-neurophys-I

Visualizing the microanatomy of the brain

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EyeWire.org

http://eyewire.org

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Neural communication

- Electrical
  - Fast(er)
  - Within neurons
- Chemical
  - Slow(er)
  - Between neurons

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How are messages generated?

- Electrical potential (== voltage)
  - Think of potential energy
  - Voltage ~ pressure
  - Energy that will be released if something changes

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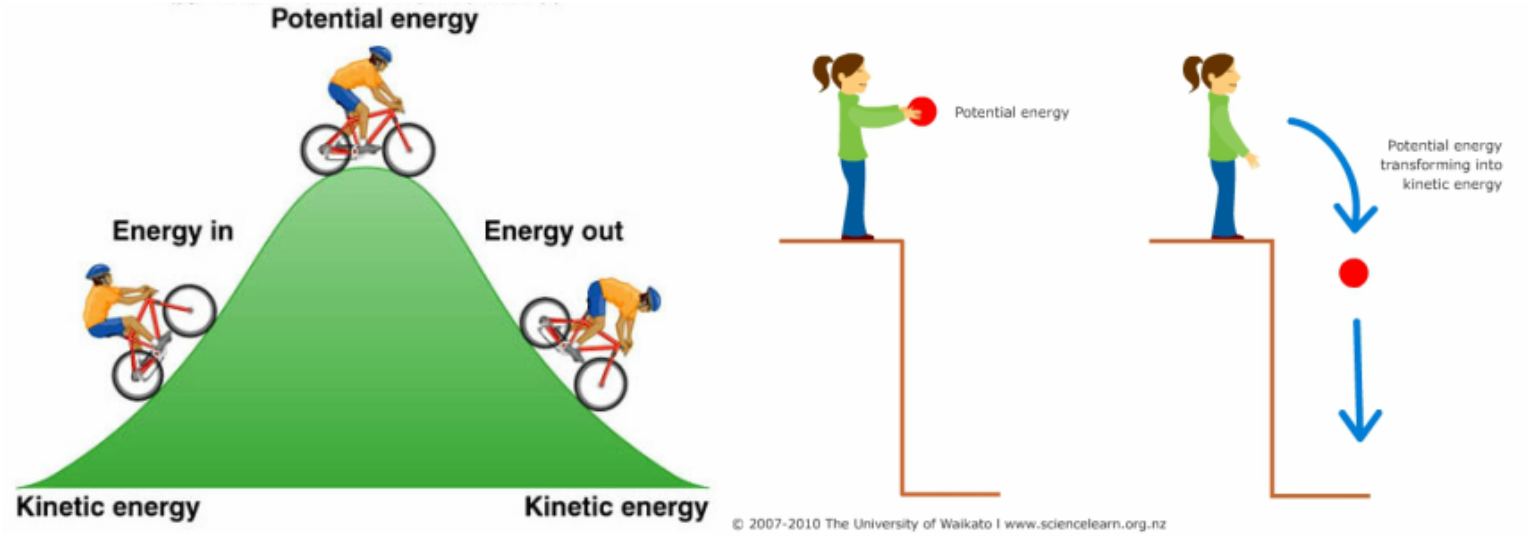
Potential energy



http://physics20project.weebly.com/uploads/1/6/4/8/16484122/1358825569.png

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Types of neural electrical potentials

- Resting potential
- Action potential

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Resting potential

- Measurement
  - Electrode on inside
  - Electrode on outside
  - Inside - Outside = potential

