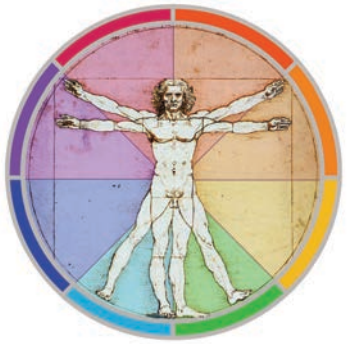
HUBS191 Lecture Material

This pre-lecture material is to help you prepare for the lecture and to assist your note-taking within the lecture,

it is NOT a substitute for the lecture !



Please note that although every effort is made to ensure this pre-lecture material corresponds to the live-lecture there may be differences / additions.

Physiological Principles of
Human Movement and Sensation

HUBS191

Lecture 21

Dr Martin Fronius
Department of Physiology
3. April 2017

Anatomy to Physiology

Full Definition of ANATOMY

plural **anat·o·mies**

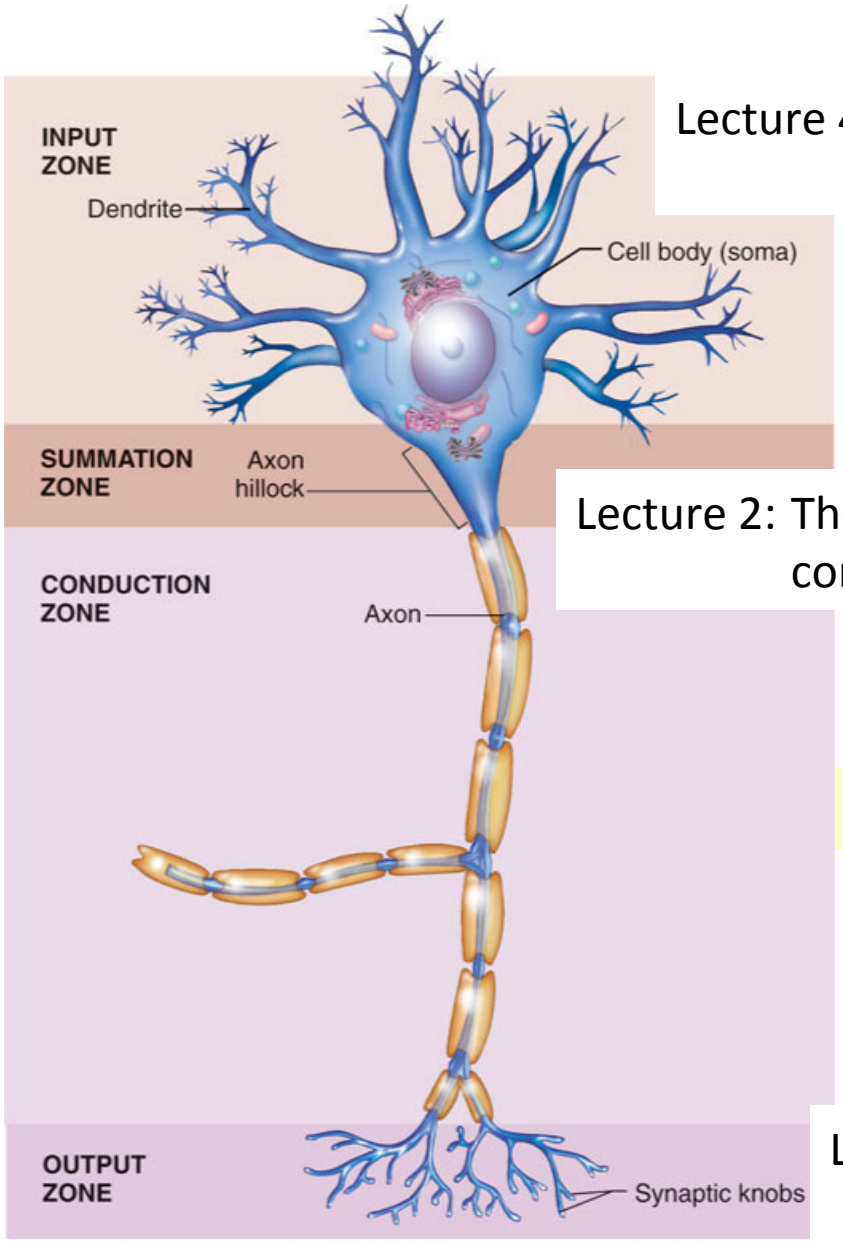
1 : a branch of morphology that deals with the structure of organisms

Full Definition of PHYSIOLOGY

1 : a branch of biology that deals with the functions and activities of life or of living matter (as organs, tissues, or cells) and of the physical and chemical phenomena involved — compare ANATOMY

From http://www.merriam-webster.com

In the next four lectures…



Lecture 4: Synaptic Networks and Integration (input zone)

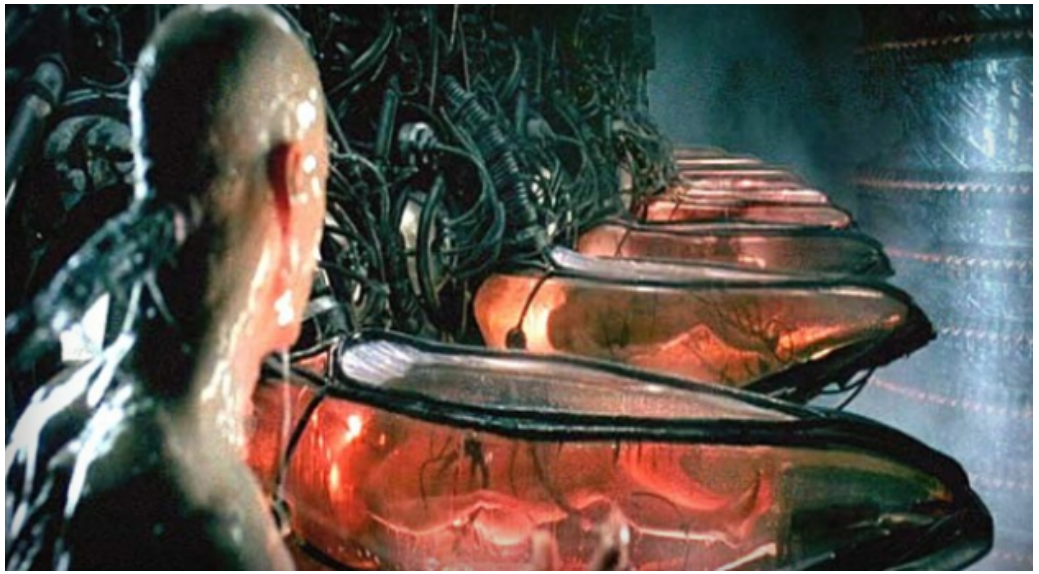
Lecture 2: The Action Potential and its conduction (axon hillock, axon)

Lecture 1: Bioelectricity and membrane potentials

Lecture 3: The Synapse – 'connecting' neurons (output zone)

Aims of Today's Lecture

Lecture 21 – Bioelectricity, Membrane Potentials



http://www.extremetech.com/extreme/135481-will-your-body-be-the-battery-of-the-future

Outline

- What is Electricity?
- What is Bio-Electricity
- Membrane Electrical Potential
- Types of Membrane Electrical Potentials

Objectives of Today's Lecture

- Know the **two main cations** that contribute to the electrical properties of a neuron
- Understand how these cations can move across membrane of the neuron → **ion channels/pump**
- List the different types of polarisation of a nerve cell membrane.
- Explain what is meant by the resting membrane potential
- Explain what is meant by a local potential

What is Electricity?

