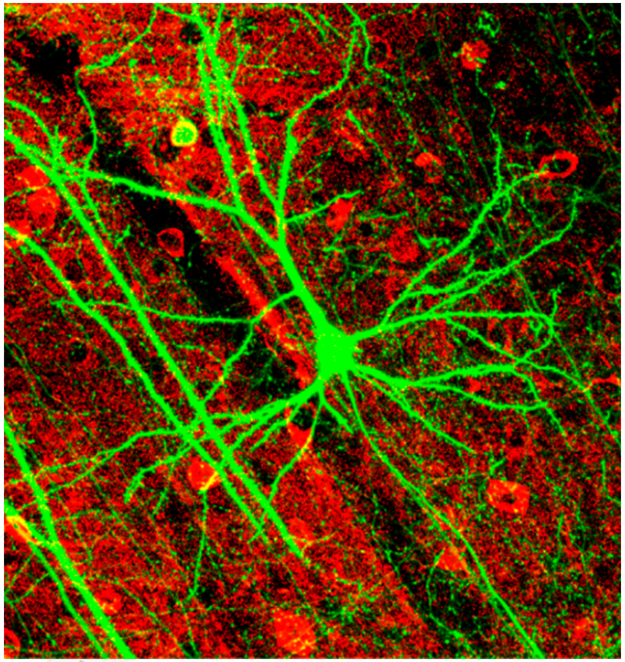
Computing in carbon



Neuroelectronics

- membranes
- ion channels
- wiring

Simplified neuron models

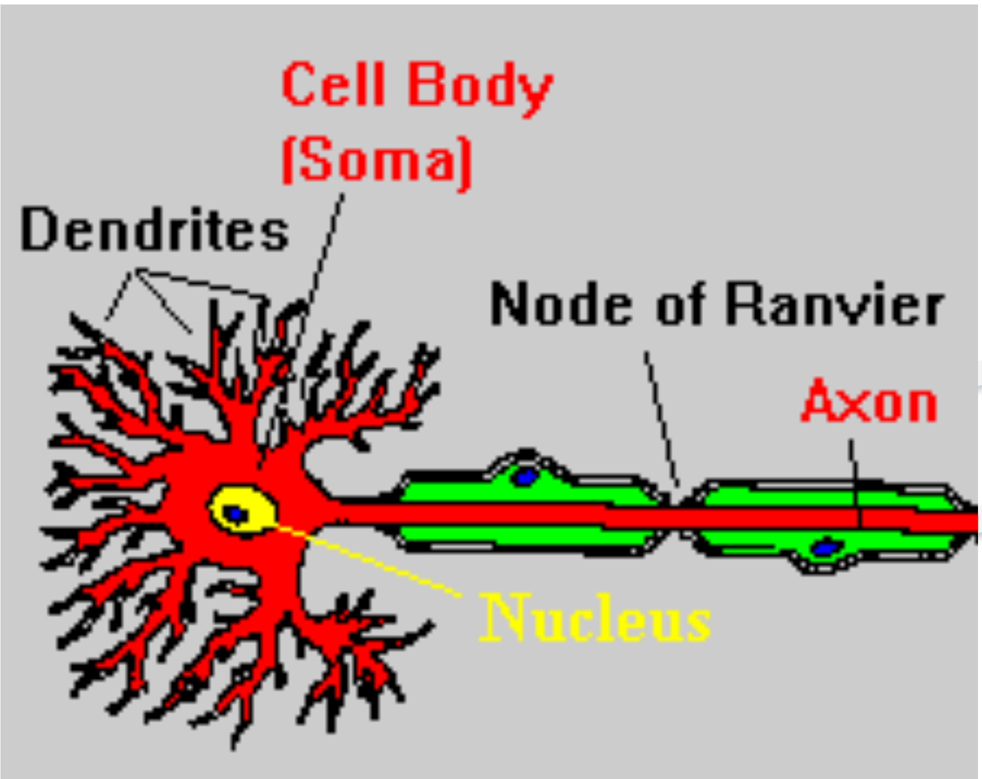
- the basic dynamics of neuronal excitability

