Exercise walk-through

1.2
Membranes and transport

University Medicine

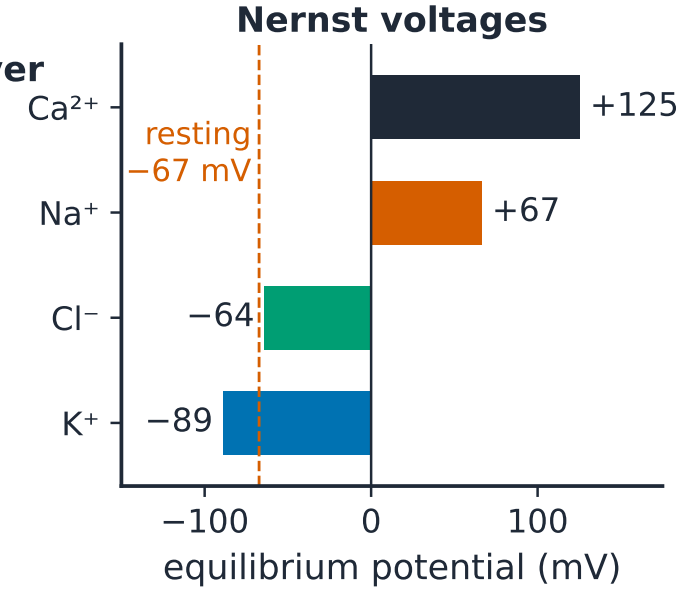
Membranes: four doors and a voltage

1. **Voltages** K^+ −89 mV, Cl^- −64 mV, Na^+ +67 mV, Ca^{2+} +125 mV - the **resting potential** sits about 20 mV above E_K because P_K dominates.
2. **Emergency** Extracellular K^+ doubles 5 → 10 mM: E_K shifts +18.5 mV = 61.5 · log10(2) - the hyperkalaemia mechanism is one logarithm.
3. **Pump** 3 Na^+ out, 2 K^+ in, 1 ATP: the pump holds the gradients the leak channels spend; Vm rests just above E_K.

The four doors

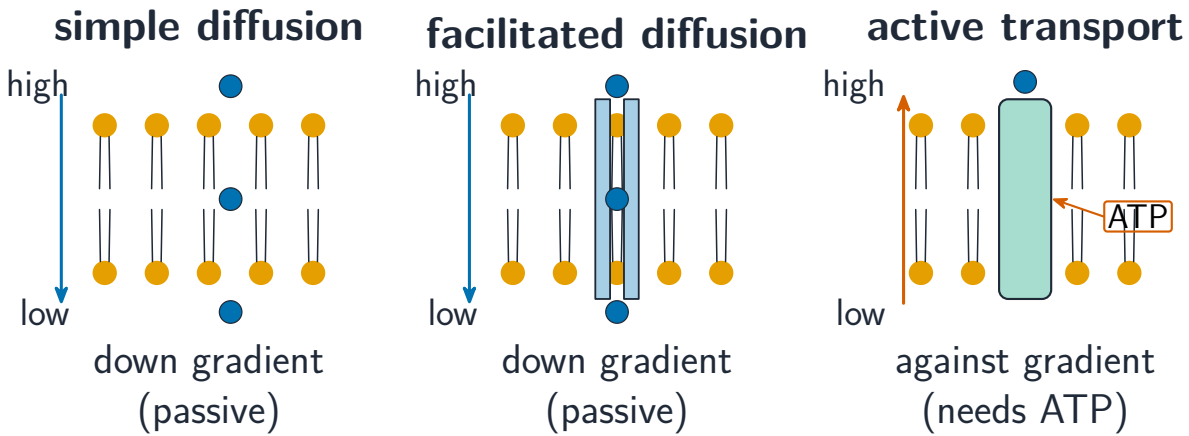
four ways across the 8 nm bilayer

diffusion	small, lipid-soluble downhill
channel / carrier	ions, sugars downhill
pump (ATP)	Na^+/K^+-ATPase ATP-driven
symport	sugar rides on Na^+ ion-powered



Four doors cross the 8 nm bilayer; the Nernst bars show why K^+ sets the resting voltage.