http://en.wikipedia.org

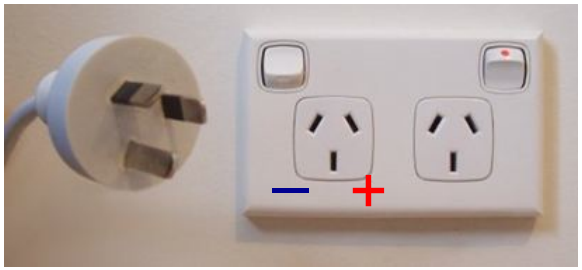
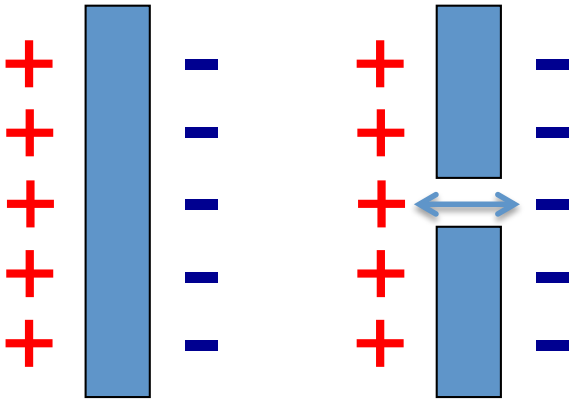


Image from www.thearrivalstore.com
Via Google Images

Image from www.octopart.com
Via Google Images



- Particles with different charge exist in nature, (+) or (–); → ions, electrons, protons
- Separation of Charge = Energy stored = Potential energy; → water dam
- Energy released – when charges OR current flows → can be used for work or signal transmission

Bio-Electricity – Science Fiction or Real?

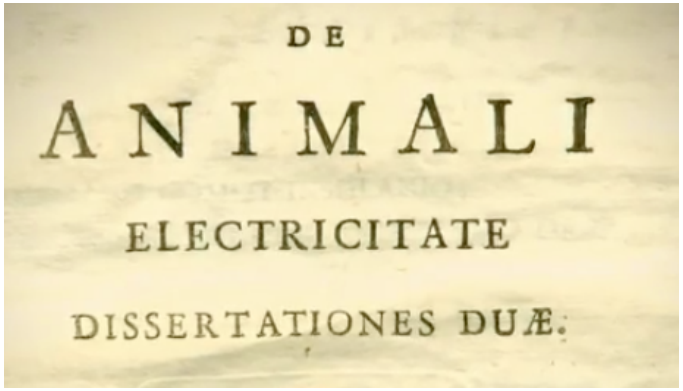
http://www.extremetech.com/extreme/135481-will-your-body-be-the-battery-of-the-future

'… will your body be the battery of the future?'

Bio-Electricity – is real!!!

http://en.wikipedia.org/wiki/Luigi_Galvani

- Experiments with frog legs
- Observed frog legs could be made to twitch

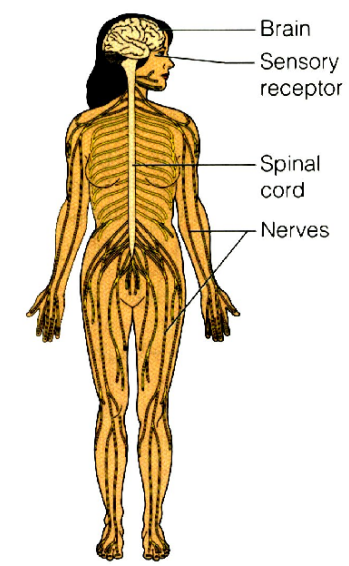


→ He concluded that animal tissue contained an innate **vital force**, termed "animal electricity."

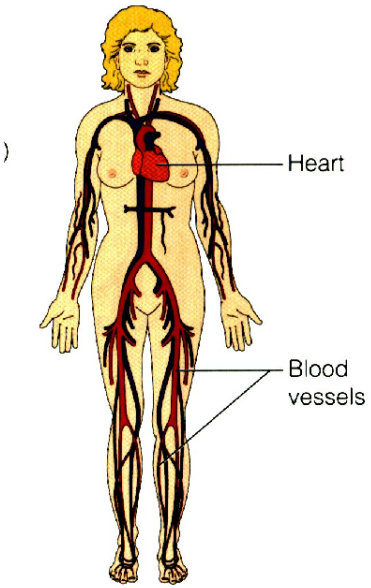
"…all life is electrical…"

All life is electrical – We are electrical

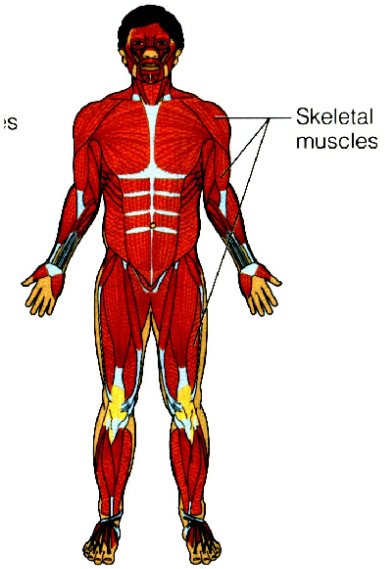
Electrical impulses control everything – RIGHT NOW



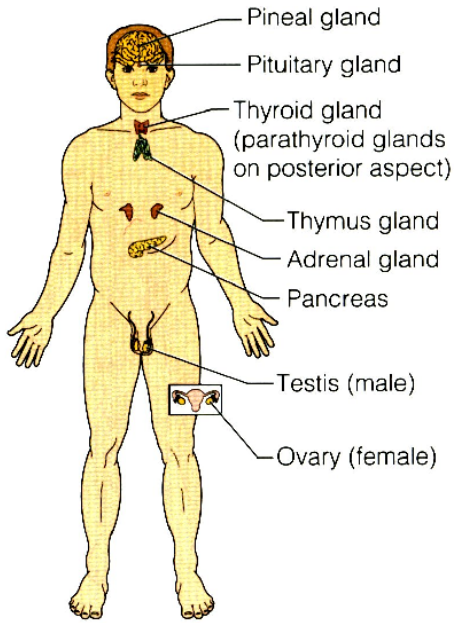
(d) Nervous system
Fast-acting control system of the body; responds to internal and external changes by activating appropriate muscles and glands.



(f) Cardiovascular system
Blood vessels transport blood which carries oxygen, carbon dioxide, nutrients, wastes, etc.; the heart pumps blood.



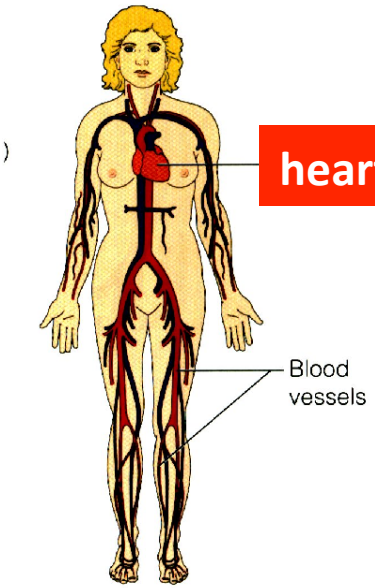
(c) Muscular system
Allows manipulation of the environment, locomotion, and facial expression; maintains posture; produces heat.



(e) Endocrine system
Glands secrete hormones that regulate processes such as growth, reproduction, and nutrient use (metabolism) by body cells.

