Biophysical Background

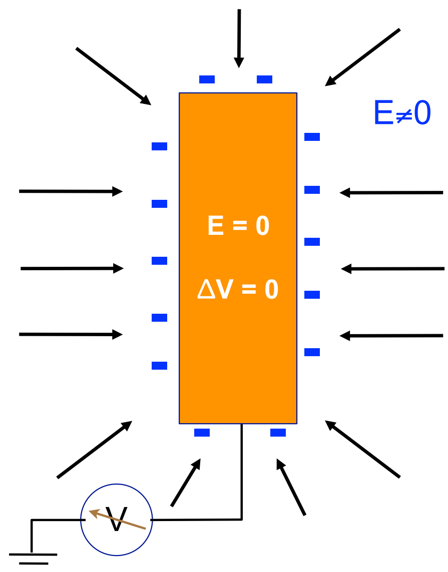
The Basics

- Materials
  - Conductor, capacitors
- Ohm's Law and Circuits
  - Ohms law, IV curves, dynamic circuit analysis
- Fields
  - Electric field, potential field
- Sources, Sinks, and Vector Calculus
  - Current monopoles, dipoles
  - Volume conductor fields
  - Div, grad, curl and all that

Conductors & Resistors

- Conductors
  - Electrons free to move
  - Current flow in response to electric field
  - In static state, no net charge (E=0)
- Resistors
  - Electrons less free to move
  - Create potential differences
  - Depend on material properties

$$R = \frac{\rho l}{A}$$



Capacitance

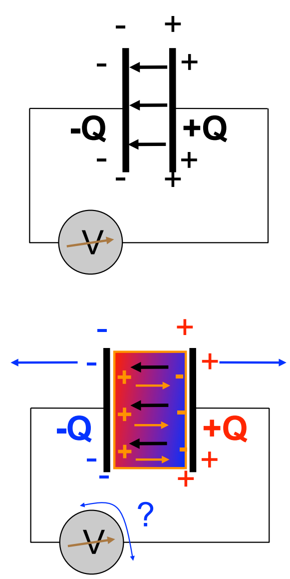
$$C = \frac{Q}{V} \qquad \frac{dV}{dt} = \frac{I_c}{C}$$

- Dielectric
  - Charges not free to move, just shift
  - E≠0 inside, opposes applied E
  - Result is reduce v and increased C

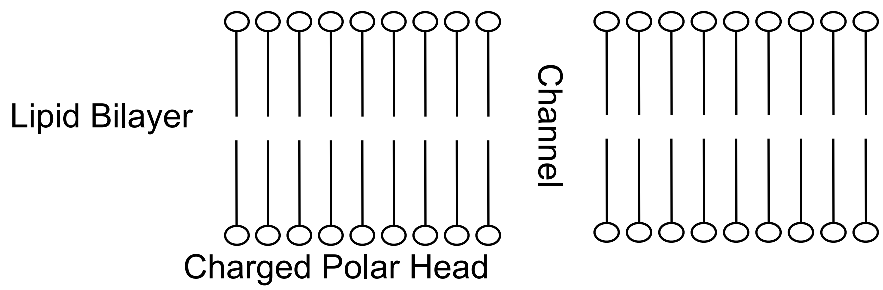
Does anything change when the plates move?

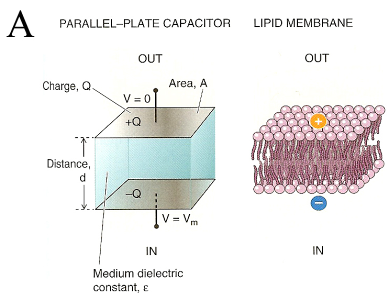
Q = CV

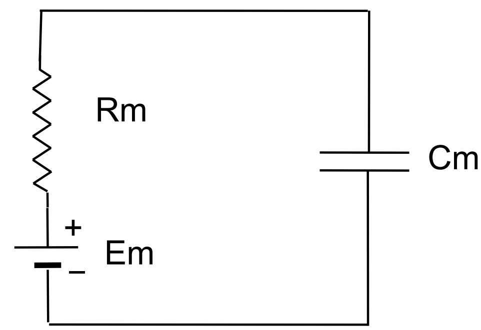
Yes, V increases while Q and E are the same so C decreases.