Three ways across a membrane



Active transport moves against the gradient and needs ATP

Exercise 2.1

2.1 Name the transport route for each substance shown. [3]

O_2 entering a cell	
glucose entering a red blood cell through GLUT1	
Na^+ leaving a cell through the Na^+/K^+ pump	

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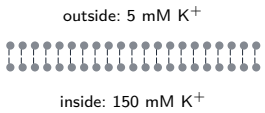
O_2: simple diffusion

glucose by GLUT1: facilitated diffusion

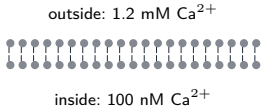
Na^+ by the pump: primary active transport

Exercises 2.2·2.3

2.2 Find E_K when K^+ is 150 mM inside and 5 mM outside. [2]

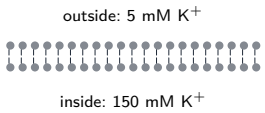


2.3 Find E_{Ca} with Ca^{2+} 100 nM inside and 1.2 mM outside. [3]



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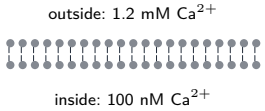


2.2

$61.5 \log_{10}(5/150)$

$\approx -\mathbf{90.8}$ mV

2.3 Find E_{Ca} with Ca^{2+} 100 nM inside and 1.2 mM outside. [3]



2.3

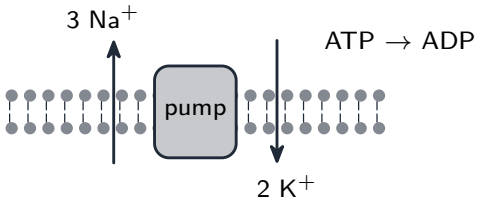
$z = 2$, so the factor is $61.5/2 = 30.75$

ratio $1.2 \times 10^{-3}/10^{-7} = 1.2 \times 10^{4}$

$30.75 \times 4.08 \approx +\mathbf{125}$ mV

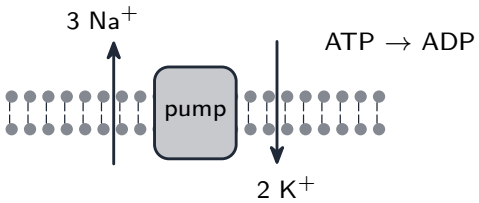
Exercise 2.4

2.4 The Na^+/K^+ pump moves 3 Na^+ out and 2 K^+ in for each ATP. Explain why it is called **electrogenic** . [2]



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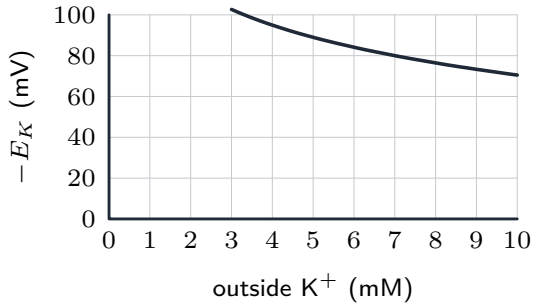
each cycle moves one more positive charge out than in

so it makes a small current and the inside becomes more negative

Exercise 3.1 (a)

3.1 A (fictional) patient's blood potassium rises. Inside the cells, K^+ stays at 140 mM.

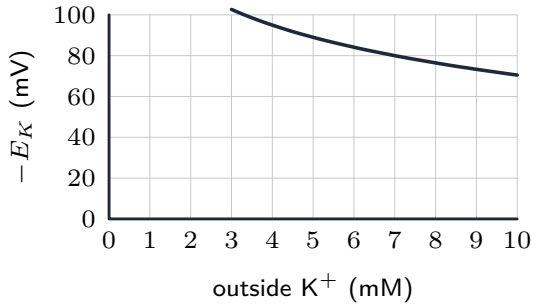
(a) Find E_K at an outside K^+ of 5 mM and of 8 mM. [3]



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(a) Find E_K at an outside K^+ of 5 mM and of 8 mM. [3]



(a) 5 mM: $61.5 \log_{10}(5/140) = -\mathbf{89.0}$ mV; 8 mM: $61.5 \log_{10}(8/140) = -\mathbf{76.4}$ mV

Exercise 3.1 (b)

3.1 A (fictional) patient's blood potassium rises. Inside the cells, K^+ stays at 140 mM.

(b) Explain how this changes the resting membrane potential. [2]

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(b) the resting potential mostly follows E_K, so it becomes less negative: the cells are depolarised

Exercise 3.1 (c)

3.1 A (fictional) patient's blood potassium rises. Inside the cells, K^+ stays at 140 mM.

(c) Explain why this is dangerous for the heart. [2]

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(c) Explain why this is dangerous for the heart. [2]

(c) heart cells sit closer to threshold and their Na^+ channels become inactivated, so conduction slows and dangerous rhythms can start

Exercise 3.2 (a)

3.2 Gases cross the wall of the lung's air sacs by diffusion, as shown.

(a) Lung scarring doubles the wall thickness. By what factor does the diffusion rate change? [1]

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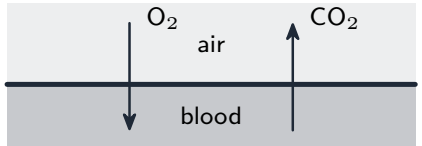
(a) Lung scarring doubles the wall thickness. By what factor does the diffusion rate change? [1]

(a) halved: $\times\frac{1}{2}$

Exercise 3.2 (b)