Fig from Essentials of Human Anatomy & Physiology Marieb 7th Edn. p.5

Evidence for Bio-Electricity



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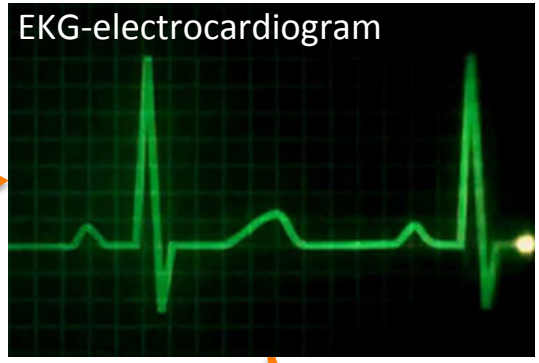
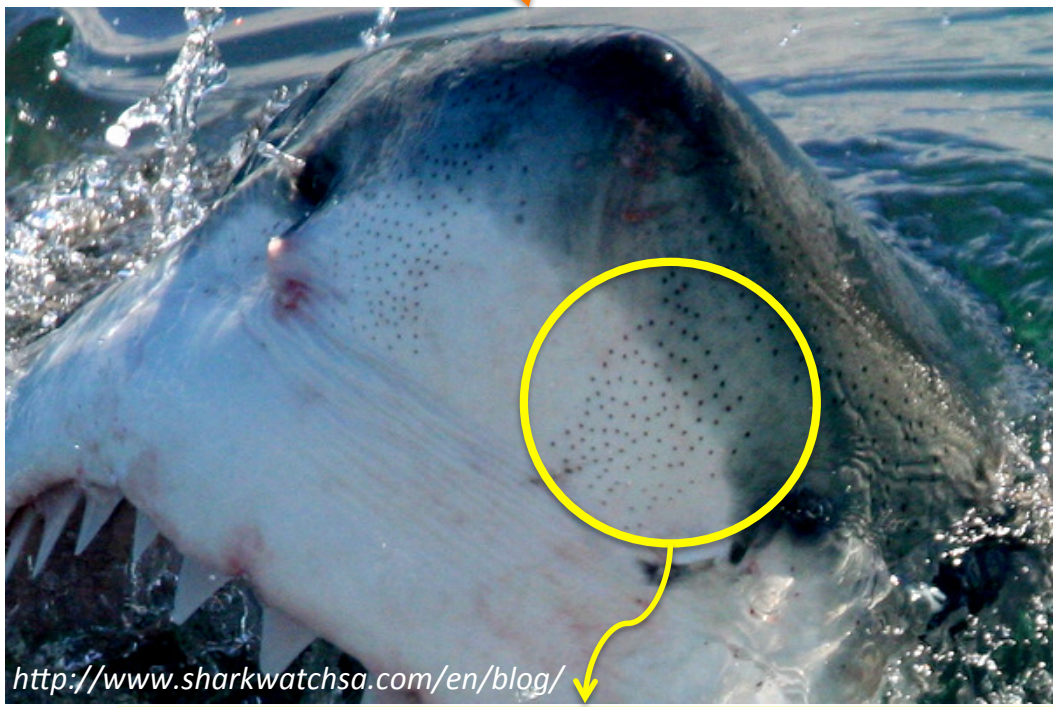
Blood vessels transport blood which carries oxygen, carbon dioxide, nutrients, wastes, etc.; the heart pumps blood.

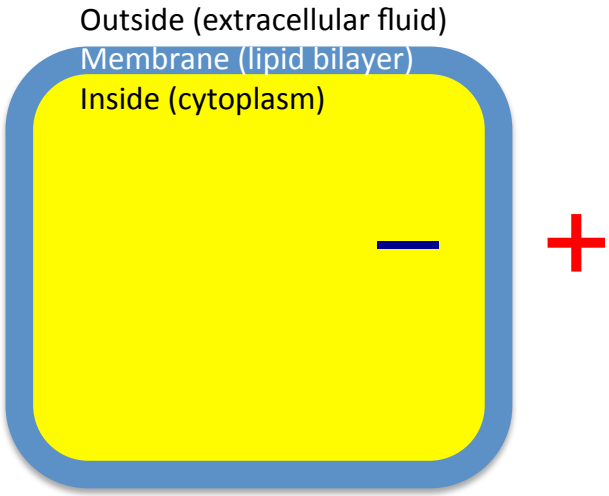


- Lab 3 and 4 measuring electrical activity generated in muscles → electromyography

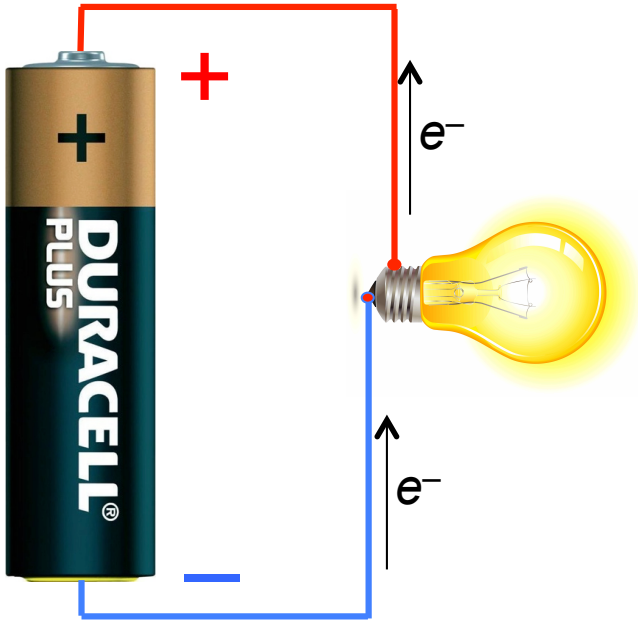


Ampullae of Lorenzini = electrical detectors

Origin of Bio-Electricity



Cell/neuron

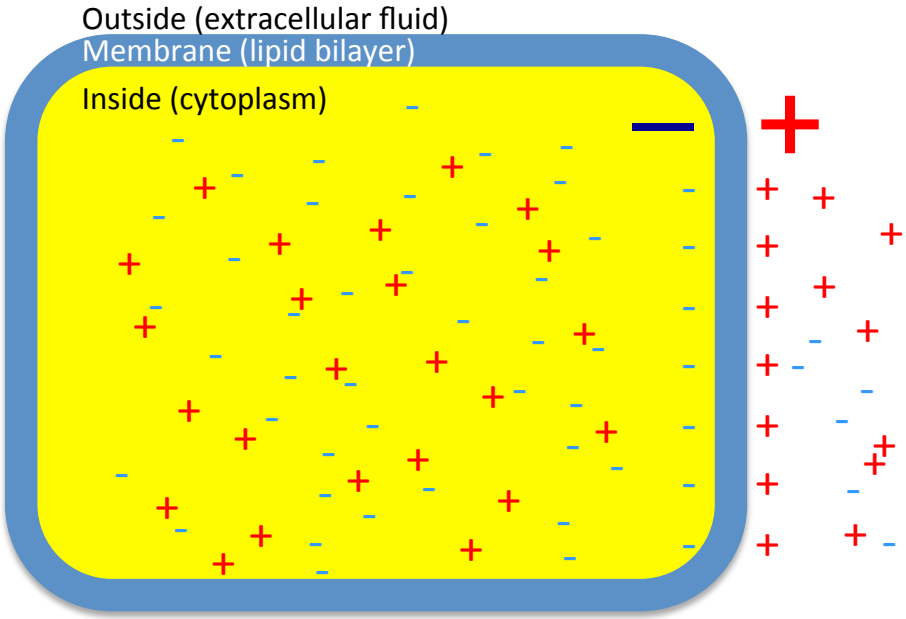


Images Image from www.octopart.com via Google

- Battery stores charges
  → that can be used to do work (light, start a car, run an iPod)
- Electrical CURRENT FLOWS to do the work ! → electrons

- A **cell is like a battery** – electrical charge stored across the cell membrane

What causes Bio-Electricity



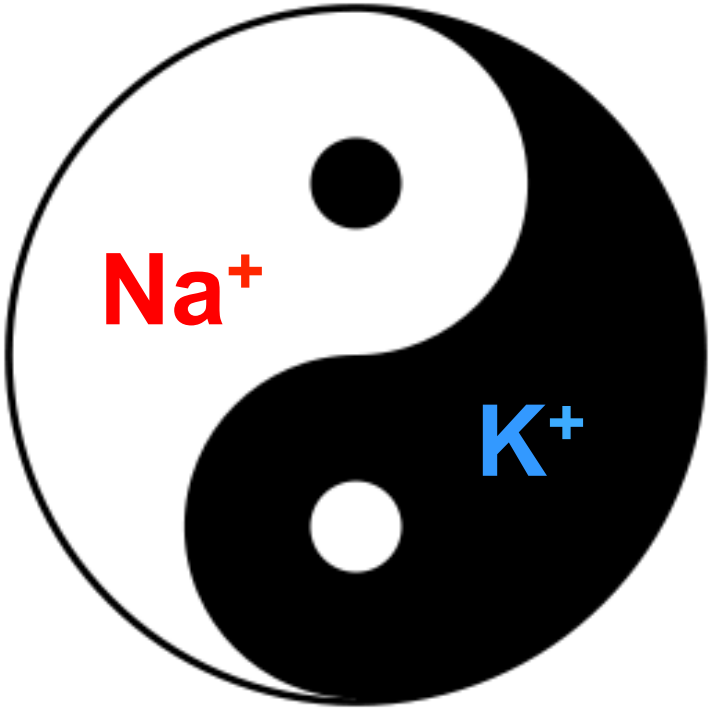
- Origin of charge in a cell are ions (dissolved in water)
- Two types: → **CATIONS (+)** and **ANIONS (–)**
- Ions: aka ‘electrolytes’