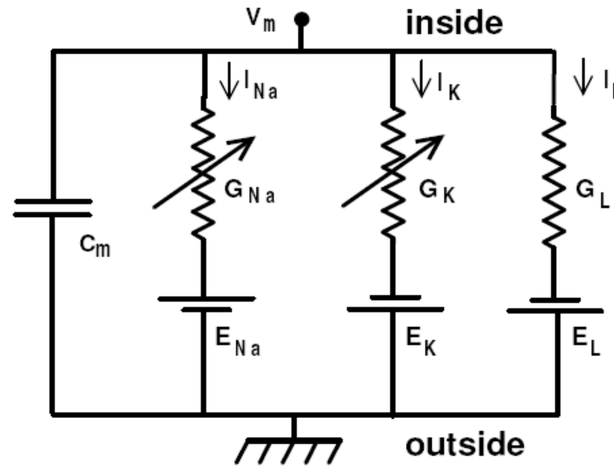
Neuronal geometry

- Dendrites and dendritic computing

Wikipedia commons

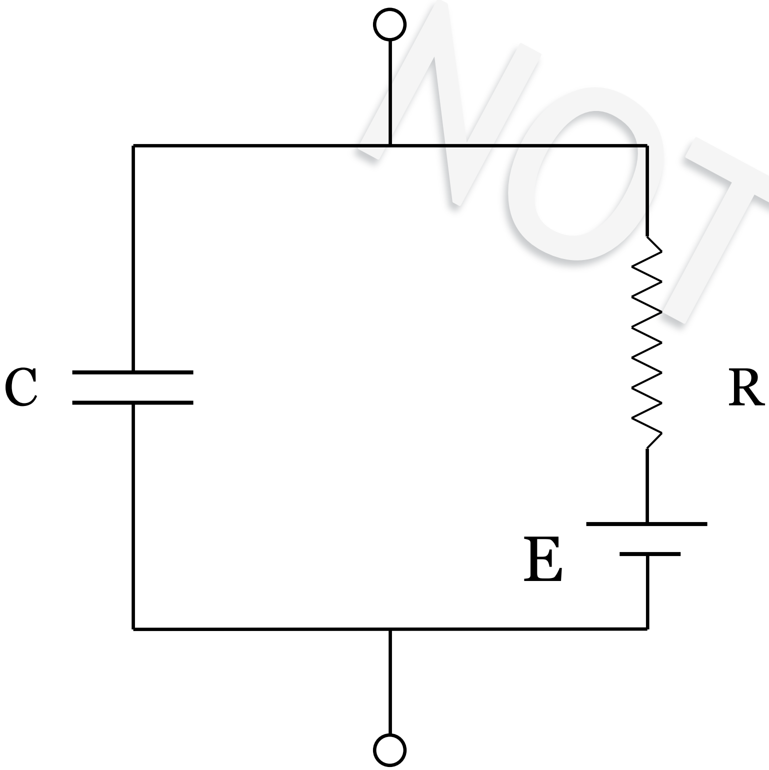
Equivalent circuit model





Eric Chudler

RC circuits



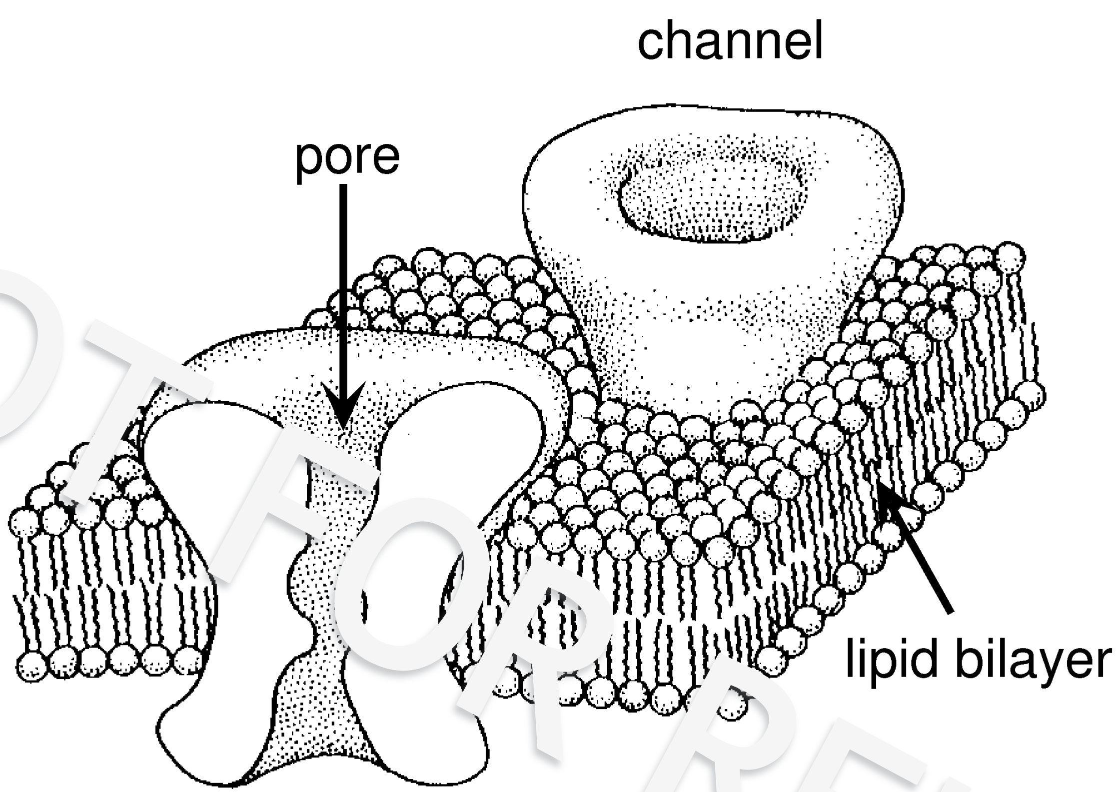
- Across a wire, the potential is the same
- The charge flowing into one element must equal the charge flowing out
- At a junction of wires, the total current is zero: Kirchhoff's law
- The potential changes by a fixed amount across a battery symbol
- The potential changes by a variable amount across a resistor symbol:

