

# 260-2015-09-16-neurophys-I

Rick Gilmore

2015-09-15 13:17:19

# Today's Topics

- Go over Quiz 1
- Neurophysiology

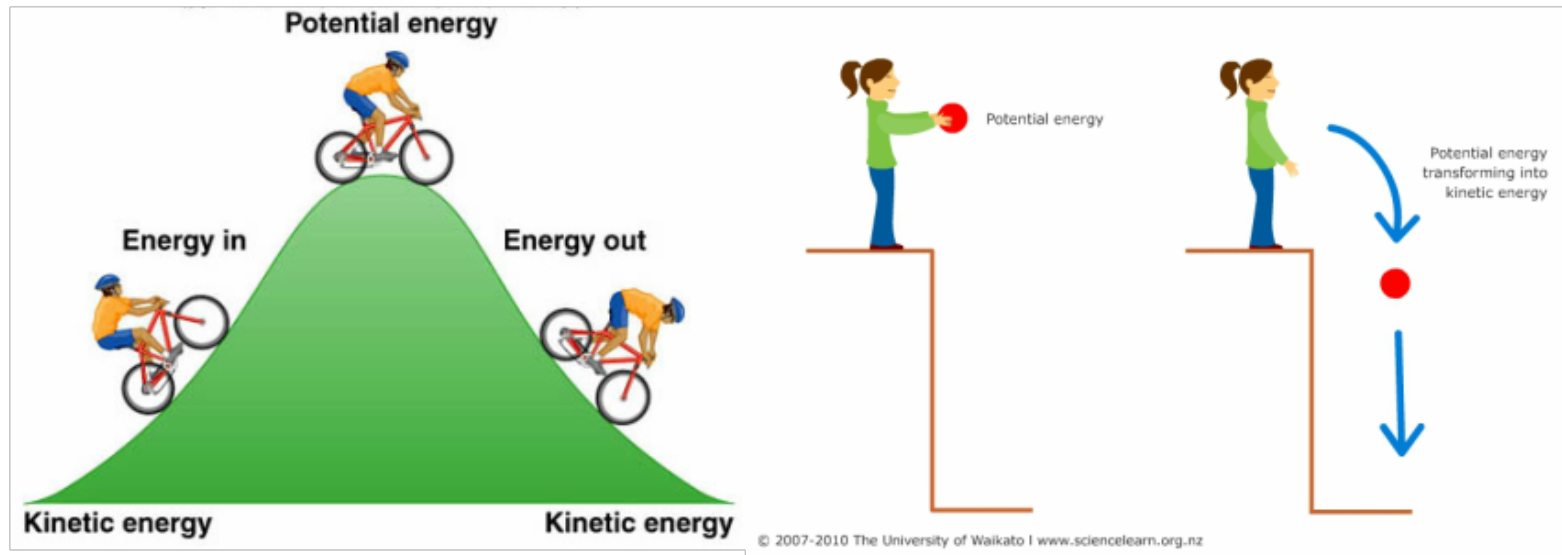
# Neural communication

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

# How are messages generated?

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

# Potential energy



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

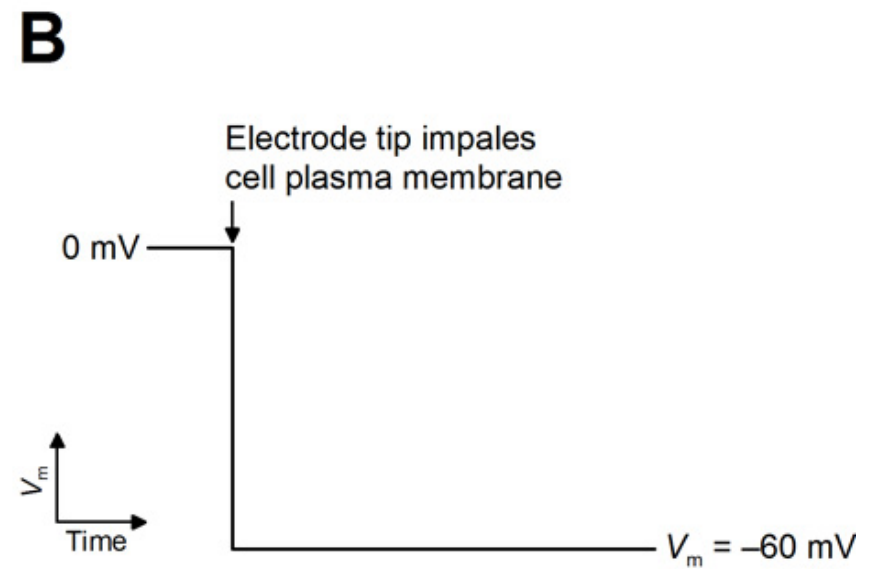
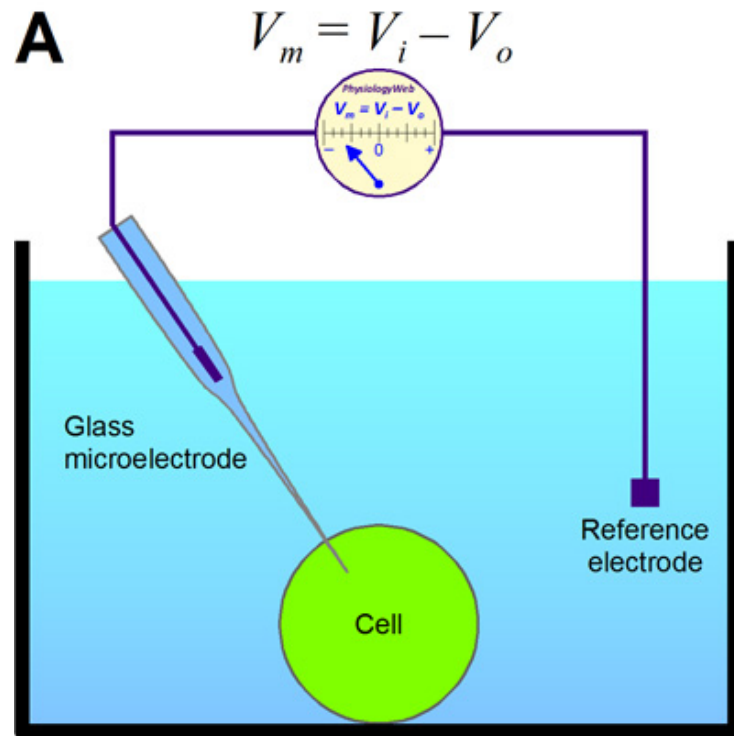
# Types of neural electrical potentials

- Resting potential
- Action potential

# Resting potential

- Measurement
  - Electrode on inside
  - Electrode on outside (reference)