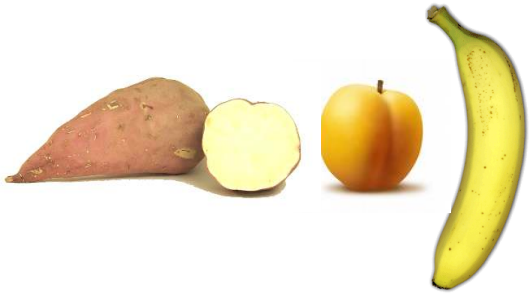
CATIONS
- Sodium → Na^+
- Potassium → K^+
- Calcium → Ca^{2+}

ANIONS
- Chloride → Cl^-
- Bicarbonate → HCO_3^-
- Proteins

CATIONS and ANIONS are uneven distributed outside and inside of cells

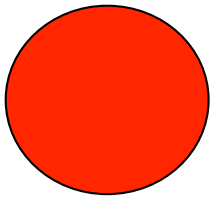
Two very important Cations…



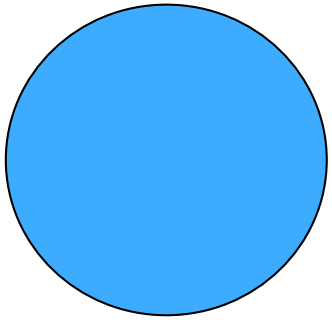


Na+

K+

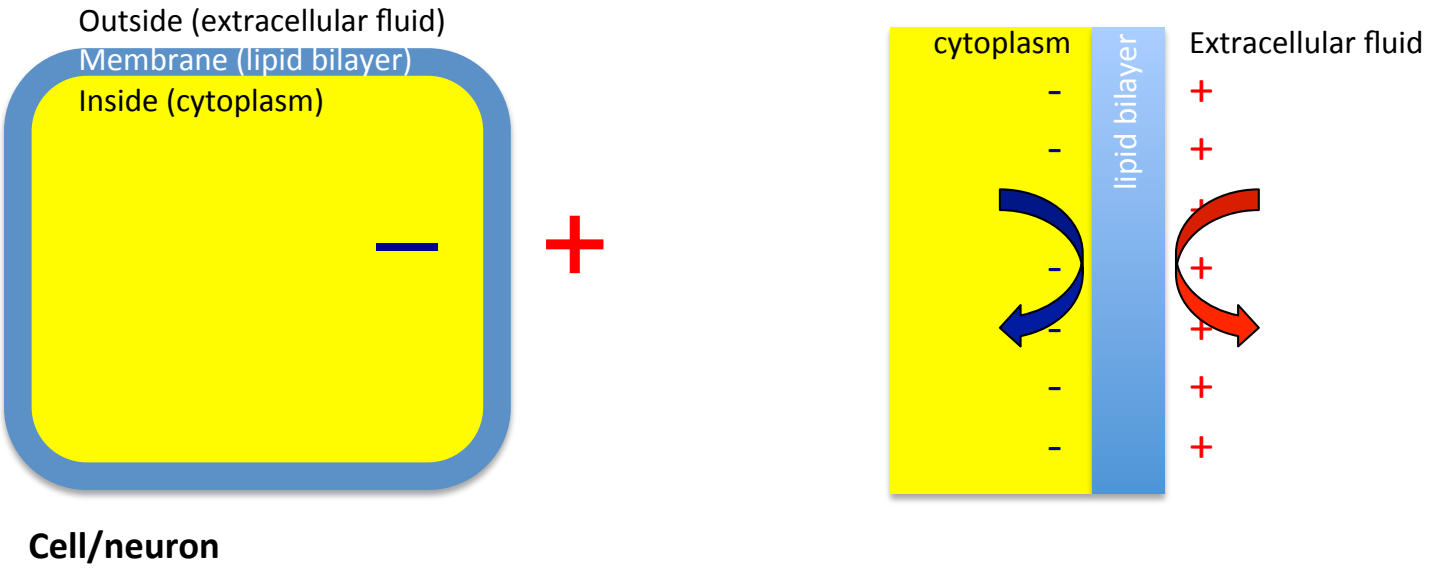


Note different sizes



- Bio-Electricity of neurons relies primarily on Na^+ and K^+
- **Na^+** and K^+ are vitally important for the health of our nervous systems

Cations and anions are present in- and outside of cells, but separated by the lipid bilayer



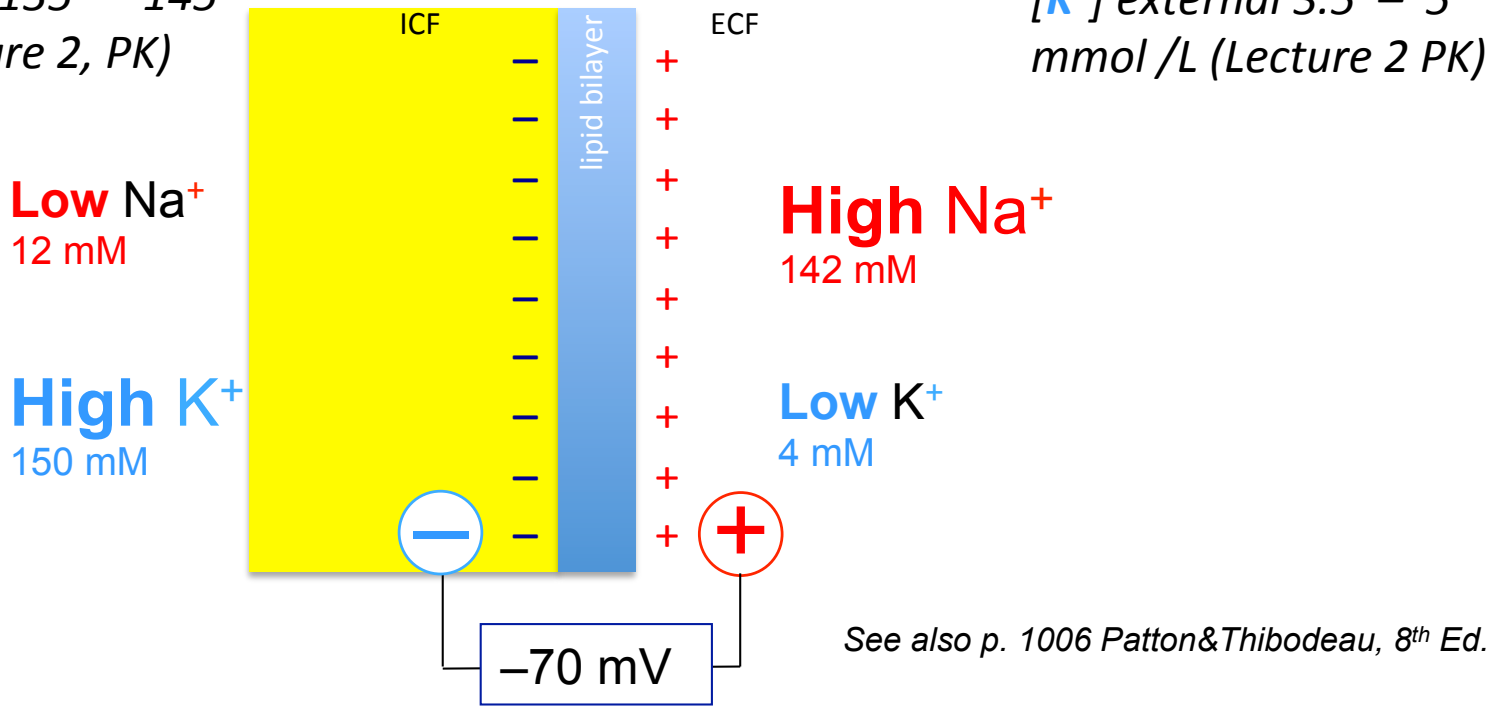
- Lipid bilayer is an INSULATOTR (diffusion barrier)!

