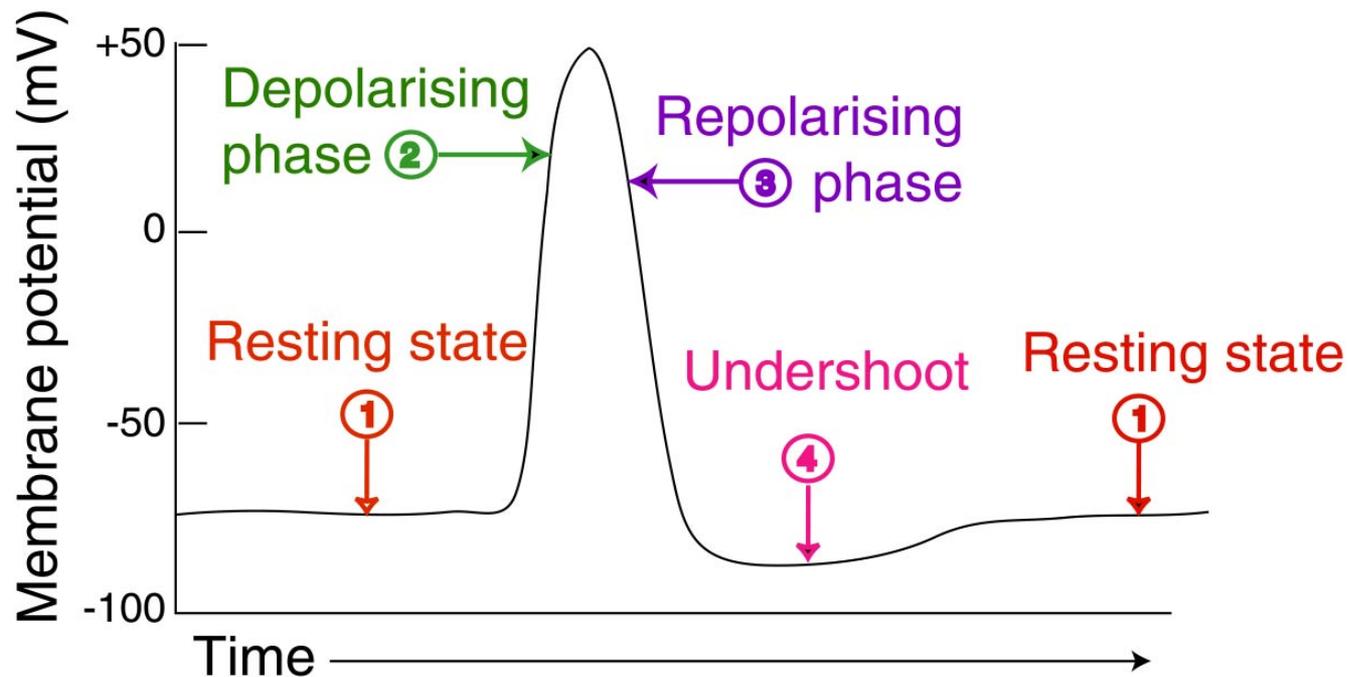


Ion Channels

- Current is carried across cell membranes by ions through selectively-permeable ion channels
- Voltage-controlled channels and their ion-selective variability is the key to transmitting an action potential
- The main ion channels important for action potentials are sodium and potassium
- Membrane permeabilities to these ions are not constant