  - Inside - Outside = potential

# Resting potential



© PhysiologyWeb at [www.physiologyweb.com](http://www.physiologyweb.com)

[http://www.physiologyweb.com/lecture\\_notes/resting\\_membrane\\_potential/figs/meas](http://www.physiologyweb.com/lecture_notes/resting_membrane_potential/figs/meas)



# 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

# Where does the resting potential come from?

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

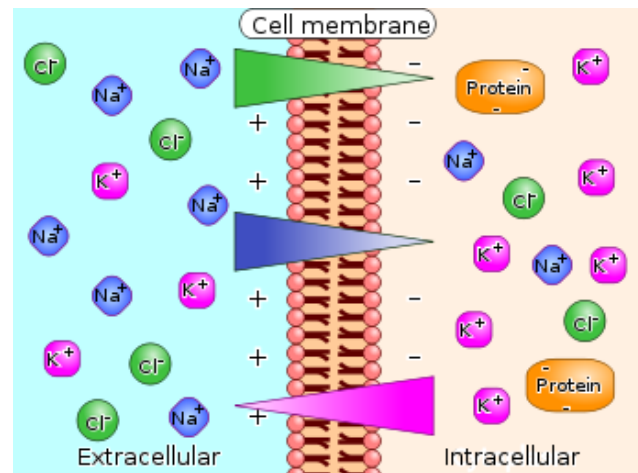
# We are the champlONs, my friend

- Potassium,  $K^+$
- Sodium,  $Na^+$
- Chloride,  $Cl^-$
- Calcium,  $Ca^{++}$
- Organic anions,  $A^-$