→ **Cations** and **Anions** can not cross the lipid bilayer

The uneven distribution of ions creates cellular electricity – the membrane potential

*[**Na**$^+$] external 135 – 145 mmol /L (Lecture 2, PK)*

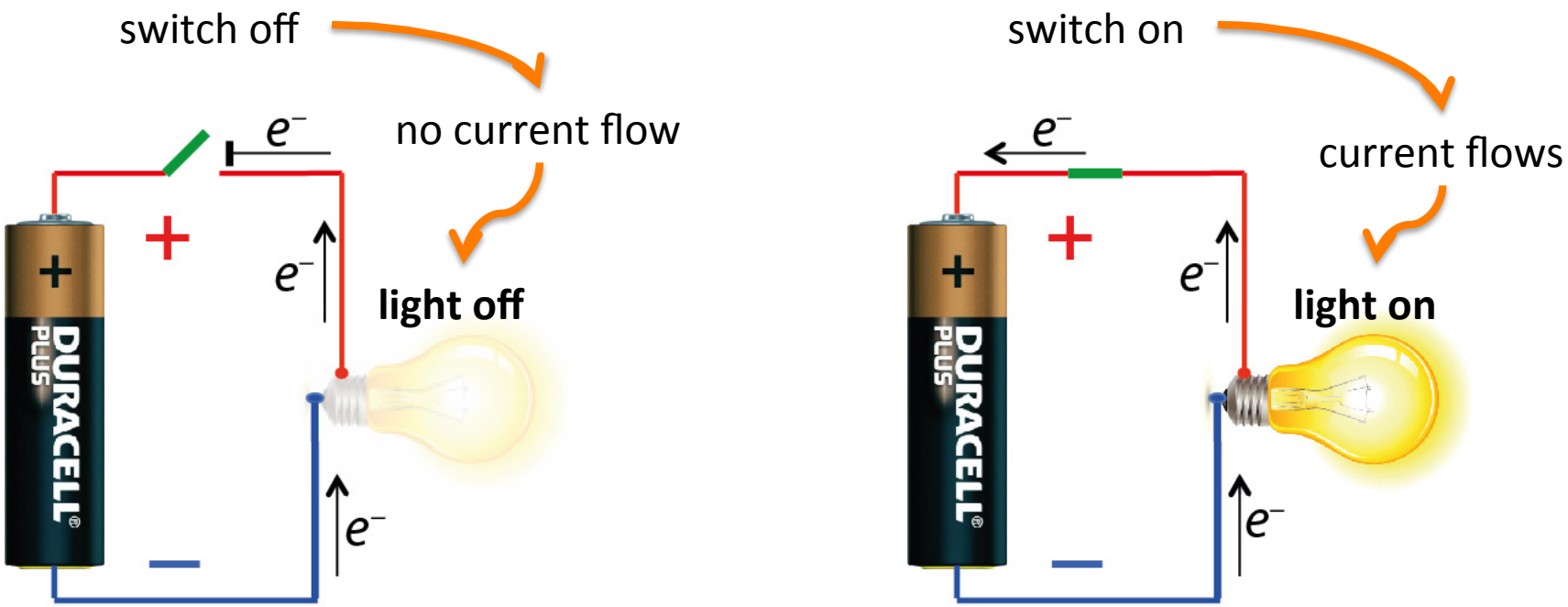
*[**K**$^+$] external 3.5 – 5 mmol /L (Lecture 2 PK)*



See also p. 1006 Patton&Thibodeau, 8th Ed.

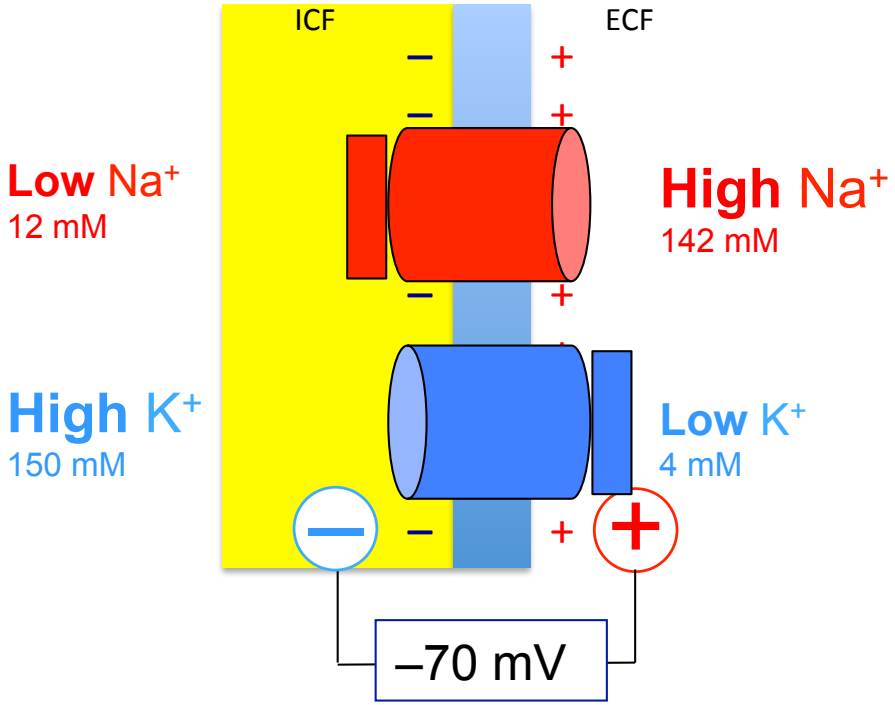
- This creates an electrical charge difference between the two sides of the membrane – like a small battery with a + and a – pole
- THIS IS CALLED THE RESTING MEMBRANE POTENTIAL
  in living neurons it is about -70 mV, slightly negative inside

For a battery to do ‘work’ – current must flow!

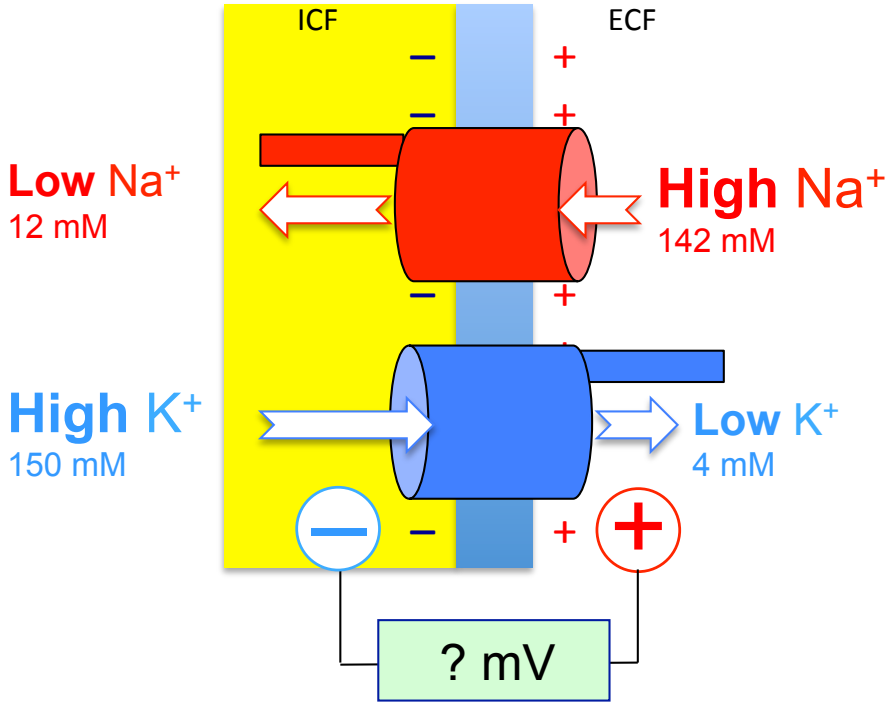


- Closed loop → electrical connection between + and – pole
- **Electrical switches** enable to control the ‘flow’ of e^-