Membrane Equivalent Circuit



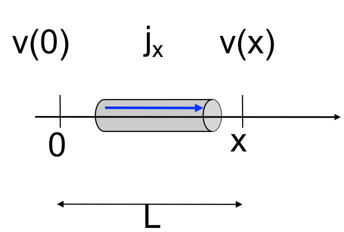




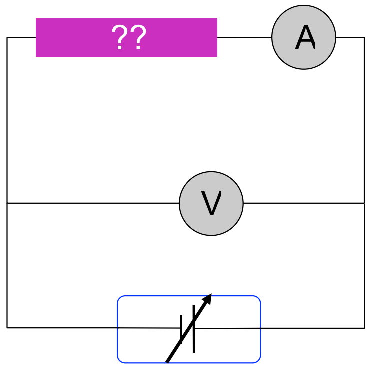
Current and Ohm's Law

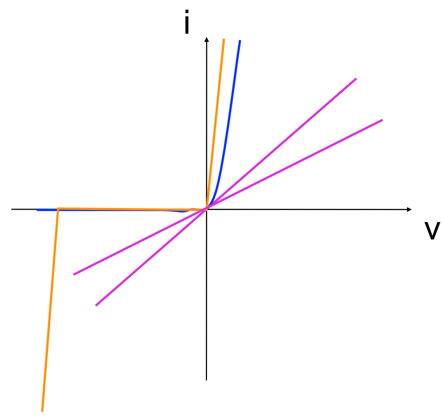
- Without potential difference there is no current!
- Without conductance, there is no current.
- Ohm's law:
  - linear relationship between current and voltage
  - not universal, especially not in living systems