# 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

# Party On

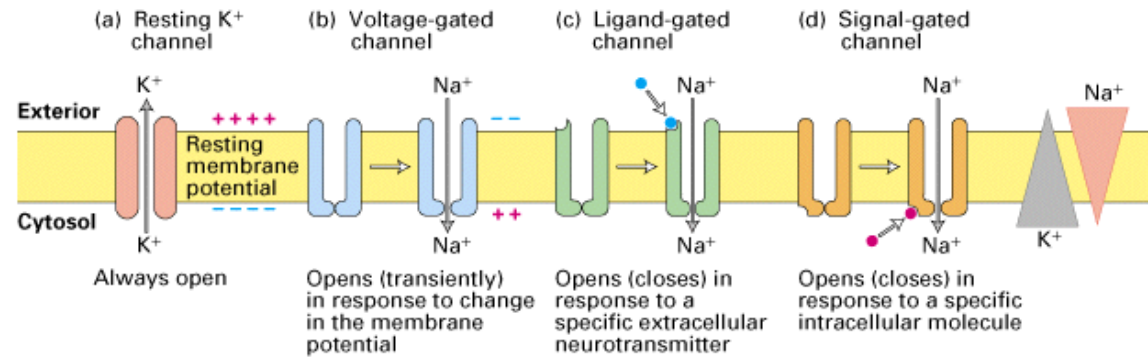


[http://chemwiki.ucdavis.edu/@api/deki/files/104/350px-Membrane\\_potential\\_ions\\_en.svg.png?size=bestfit&width=350&height=255&revision=1](http://chemwiki.ucdavis.edu/@api/deki/files/104/350px-Membrane_potential_ions_en.svg.png?size=bestfit&width=350&height=255&revision=1)