  Ohm's law: $V = IR$ or $I = Vg$

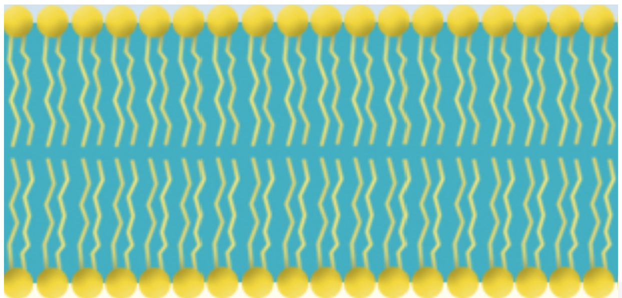
导电率

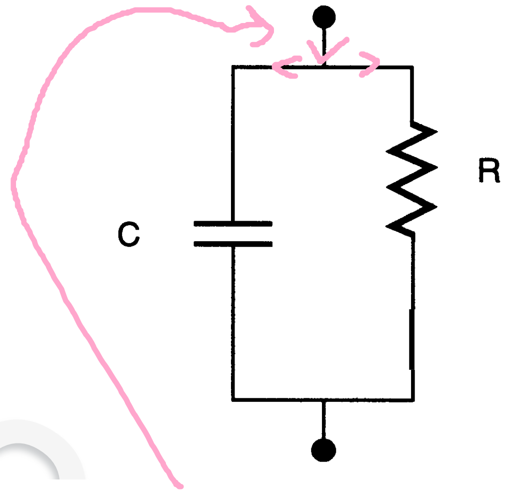
$g \sim \frac{1}{R}$

Membrane patch



The passive membrane





Kirchhoff: $I_R + I_C + I_{\text{ext}} = 0$