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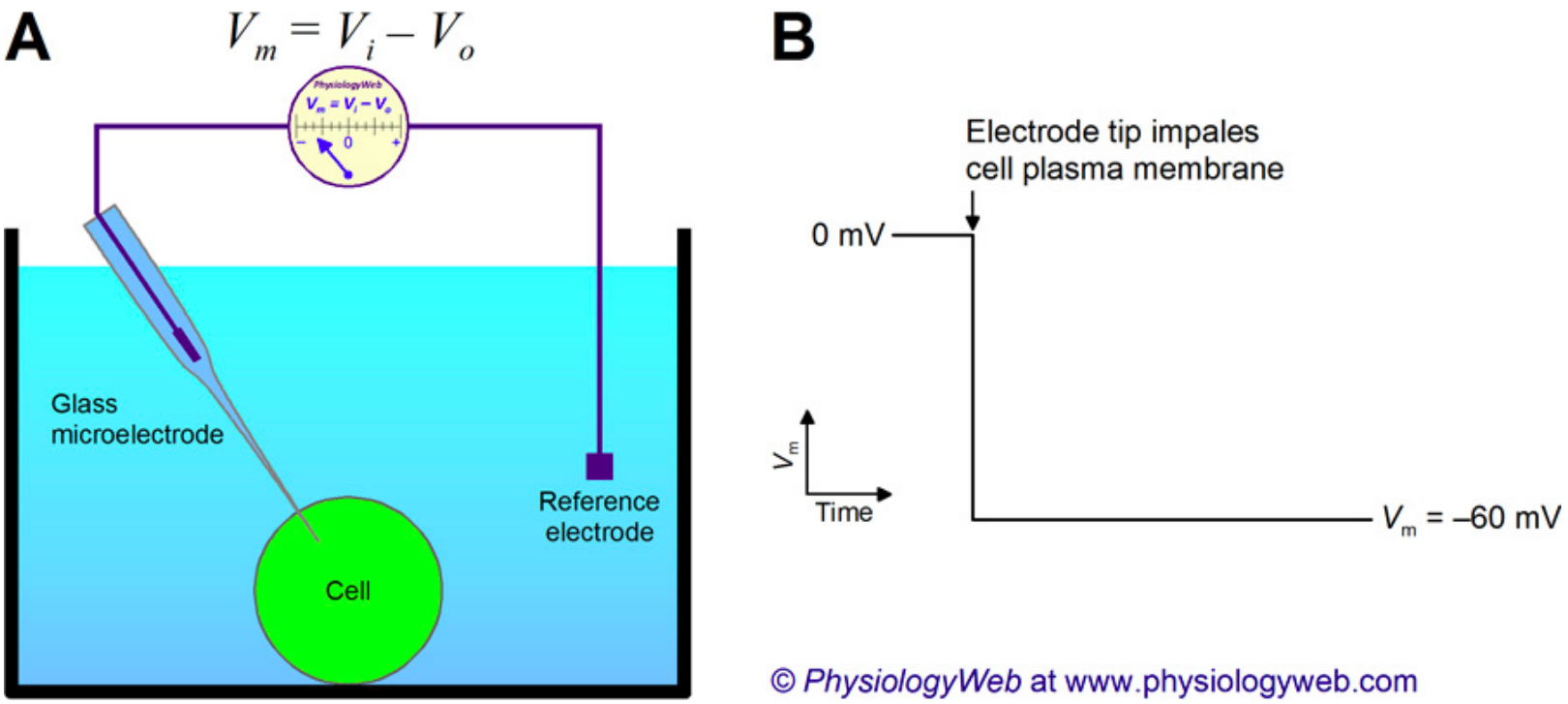
Resting potential



http://www.physiologyweb.com/lecture_notes/resting_membrane_potential/figs/meas

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Resting potential

- Neuron (and other cells) have *potential energy*
  - Inside is -60-70 mV, with respect to outside
  - About 1/20th typical AAA battery
- Like charges repel, opposites attract, so
  - Positively charged particles pulled in
  - Negatively charged particles pushed out

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Where does the resting potential come from?

- Ions
- Ion channels
- Separation between charges
- A balance of forces

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We are the champIONs, my friend

- Potassium, K+
- Sodium, Na+
- Chloride, Cl-
- Calcium, Ca++
- Organic anions, A-

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Party On

- Annie (A-) was having a party.
  - Used to date Nate (Na+), but now sees Karl (K+)
- Hired bouncers called
  - "The Channels"
  - Let Karl and friends in or out, keep Nate out
- Annie's friends (A-) and Karl's (K+) mostly inside
- Nate and friends (Na+) mostly outside
- Claudia (Cl-) tagging along