# Ion channels

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

# Ion channels



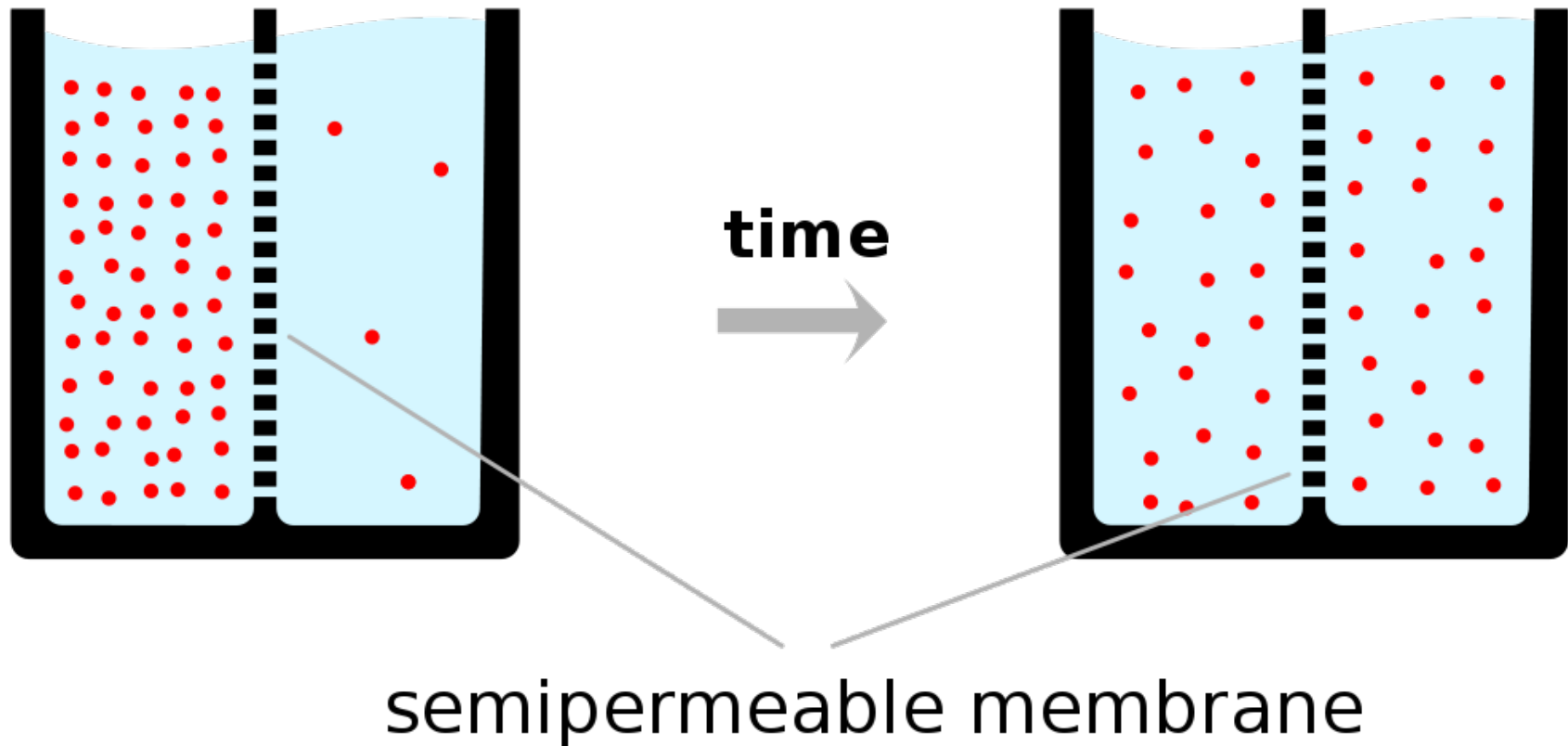
<http://www.zoology.ubc.ca/~gardner/F21-08.GIF>

# 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



# Force of diffusion



<https://upload.wikimedia.org/wikipedia/commons/thumb/7/72/Diffusion.en.svg/1000px-Diffusion.en.svg.png>