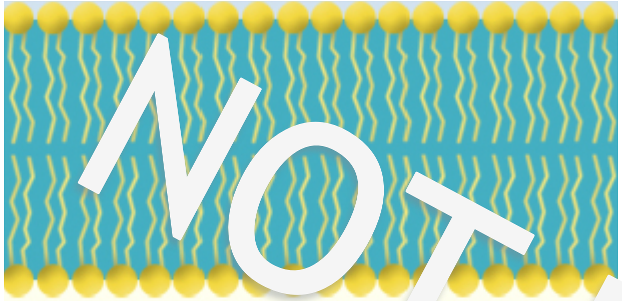
Ohm's law: $V = I_R R$

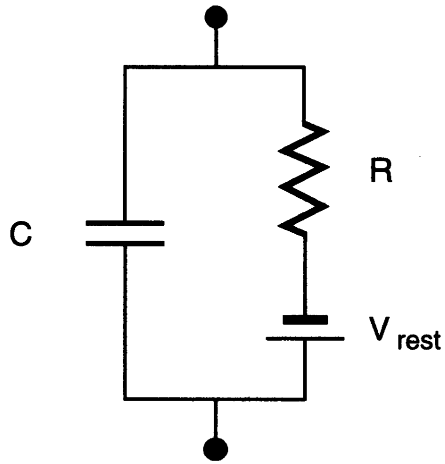
Capacitor: $C = Q/V$

$$I_C = C\frac{dV}{dt}$$

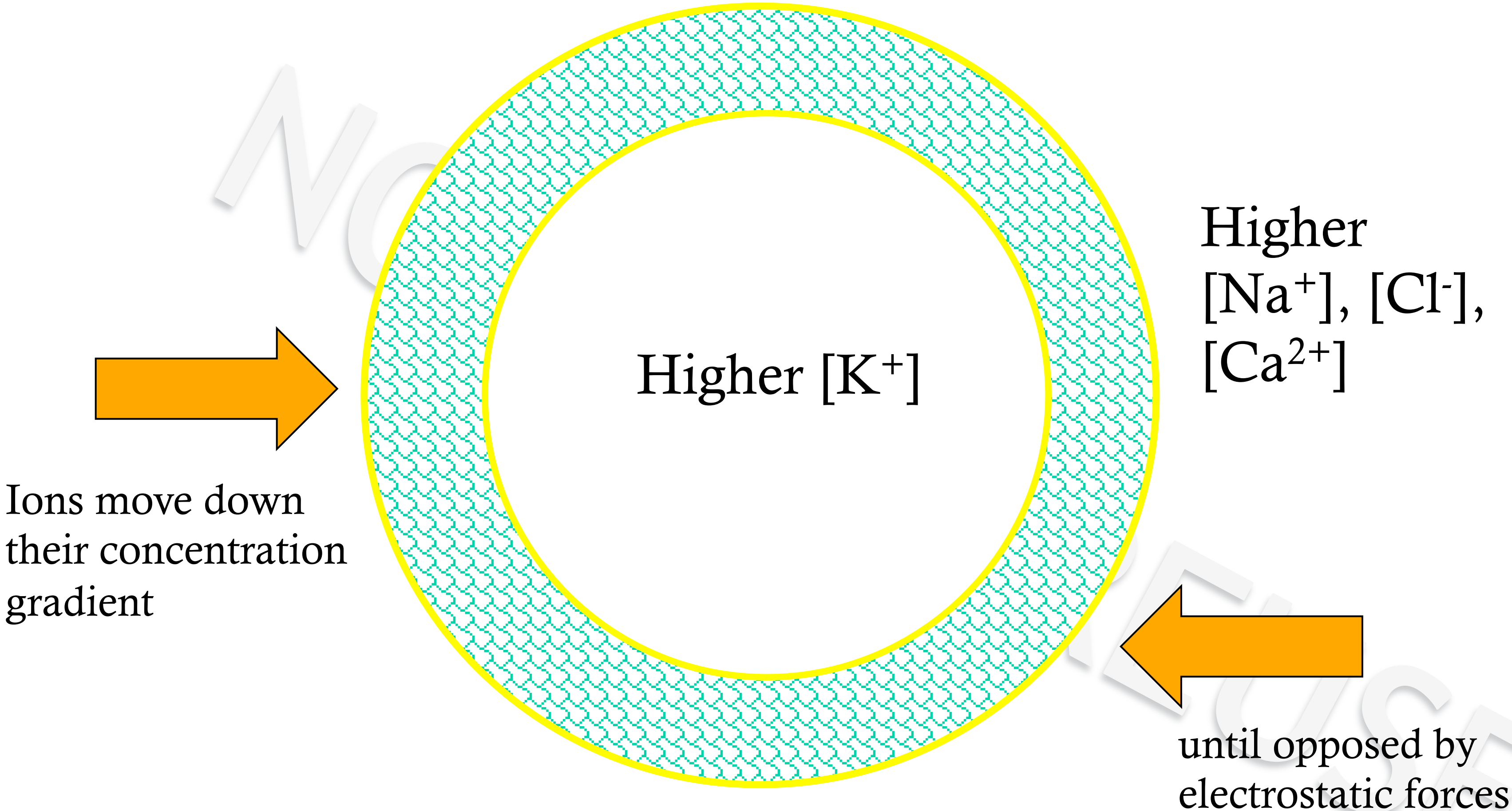
$$C\frac{dV}{dt} = -\frac{V}{R} + I_{\text{ext}}$$