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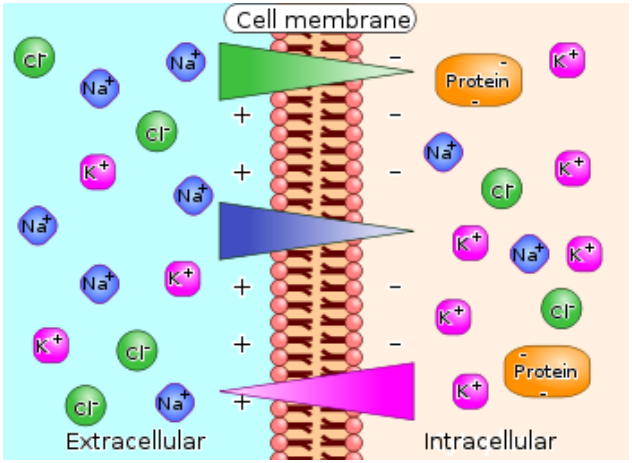
Party On



http://chemwiki.ucdavis.edu/@api/deki/files/104/350px-Membrane_potential_ions_en.svg.png?size=bestfit&width=350&height=255&revision=1

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Ion channels

- Openings in neural membrane
- Selective
- Vary in permeability
- Types
    - Passive/leak
    - Voltage-gated
    - Ligand-gated (chemically-gated)
    - Transporters

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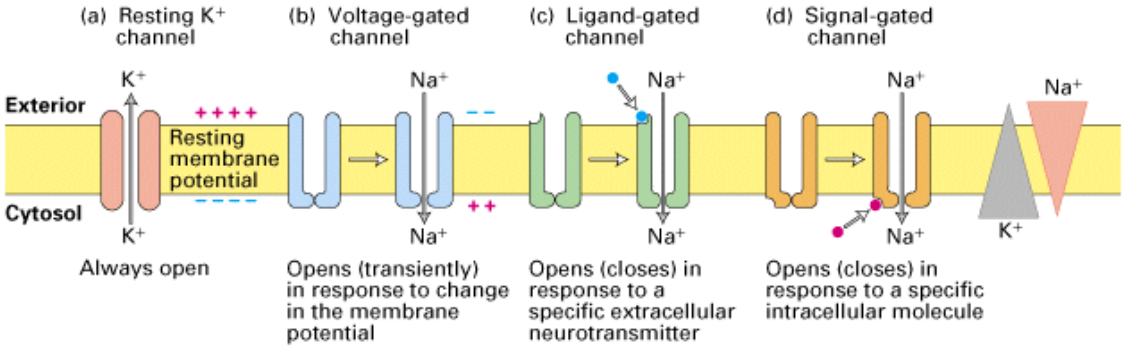
Ion channels



http://www.zoology.ubc.ca/~gardner/F21-08.GIF

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Neuron at rest permeable to K+

- Passive K+ channels open
- K+ flows out
- K+ outflow creates charge separation
- Charge separation creates voltage
- Voltage prevents K+ concentration from equalizing b/w inside and out