17/27

# Force of diffusion



# Neuron at rest

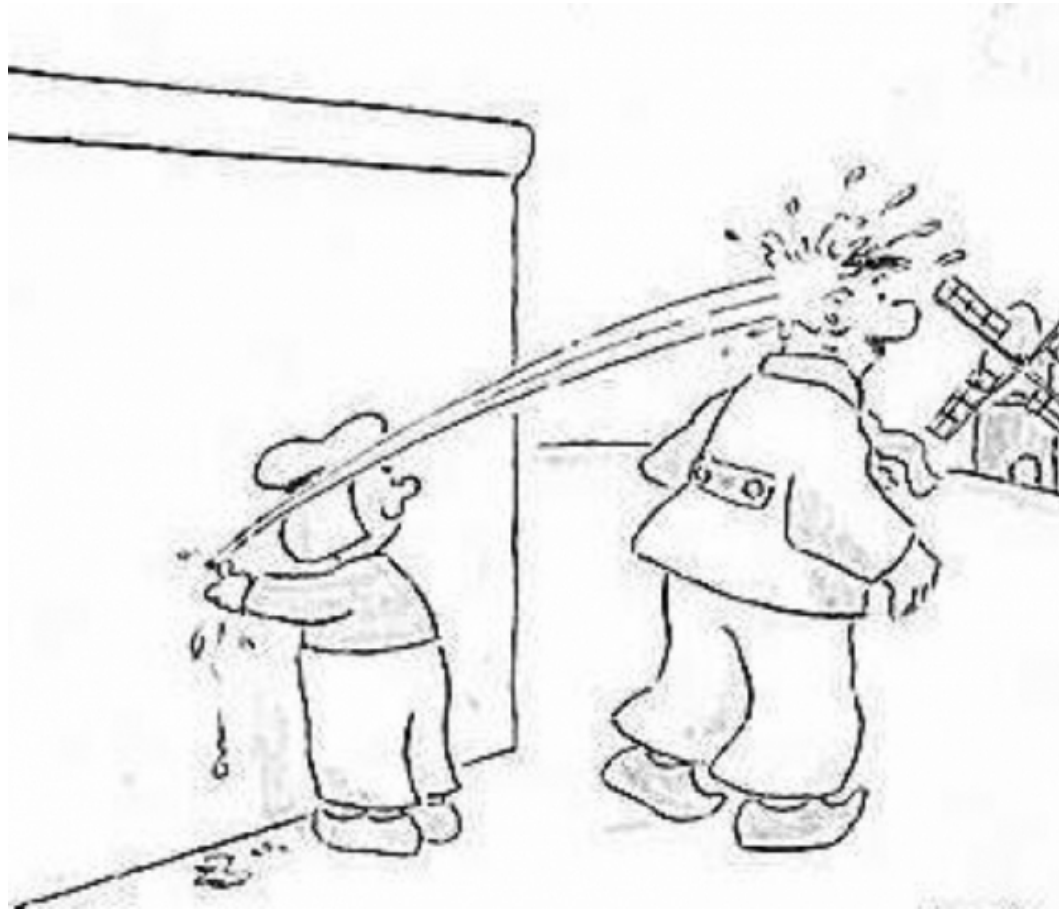
- Force of diffusion
  - $K^+$  moves from high concentration (inside) to low (outside)
- Electrostatic pressure
  - Voltage build-up stops  $K^+$  outflow
  - Voltage called "reversal potential"
  - $K^+$  positive, so reversal potential negative (w/ respect to outside)
  - Reversal potential close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

# Equilibrium potential and Nernst equation

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

[http://www.physiologyweb.com/lecture\\_notes/resting\\_membrane\\_potential/figs/nerns](http://www.physiologyweb.com/lecture_notes/resting_membrane_potential/figs/nerns)

# Building on intuition



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

21/27

# Back to neurons

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

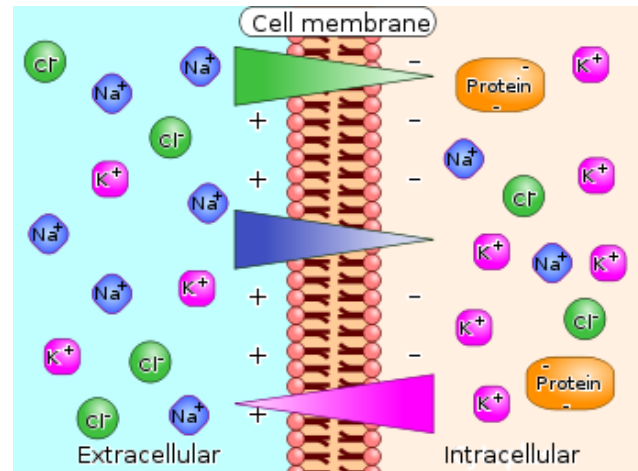
# Resting potential

- 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](http://www.physiologyweb.com/calculators/figs/ghk_equation.gif)

# Resting potential



[http://chemwiki.ucdavis.edu/@api/deki/files/104/350px-Membrane\\_potential\\_ions\\_en.svg.png?size=bestfit&width=350&height=255&revision=1](http://chemwiki.ucdavis.edu/@api/deki/files/104/350px-Membrane_potential_ions_en.svg.png?size=bestfit&width=350&height=255&revision=1)



# 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

# What happens if something changes?

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

# Next time

- The action potential