Ion channels control the ‘current flow’ in neurons



Channel **closed** (off) → no current



Channel **open** (on) → current flow

- **Ion channels** (tunnel proteins) are cellular switches
- Closed (‘off mode’); open (‘on mode’)
- Open ion channels allow the passage of ions across the cell membrane → **ion current**

Different types of ion channels in the membrane of neurons

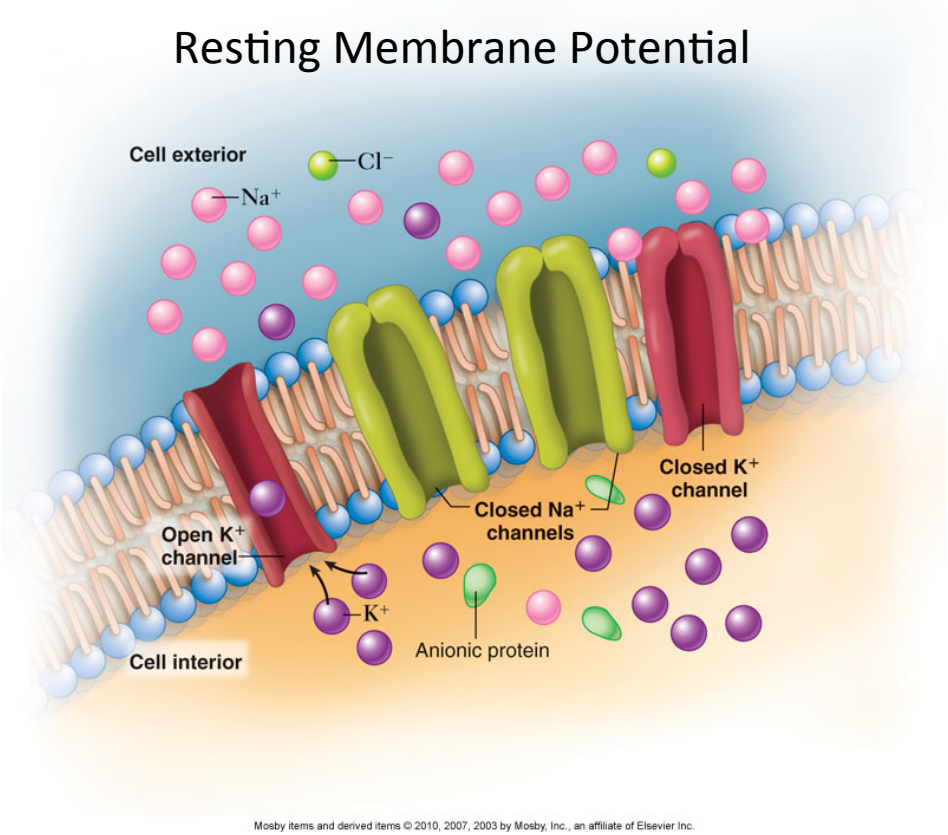


Fig. 13-15 Thibodeau and Patton 8th Ed p. 394

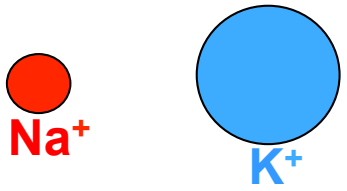
Ion channels are …

… responsible for the **permeability** of the cell membrane (semi-permeable)

… are **selective**

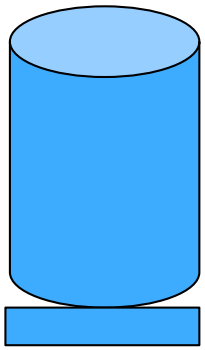
- Na^+ channels → Na^+ ions
- K^+ channels → K^+ ions

Remember Na^+ and K^+ are different sizes

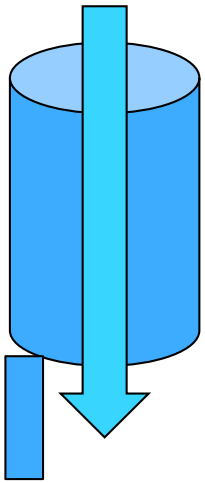


At Resting Membrane Potential (–70 mV) most Na^+ channels are closed; some K^+ channels are open

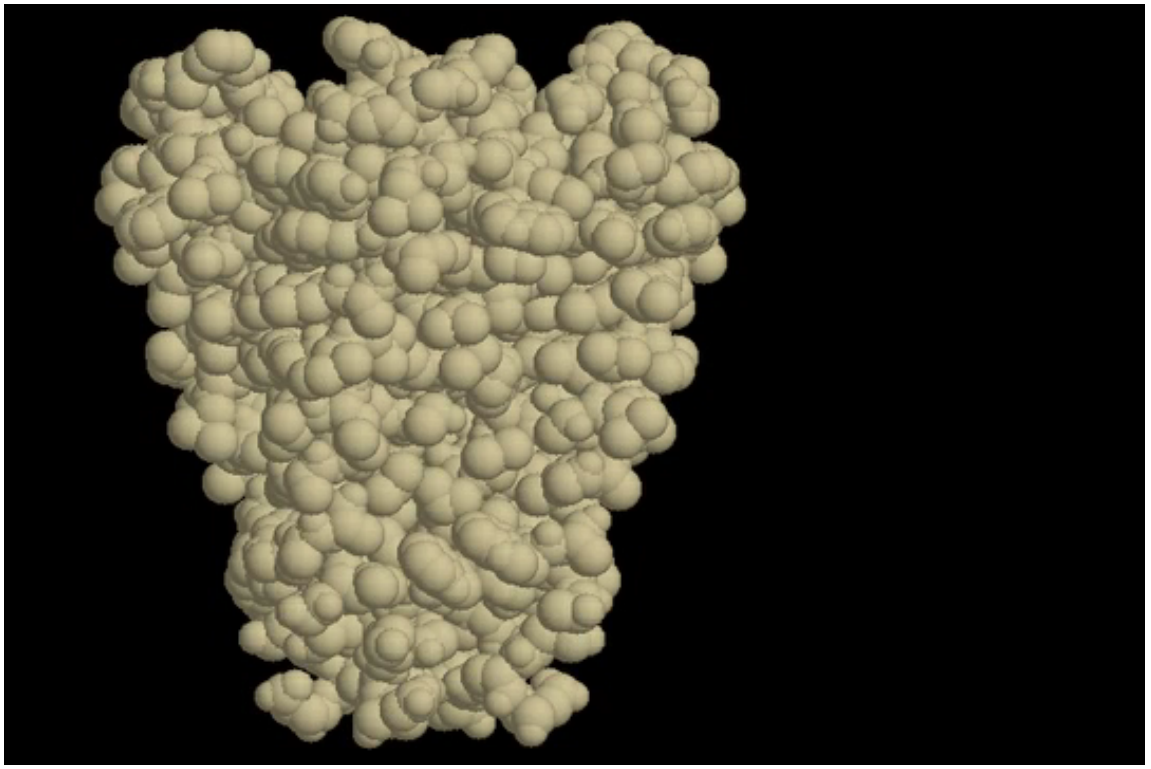
Ion channels form pores through the lipid bilayer to enable ion movement