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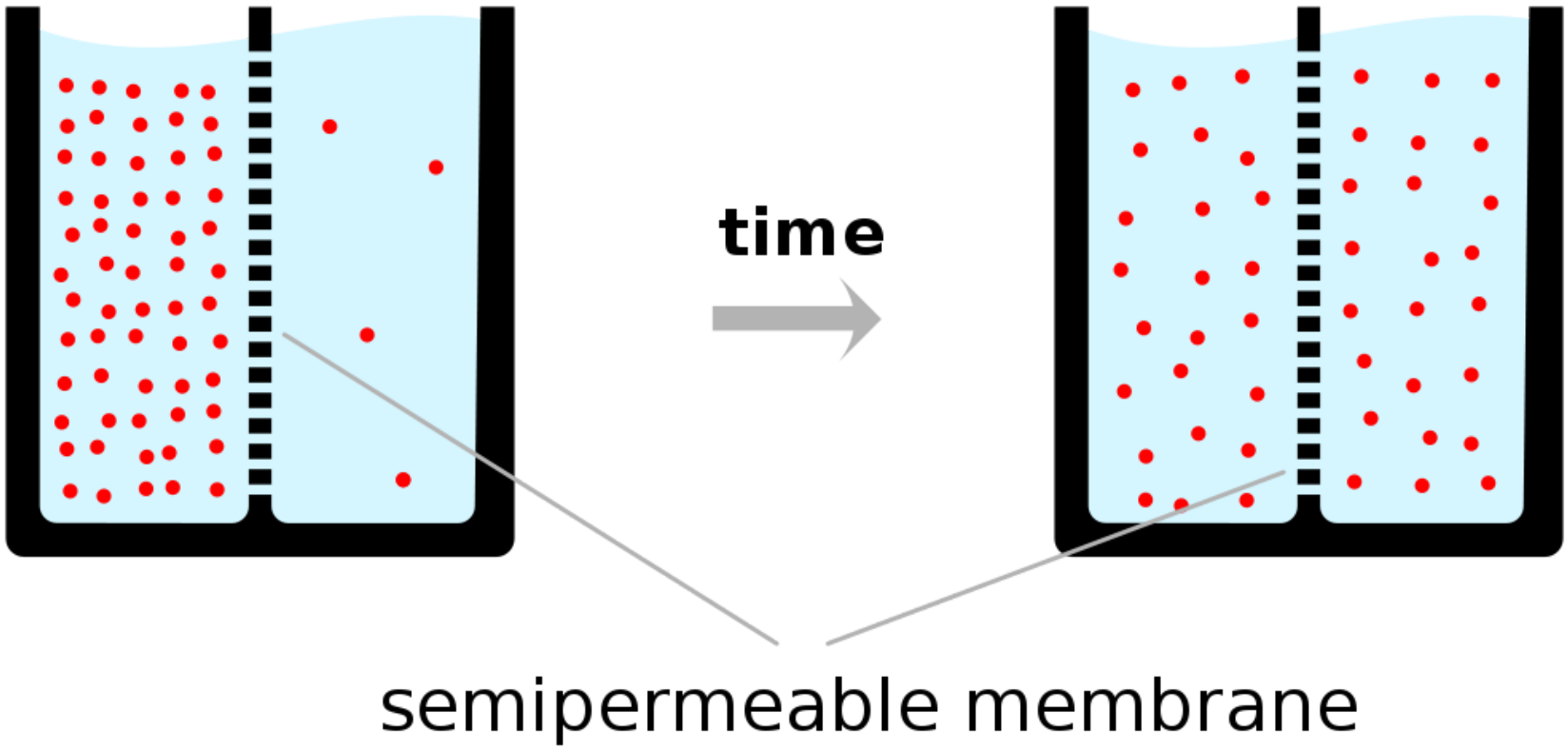
Force of diffusion



https://upload.wikimedia.org/wikipedia/commons/thumb/7/72/Diffusion.en.svg/1000p
Diffusion.en.svg.png

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Force of diffusion

https://upload.wikimedia.org/wikipedia/commons/1/12/Bubble_bath.jpg

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Neuron at rest

- Force of diffusion
  - K+ moves from high concentration (inside) to low (outside)
- Electrostatic pressure
  - Voltage build-up stops K+ outflow
  - Voltage called "reversal potential"
  - K+ positive, so reversal potential negative (w/ respect to outside)
  - Reversal potential close to resting potential

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Equilibrium potential and Nernst equation

$$V_{\mathrm{K}} = \frac{RT}{(+1)F} \ln \frac{[\mathrm{K}^+]_o}{[\mathrm{K}^+]_i}$$