The cell has a battery



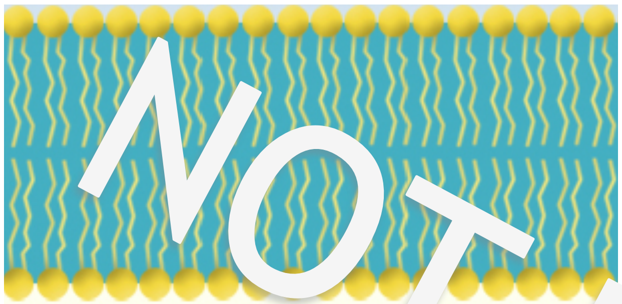


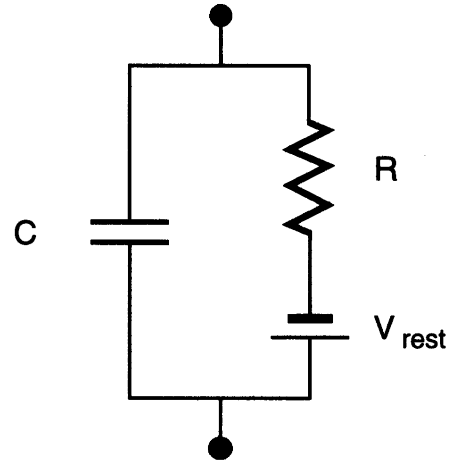
The cell's battery: the equilibrium potential



Nernst: $$E = \frac{k_B T}{\underbrace{zq}_{\text{const}}} \ln \frac{[\text{inside}]}{[\text{outside}]}$$

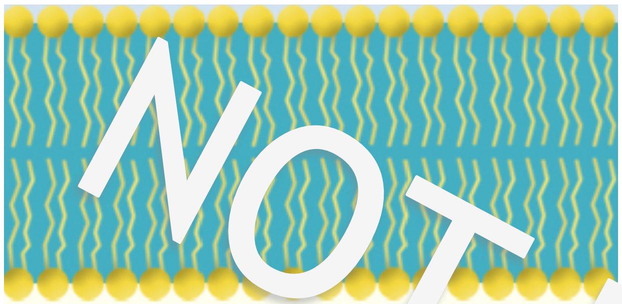
The cell has a battery

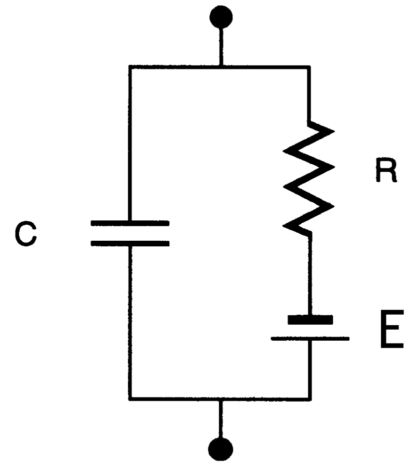




$$C\frac{dV}{dt} = -\frac{(V - V_{\text{rest}})}{R} + I_{\text{ext}}$$

How does such a membrane behave?





