- Intra-organism communication
- Basic physics of signal transmission along neurons
- Hodgkin-Huxley model

- Chemical signals transported by:

  → diffusion

$$\mathrm{RMS} = \sqrt{2\alpha t} \Rightarrow t = \frac{\mathrm{RMS}^2}{2\alpha}, v_{\mathrm{dif}} = \frac{\mathrm{RMS}}{t} = \sqrt{\frac{2\alpha}{t}}$$

  Typical $v_{\mathrm{dif}} \sim 10^{-3}$ cm/sec

  → convection: transport of a signal by blood flow

  Typical $v_{\mathrm{circ}} \sim 10 - 100$ cm/sec

- Electrical signals traverse a nervous system at $v_{\mathrm{nrv}} \sim 100$ m/sec (10^4 cm/sec)

  → Much slower than speed of light in vacuum $c \sim 3 \times 10^5$ km/sec

  → Much slower than speed of light in copper $c_{\mathrm{Cu}} \sim 3 \times 10^5$ km/sec

  → Much faster than diffusion of e^- in copper $v_{\mathrm{Cu}} \sim 0.02$ cm/sec

- Electrical signals are transmitted in the nervous system through a combination of diffusion and electromagnetic wave propagation
- A neuron is a cell specialized in electrical signal transmission

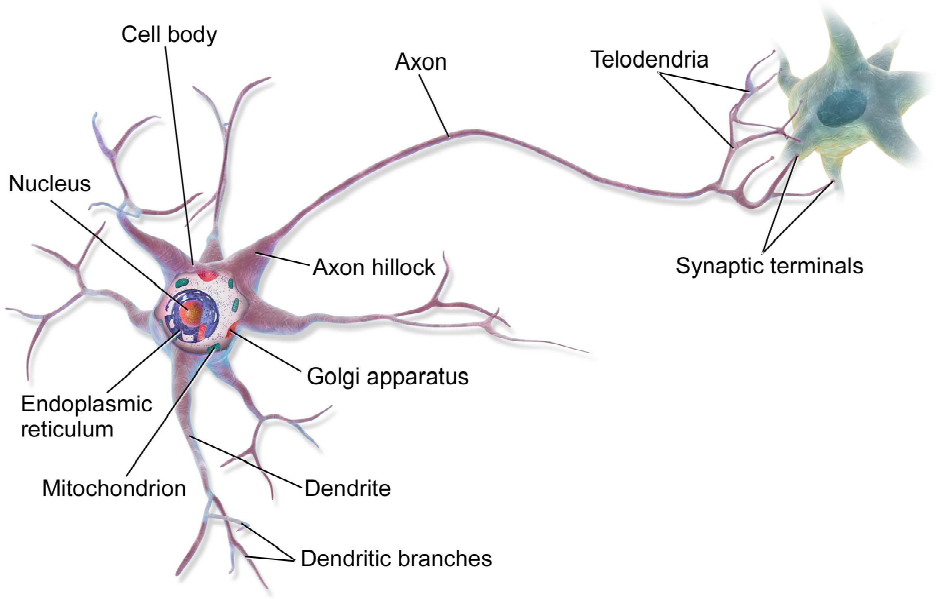

Figure 1.

- Neurons maintain electrical potential differences across membranes
- Electrical charge carriers are ions: Na^+, K^+, Cl^-
- Nernst equation gives voltage to difference in/out concentrations

$$V = \frac{RT}{F} \ln \frac{C_i}{C_o}$$

$R = 8.314\,\mathrm{J/(mol\,K)}$, $F = 96,485\,\mathrm{C}$

	Inside axon	Extracellular fluid	C_i/C_o	Nernst equivalent
Na^+	15	145	0.10	-55 mV
K^+	150	5	30.0	82 mV
Cl^-	7.5	110	0.068	-68 mV

Table 1. Ion concentrations

- Electrical signals travel at high speed along axon
- At axon terminus the signal triggers release of a neurotransmitter