$$I = \frac{1}{R} V = GV$$

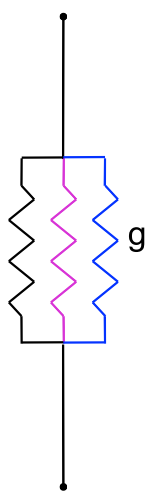


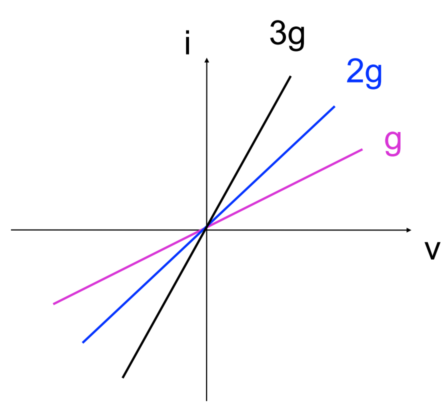
Current-Voltage (I-V) Curves



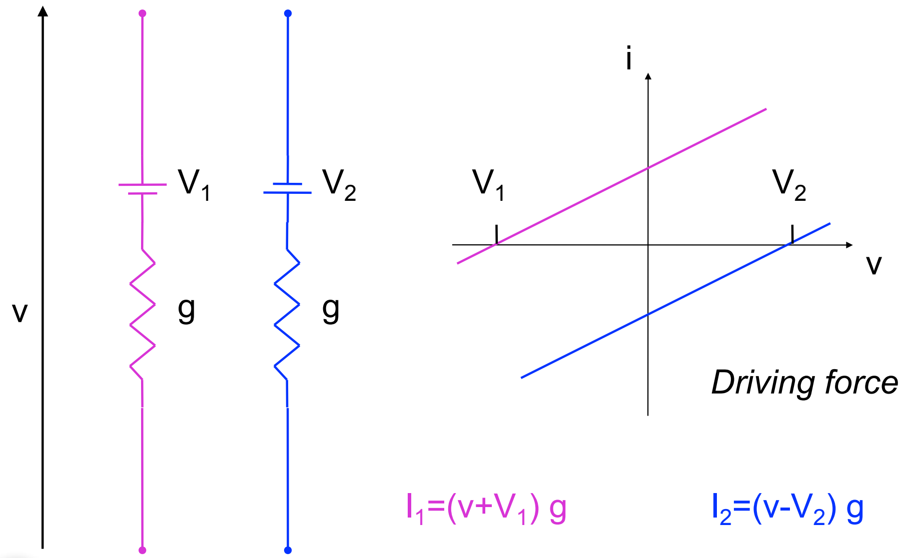


Equivalent circuits 1



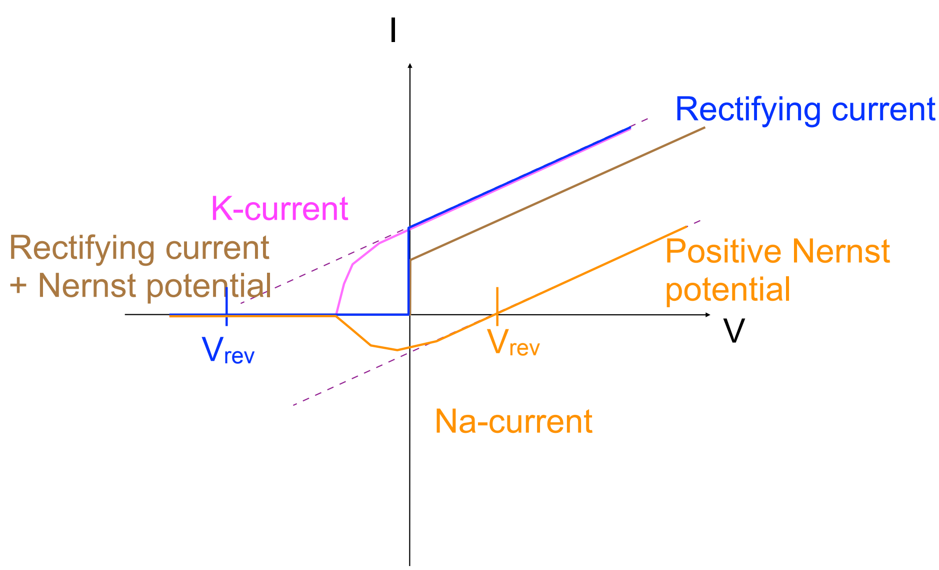


Equivalent circuits 2



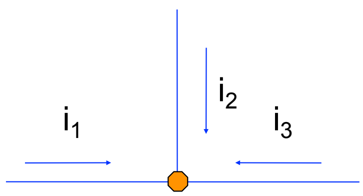
$I_1=(v+V_1)\ g$ $\quad$ $I_2=(v-V_2)\ g$

I-V Curve Examples

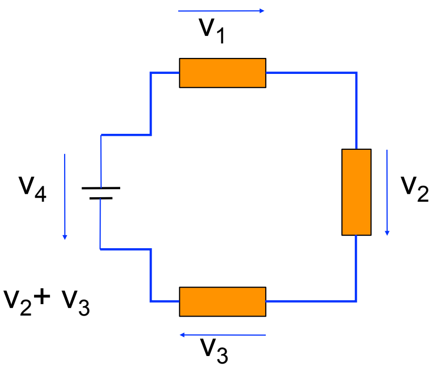


Circuit Analysis

- Conservation of charge: currents sum at nodes
- Conservation of energy: sum of voltages = 0



$i_1 + i_2 + i_3 = 0$



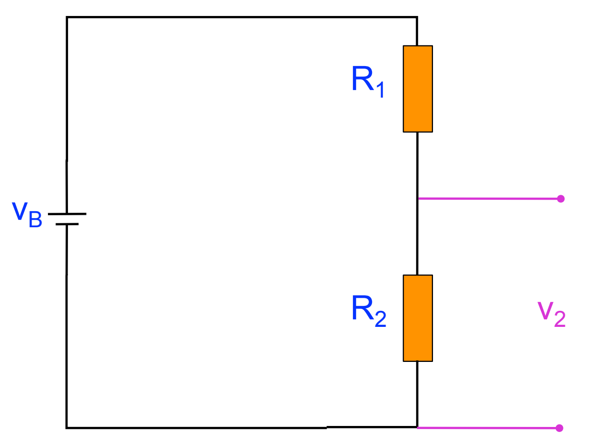
$v_4 = v_1 + v_2 + v_3$

Voltage Divider

$i = v_B/(R_1+R_2)$

$i = v_2/R_2$

$v_2 = v_B\, R_2/(R_1+R_2)$



Examples of voltage dividers in EP measurements?

Electrical Profile of a Cell