

1.2 Membranes and transport

Name: _____ Class: _____ Date: _____

Total: 25 marks

KEY WORDS Nernst equation

Objective

Compute Nernst and GHK voltages, classify the four transport doors, and trace a channel defect to its disease mechanism.

1 Key knowledge and worked examples

■ The Nernst equation at 37 °C

$E_X = \frac{61.5}{z} \log_{10} \frac{[X]_{out}}{[X]_{in}}$ mV: K⁺ (5/140) −89.0 mV, Na⁺ (145/12) +66.6 mV, Cl[−] (110/10, $z = -1$) −64.0 mV, Ca²⁺ (1.2 mM/100 nM) +125.6 mV ✓.

■ Worked example: the resting potential

GHK with $P_K:P_{Na}:P_{Cl} = 1:0.04:0.45$: $V_m = 61.5 \log_{10} \frac{5+5.8+4.5}{140+0.48+49.5} = -67.3$ mV ✓ – a hair above E_K ; the Na⁺/K⁺ pump (3 out / 2 in / 1 ATP) holds the gradients.

2 Practice

2.1 Compute E_K for [K]_o = 15 mM, [K]_i = 140 mM. [3]

2.2 Which door does glucose take into an erythrocyte, and why not simple diffusion? [3]

2.3 Why does doubling [K]_o shift E_K by exactly $61.5 \log_{10} 2$ mV? [3]

3 Exam-style questions

3.1 A (fictional) patient's serum K^+ rises $5 \rightarrow 10$ mM.

Compute the shift in E_K and the new value. Explain why the resting potential depolarises and why this is a cardiac emergency. State what the Na^+/K^+ pump does to the gradients and its stoichiometry. [8]

3.2 $\Delta F508$ cystic fibrosis (fictional case used as mechanism).

Name the door class affected. Trace the mechanism from misfolded channel to dehydrated airway surface. Explain why salt and water follow the trapped Cl^- (osmosis, 290 mOsm). State why small molecules that hold the fold open are a therapy rationale. [8]

Solutions

2.1

- $61.5 \log_{10}(15/140) = 61.5 \times (-0.970) = -59.7 \text{ mV}$.

2.2

- Facilitated diffusion via the GLUT carrier: glucose is hydrophilic, so the bilayer alone is impassable; movement is downhill, no ATP.

2.3

- $E_K \propto \log_{10}([out]/[in])$; doubling [out] adds $\log_{10} 2$ inside the log: $+18.5 \text{ mV}$.

3.1

- Shift $61.5 \log_{10} 2 = +18.5 \text{ mV}$; new $E_K = -89.0 + 18.5 = -70.5 \text{ mV} \checkmark$.
- V_m tracks E_K (P_K dominates), so depolarisation.
- Cardiac: depolarised myocytes sit closer to threshold – arrhythmia risk.
- Pump: 3 Na^+ out, 2 K^+ in, 1 ATP – it maintains the gradients but cannot by itself fix an extracellular load.

3.2

- Door: a Cl^- channel (facilitated diffusion class).
- Misfolded $\rightarrow$ retained in the ER $\rightarrow$ never reaches the membrane $\rightarrow \text{Cl}^-$ cannot leave.
- Cl^- trapped $\rightarrow$ salt accumulates luminal-side $\rightarrow$ water follows osmotically (290 mOsm gradients equalise) $\rightarrow$ surface liquid dehydrates $\rightarrow$ mucus cannot clear.
- Therapy: folding correctors hold the channel open through processing, restoring some Cl^- flow.