$C_m = c_m A$

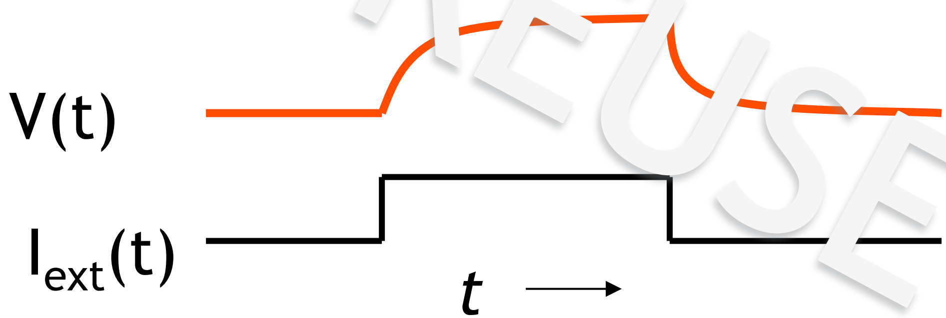
$c_m \approx 10\ \mathrm{nF/mm^2}$

$R_m = r_m / A$

$r_m \approx 1\ \mathrm{M\Omega\ mm^2}$

$$C\frac{dV}{dt} = -\frac{(V - V_{\mathrm{rest}})}{R} + I_{\mathrm{ext}}$$

$$\tau\frac{dV}{dt} = -V + V_{\infty}$$

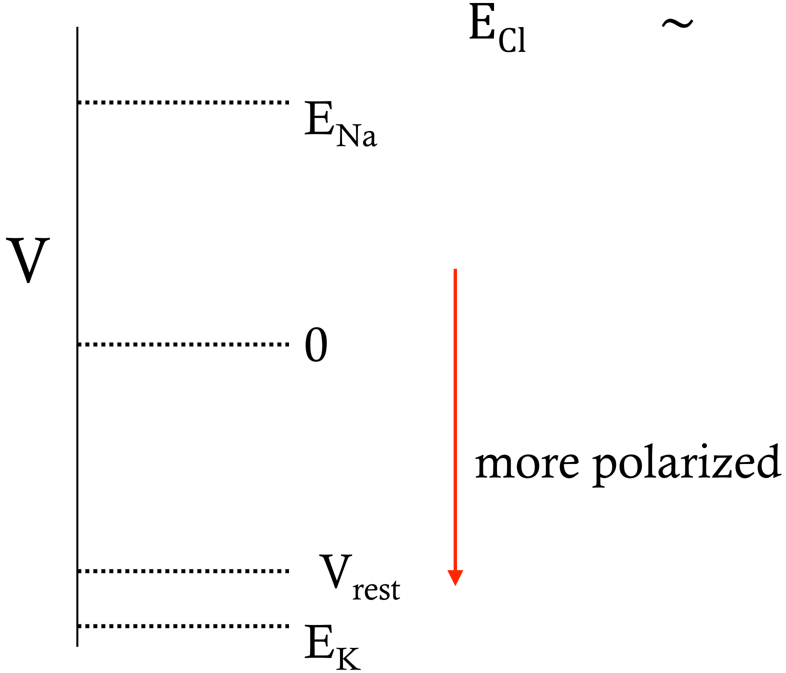


Each ion type is independent and has its own battery

Different ion channels have associated *conductances*.

A given conductance tends to move the membrane potential toward the equilibrium potential for that ion

E_{Na}	~	50mV	depolarizing
E_{Ca}	~	150mV	depolarizing
E_K	~	-80mV	hyperpolarizing
E_{Cl}	~	-60mV	shunting



But what makes a neuron *compute*?