closed channel



open channel

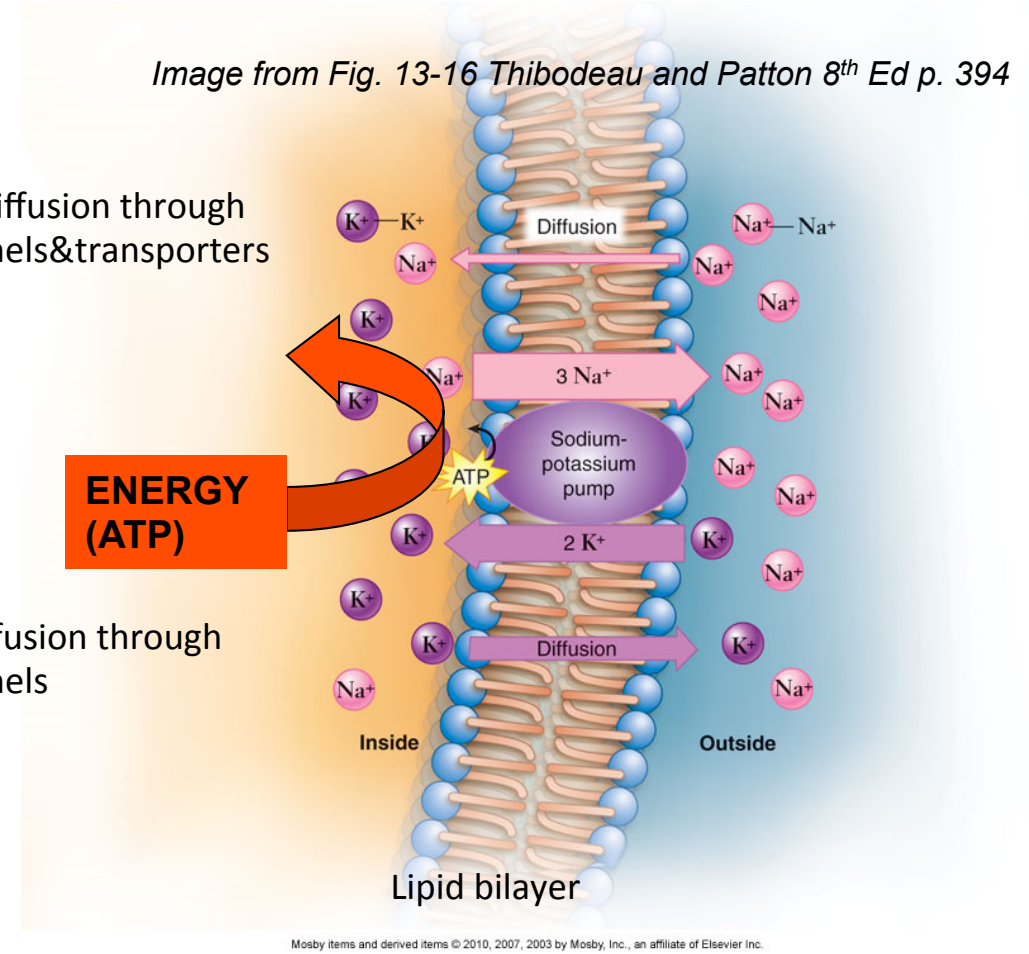


Movie from: Molecular Biology of the Cell, 5th Edition, Alberts et al.

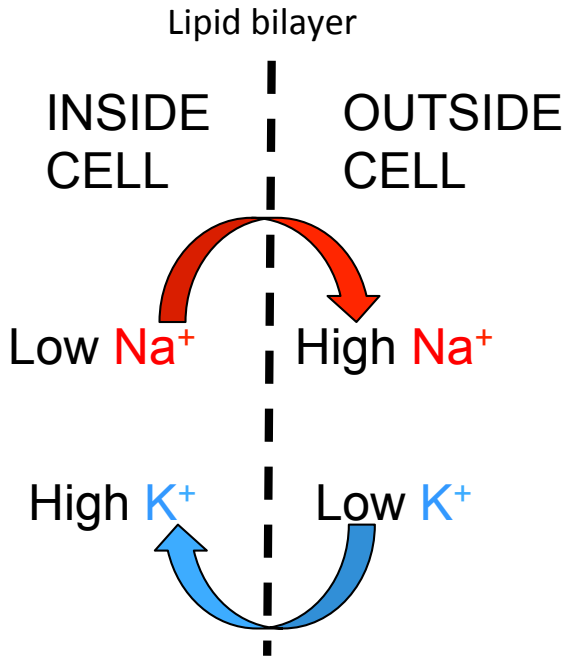
- They are highly selective for their ion
- ONLY Na^+ ions go through Na^+ channels
- ONLY K^+ ions go through K^+ channels

How is the membrane potential maintained?

Image from Fig. 13-16 Thibodeau and Patton 8th Ed p. 394



Na+/K+ ATPase (aka Na+/K+ PUMP)



Shifts 3 x **Na+** cations OUT of the cell

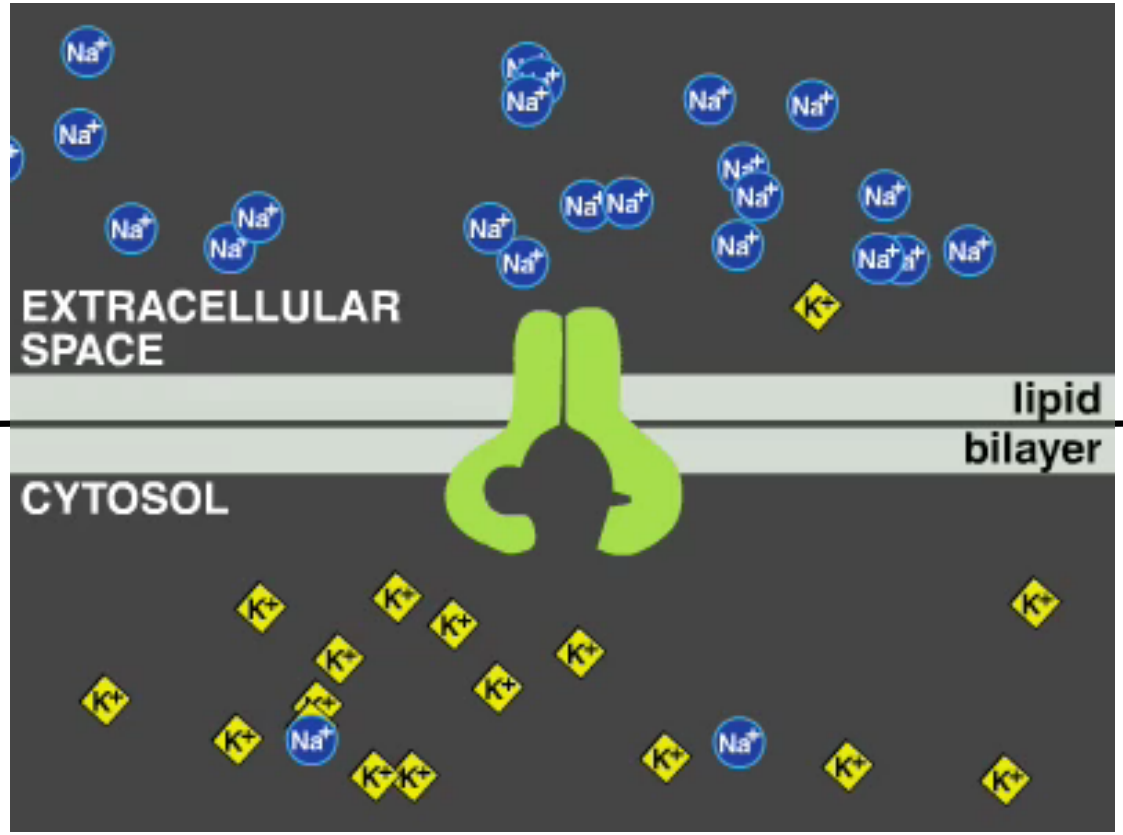
For

2 x **K+** cations IN the cell

Function of the Na^+/K^+ ATPase

Hi Na^+

Low K^+



Low Na^+

Hi K^+

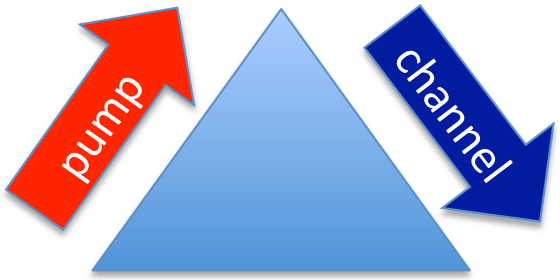
Movie from: Molecular Biology of the Cell, 5th Edition, Alberts et al.

