Assignment 6

Part A Solution

1)

Given: transport of LDL across endothelium.

$k = 10^{-8}$ cm/s

$C_{blood} = 100 mg/dL = 1 mg/cm^3$

$C_{wall} = 0 mg/cm^3$

Find: N_{LDL} over a 0.5-cm diameter, 2-cm length tube over 24 hr.

Assume: steady state
no convective transport
electrically neutral

Solution. This is simple 1-D membrane transport by diffusion only. Therefore,

$$J = k\Delta C = (10^{-8} cm/s)(1 mg/cm^3 - 0 mg/cm^3) = 10^{-8} mg/cm^2 \cdot s$$

$$N = J \cdot A \cdot \Delta t = \left(10^{-8} \frac{mg}{\cancel{cm^2} \cdot \cancel{s}}\right)\left[\pi \cdot (0.5 \cancel{cm})(2 \cancel{cm})\right]\left(24 \cancel{hr}\left(\frac{3600 \cancel{s}}{1 \cancel{hr}}\right)\right)$$

$$N = 0.0027 mg = \boxed{2.7 \mu g}$$

Risk factors:

- hypercholesterolemia (High LDL in blood)
  $\rightarrow \uparrow C_{blood} \rightarrow \uparrow \Delta C \rightarrow \uparrow J \rightarrow \uparrow N$
- smoking, diabetes, irregular blood flow patterns all affect the endothelial cells, making them extra leaky to LDL.
  $\rightarrow \uparrow k \rightarrow \uparrow J \rightarrow \uparrow N$

2) a) Let k be the permeability of Na^+.

→ permeability of $K^+ = 10k$

→ permeability of $Cl^- = xk$

Substituting into expanded Nernst equation, with $V_m = -86mV$ and $RT/F = 26.72mV$,

$$-86mV = 26.72mV \ln \frac{10k[K^+]_o + k[Na^+]_o + xk[Cl^-]_i}{10k[K^+]_i + k[Na^+]_i + xk[Cl^-]_o}$$

(i = inside cell, o = outside cell)

Substituting in given values of concentration,

$$-86mV = 26.72mV \ln \frac{10k(2.5mM) + k(122mM) + xk(2mM)}{10k(140mM) + k(9mM) + xk(122mM)}$$

$$-3.219 = \ln \frac{25 + 122 + 2x}{1400 + 9 + 122x} = \ln \frac{147 + 2x}{1409 + 122x}$$

$$0.040 = \frac{147 + 2x}{1409 + 122x}$$

$$56.4 + 4.88x = 147 + 2x$$

$$2.88x = 90.6$$

$\boxed{x = 31.5}$ ⇒ permeability of Cl^- is 31.5x that of Na^+.

b) very large Na^+ permeability makes permeability of Cl^- & K^+ negligible, so

$$V_m = (26.72mV) \ln \frac{[Na^+]_o}{[Na^+]_i} = 26.72mV \ln \frac{122mM}{9mM} = \boxed{69.7mV}$$

For K^+:

$$V_m = (26.72mV) \ln \frac{[K^+]_o}{[K^+]_i} = 26.72mV \ln \frac{2.5mM}{140mM} = \boxed{-107.6mV}$$

For Cl^-:

$$V_m = (26.72mV) \ln \frac{[Cl^-]_i}{[Cl^-]_o} = 26.72mV \ln \frac{2mM}{122mM} = \boxed{-109.8mV}$$