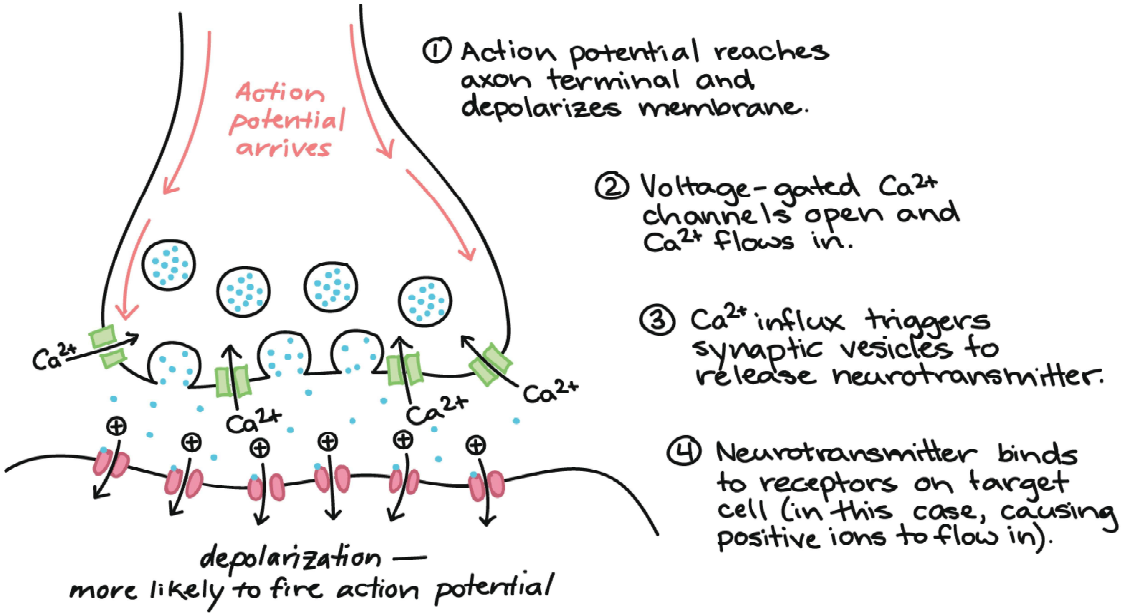

Figure 2.

- The relaying of the signal is modulated by ion channels in the dendrite membrane

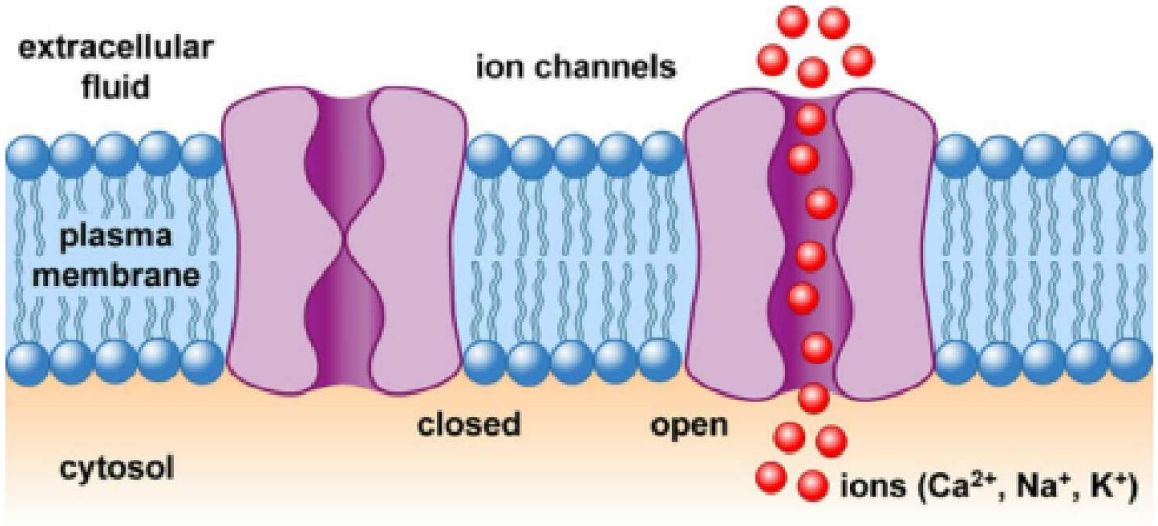

Figure 3.

- The action potential is the potential difference that stimulates ion channel opening/closing

Figure 4.

- The detailed molecular physics of each process is very difficult, but is now being carried out, e.g., ion channel from molecular dynamics

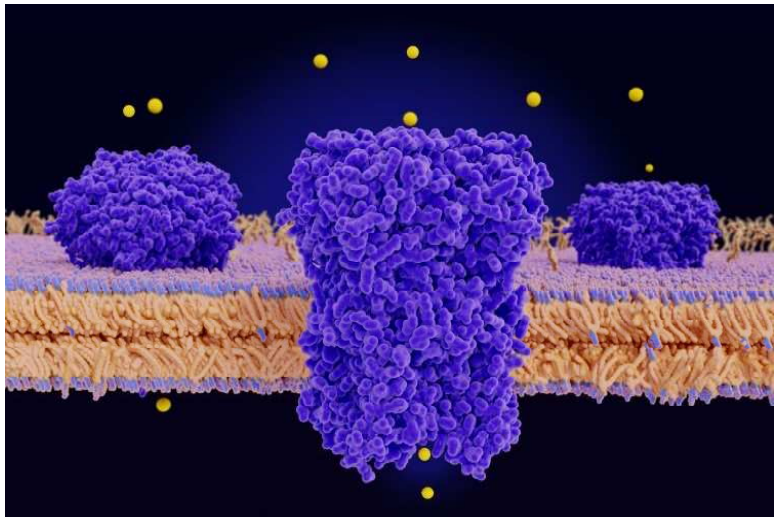

Figure 5.

- Hodgkin-Huxley model introduces approximations for each stage of the process