http://www.physiologyweb.com/lecture_notes/resting_membrane_potential/figs/nerns

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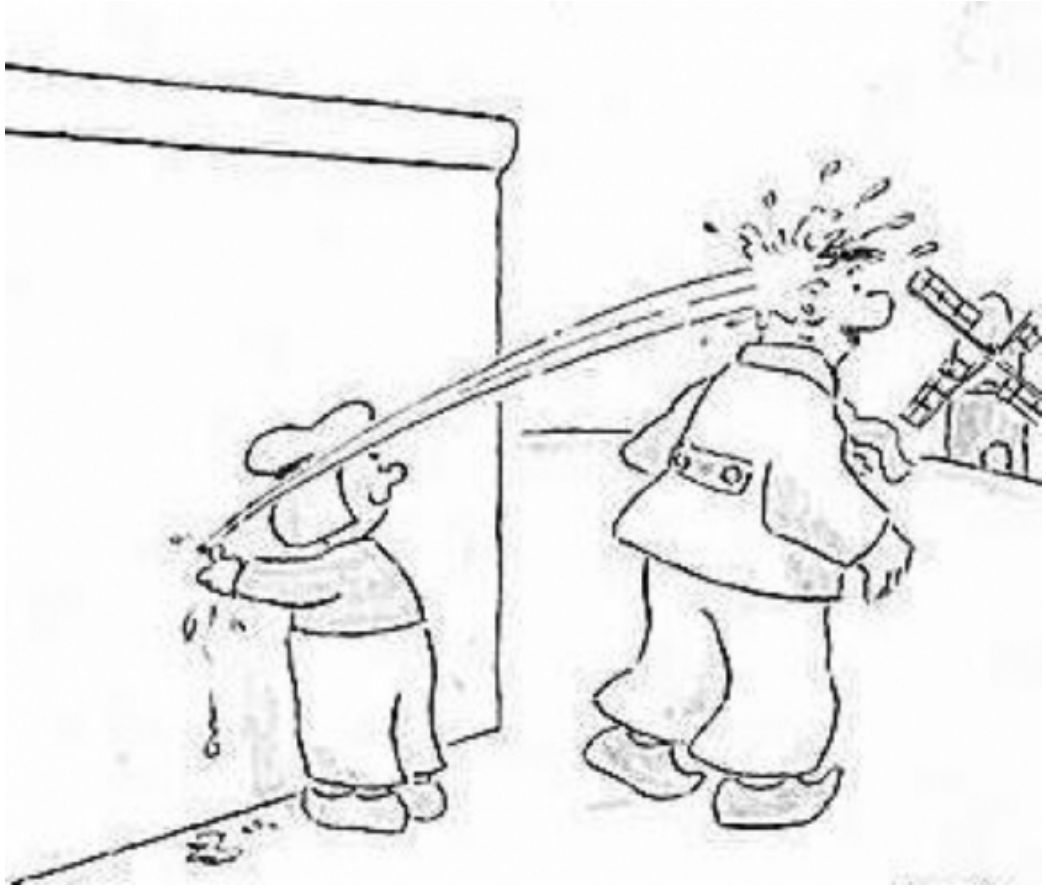
Building on intution



http://www.daily-player.com/images/articles/finger-in-the-dyke.jpg

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Back to neurons

- Na+ has reversal potential
- Membrane at rest not very permeable to Na+
- Concentrated outside neuron
- Some Na+ flows *in*
- Equilibrium potential is positive (with respect to outside)

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Resting potential

- Net effects of ion flow across membrane
- Goldman-Hodgkin-Katz equation

$$V_m = \frac{RT}{F} \ln\left(\frac{p_K[K^+]_o + p_{Na}[Na^+]_o + p_{Cl}[Cl^-]_i}{p_K[K^+]_i + p_{Na}[Na^+]_i + p_{Cl}[Cl^-]_o} \right)$$

http://www.physiologyweb.com/calculators/figs/ghk_equation.gif

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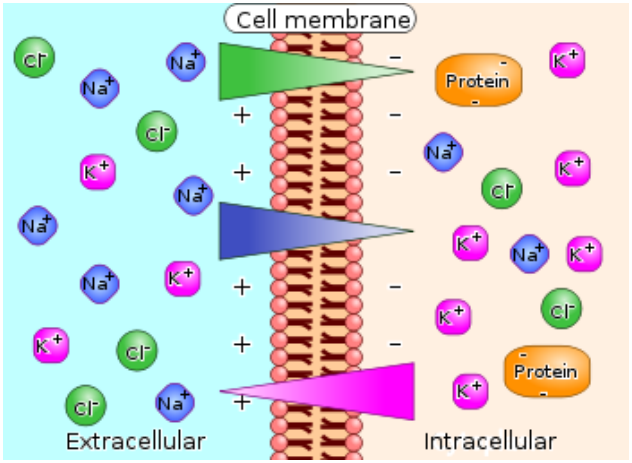
Resting potential



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What happens if something changes?

- Easier for Karl [K+] to exit?
- Easier for Nate [Na+] to enter?
- Some action!

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