3.2 Gases cross the wall of the lung's air sacs by diffusion, as shown.

(b) In another disease the area halves and the thickness doubles. Find the new rate as a fraction of normal. [2]

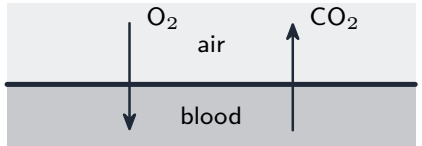


wall: thickness d, area A

Exercise 3.2 (b)

3.2 Gases cross the wall of the lung's air sacs by diffusion, as shown.

(b) In another disease the area halves and the thickness doubles. Find the new rate as a fraction of normal. [2]



wall: thickness d, area A

(b) $\frac{1}{2} \times \frac{1}{2} = \mathbf{\frac{1}{4}}$

Exercise 3.2 (c)

3.2 Gases cross the wall of the lung's air sacs by diffusion, as shown.

(c) CO_2 is about 20 times more soluble than O_2. Which gas is affected first by a thick wall, and why? [2]

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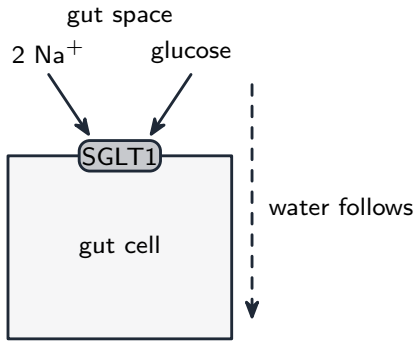
(c) CO_2 is about 20 times more soluble than O_2. Which gas is affected first by a thick wall, and why? [2]

(c) O_2: it diffuses much less easily, so it is limited first, while CO_2 still has a large margin

Exercise 3.3 (a)

3.3 In a (fictional) cholera outbreak, a clinic gives **oral rehydration solution** (ORS). One litre holds: Na^+ 75, Cl^- 65, K^+ 20, citrate 10 and glucose 75 mmol.

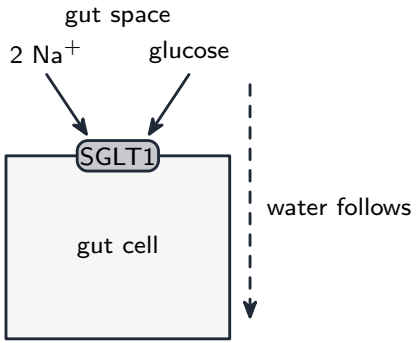
(a) Explain why glucose and salt together are absorbed even when the gut is losing fluid. [3]



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(a) Explain why glucose and salt together are absorbed even when the gut is losing fluid. [3]



(a) SGLT1 carries Na^+ and glucose in together, using the Na^+ gradient; this carrier still works in cholera; the absorbed solutes pull water in by osmosis

Exercise 3.3 (b)

3.3 In a (fictional) cholera outbreak, a clinic gives **oral rehydration solution** (ORS). One litre holds: Na^+ 75, Cl^- 65, K^+ 20, citrate 10 and glucose 75 mmol.

(b) Find the total of these solutes in mmol per litre, and compare it with blood (about 290). [2]

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(b) Find the total of these solutes in mmol per litre, and compare it with blood (about 290). [2]

(b) $75 + 65 + 20 + 10 + 75 = \mathbf{245}$ mmol/L: a little below blood, so water moves from gut to blood

Exercise 3.3 (c)

3.3 In a (fictional) cholera outbreak, a clinic gives **oral rehydration solution** (ORS). One litre holds: Na^+ 75, Cl^- 65, K^+ 20, citrate 10 and glucose 75 mmol.

(c) Why can a very sugary drink make diarrhoea worse? [1]

Exercise 3.3 (c)

3.3 In a (fictional) cholera outbreak, a clinic gives **oral rehydration solution** (ORS). One litre holds: Na^+ 75, Cl^- 65, K^+ 20, citrate 10 and glucose 75 mmol.

(c) Why can a very sugary drink make diarrhoea worse? [1]

(c) the extra sugar is not absorbed and draws water into the gut by osmosis

Exercise 3.3 (d)

3.3 In a (fictional) cholera outbreak, a clinic gives **oral rehydration solution** (ORS). One litre holds: Na^+ 75, Cl^- 65, K^+ 20, citrate 10 and glucose 75 mmol.

(d) Recommend how the clinic should give fluids. [2]

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3.3 In a (fictional) cholera outbreak, a clinic gives **oral rehydration solution** (ORS). One litre holds: Na^+ 75, Cl^- 65, K^+ 20, citrate 10 and glucose 75 mmol.

(d) Recommend how the clinic should give fluids. [2]

(d) give ORS by mouth in small frequent sips, matching the losses; use a drip for patients too weak or too dehydrated to drink