Chemiosmotic Theory: The membrane as capacitor

- Calculations on a neuron: For the *Torpedo* ray neuron below:

  a. Give the expected equilibrium membrane potential which would be achieved by opening ion channels specific for K⁺, Na⁺, or Ca²⁺ and Cl⁻ one at a time and allowing the system to come to equilibrium. Temperature = 37° C.

  b. A typical neuron can be approximated as a cylinder with a volume of 6300 µm³ and a surface area of 2700 µm². How many Na⁺ ions are required to charge the above neuron membrane from 0.0 mV to the equilibrium Na⁺ voltage (see above)? Assume 1.0 µF/cm² capacitance.

  c. Will the internal [Na⁺] change significantly as a result of this flux of sodium ions? Calculate the final [Na⁺] in.

\[ \Delta V = \frac{RT}{2F} \ln \frac{300}{2} = +62 \text{ mV} \]

b) \[ \Delta V = \frac{q}{C} \]

\[ 0.062 \text{ V} = \frac{q}{10^{-6} \text{ F} \left( \frac{1}{10000 \text{ µm}} \right)^2 \times 2700 \text{ µm}^2} \]

\[ q = 1.7 \times 10^{-12} \text{ C} \]

\[ \frac{1.7 \times 10^{-12} \text{ C}}{1.6 \times 10^{-19} \text{ C}} = 1.1 \times 10^7 \text{ Na}^+ \text{ ions} \]

C) \[ 0.020 \text{ mol Na}^+ \text{ L}^{-1} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \left( \frac{1 \text{ cm}}{10000 \text{ nm}} \right)^3 \times 6.02 \times 10^{23} \text{ Na}^+ \text{ mol}^{-1} \]

\[ = 7.6 \times 10^{10} \text{ Na}^+ \text{ ions} \]

\[ \text{inside} \times 2.0 \text{ mM} = 7.6 \times 10^{10} \text{ Na}^+ \text{ ions} + 1.1 \times 10^7 \text{ add} \]

\[ = 20,002 \text{ mM Na}^+ \text{ after} \]

Not significant