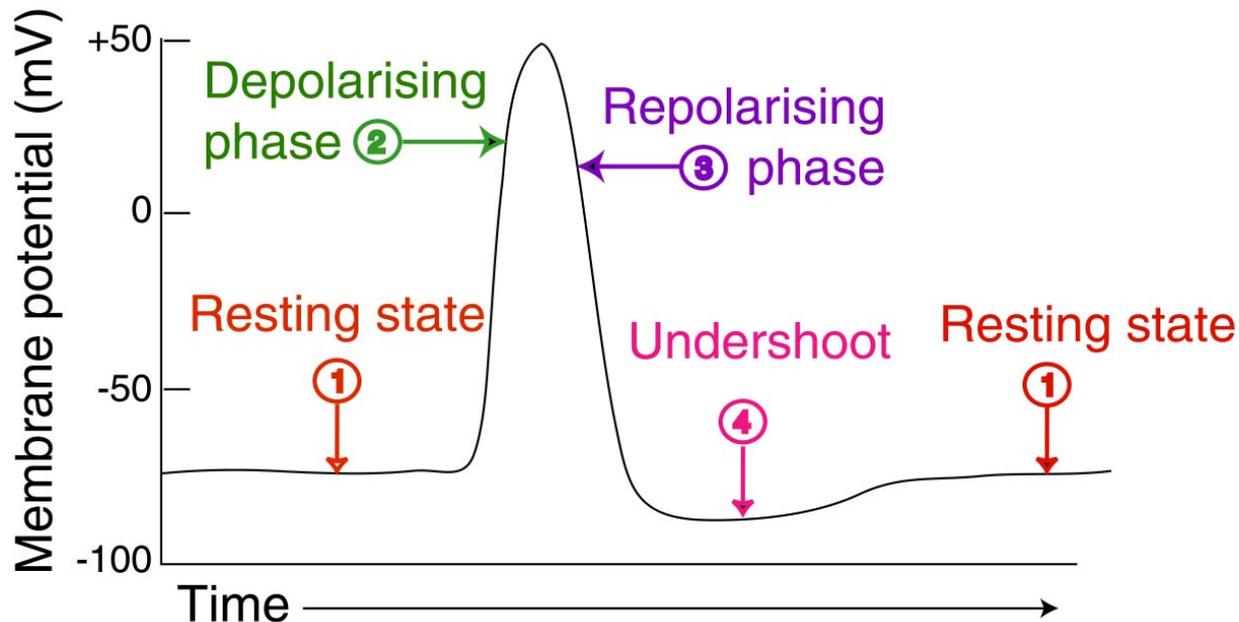
Action Potentials

An action potential is defined as the depolarisation and subsequent repolarisation of a cell



Action Potentials - Depolarisation

- An applied stimulus provides an outward current to the cell, depolarising the membrane's capacitance
- As the cell depolarises, voltage-gated sodium channels open allowing Na ions into the cell



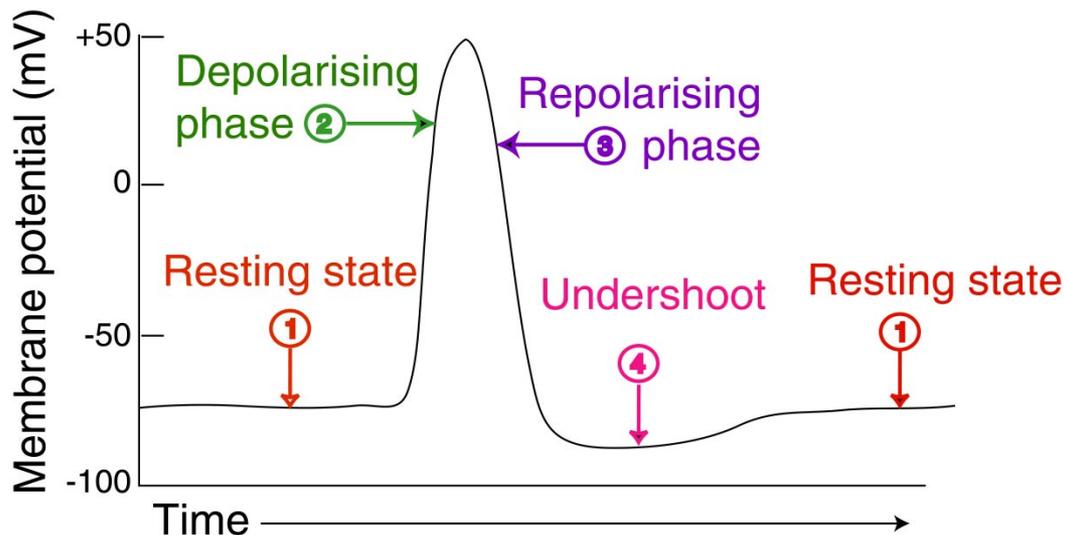
- The inward current further depolarises the cell, allowing more Na ions through the sodium channels

Smooth Muscle Contraction

- Smooth muscle contraction is caused by the sliding of myosin and actin over each other
- When the membrane is depolarised, Ca ions are also allowed to pass into the cell through voltage-activated calcium channels
- Intracellular Ca binds with calmodulin, which binds and activates myosin light-chain kinase
- This phosphorylates myosin activating myosin ATPase, resulting in movement of the filaments over each other

Action Potentials - Repolarisation

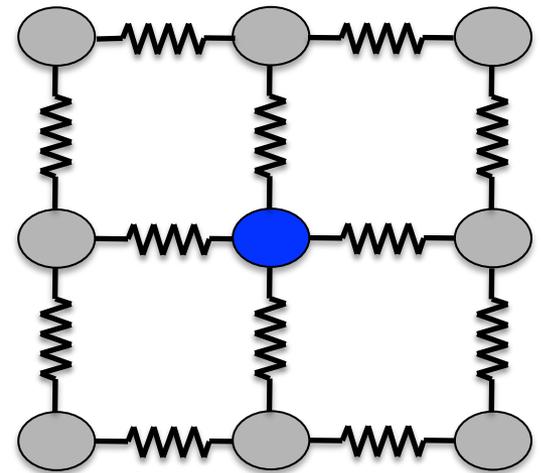
- After a set period of time, sodium channels inactivate and slowly close
- Potassium channels open allowing an efflux of K ions, repolarising the cell
- Potassium channels also inactivate and both types of channel close



- While the channels are closing, no reactivation can occur. This is the **refractory period**

Propagation of Action Potentials

- The current that flows into the cell during the upstroke of the action potential must flow out through adjacent membranes
- In muscle cells, the action potential passes between cells through gap junctions
- The outward current discharges the capacitance of the adjacent membrane triggering an action potential in neighbouring cells



Anode Break Action Potentials

- Observed after the end of a constant inward current for a significant period of time
- The stimulus hyperpolarises the cell which:
 - Decreases K^+ conductance
 - Increases inward diffusion of Na ions
- When the anodal stimulus ceases, the membrane depolarises due to the Na influx and decreased K efflux
- This depolarisation triggers an action potential

Any questions?