Pumps versus ion channels

- They all are involved in the transport of ions across the cell membrane!
- But…

… pumps transport ions **against** gradients
'uphill transport' (energy)

… ion channels transport ions **along** gradients
'downhill transport'



Neurons are excitable cells

- Mostly a neuron is NOT at its resting membrane potential
- Instead its membrane potential varies

  – In size

  – In time

- Reason: opening and closing of channels → constantly…

At rest the inflow and outflow of cations is equal → RMP constant

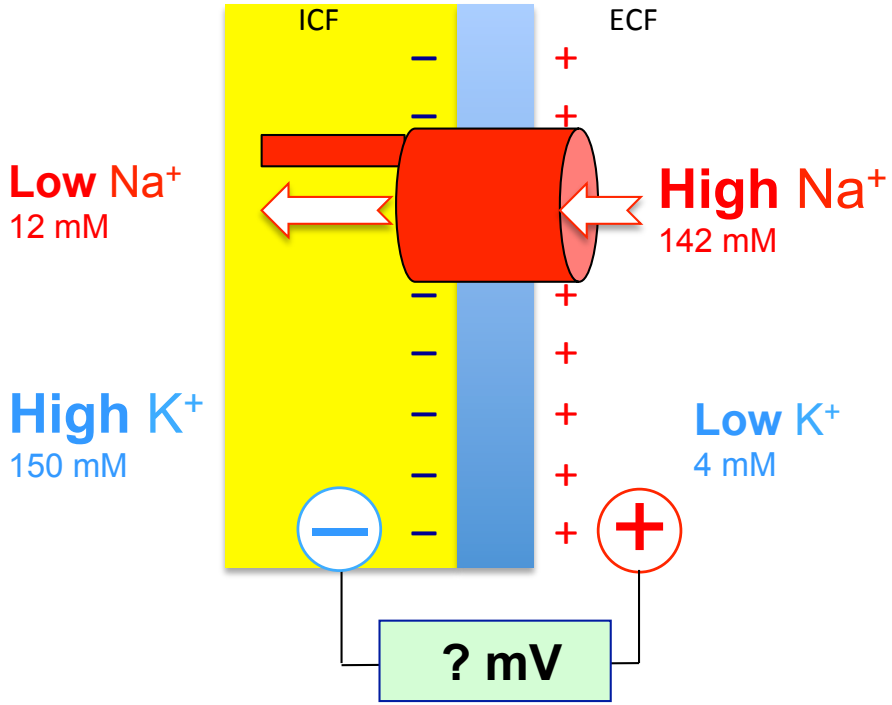
At Resting Membrane Potential:

→ most Na^+ channels are closed

→ some K^+ channels are open

→ Na^+/K^+ ATPase is operating

→ **HOMEOSTASIS**



But what happens to the RMP if:

→ More Na^+ channels open?

At rest the inflow and outflow of cations is equal → RMP constant

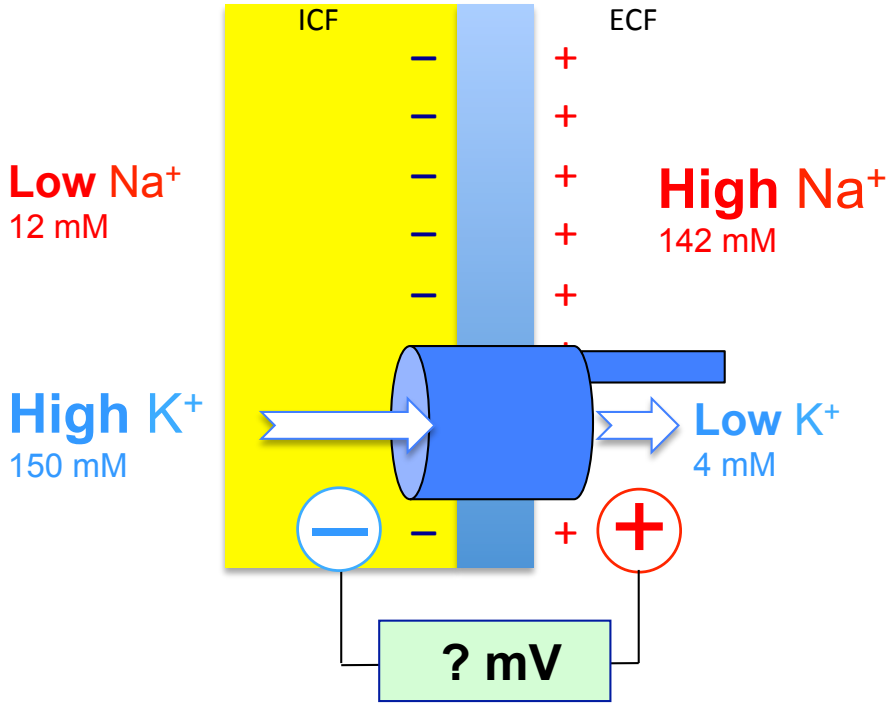
At Resting Membrane Potential:

→ most Na^+ channels are closed

→ some K^+ channels are open

→ Na^+/K^+ ATPase is operating

→ **HOMEOSTASIS**

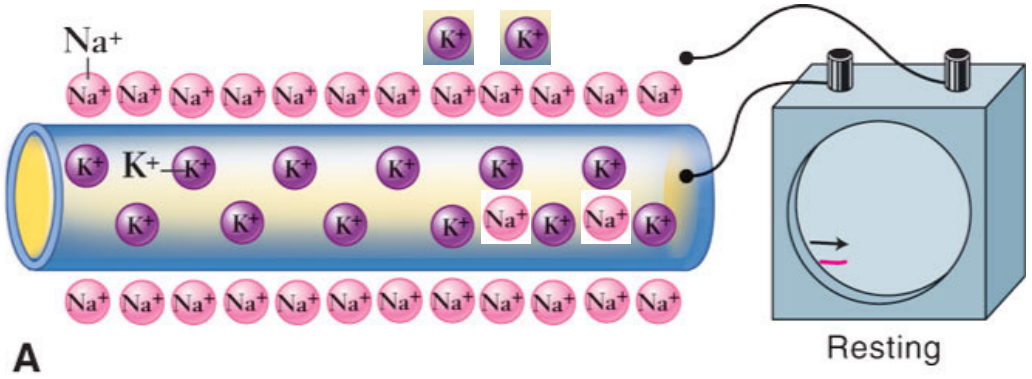


But what happens to the RMP if:

Or

→ More K+ channels

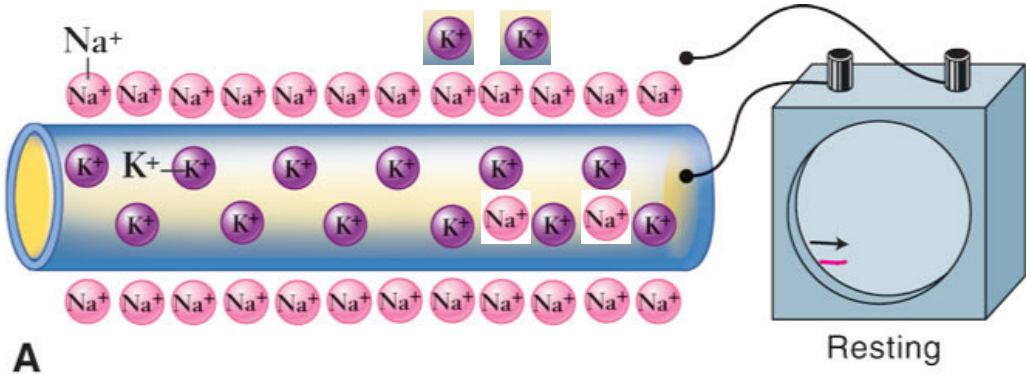
Changes (types) of membrane potentials



- RESTING
- Low Na^+ inside and high K^+ inside
- Na^+ inflow = K^+ outflow
- **–70 mV**

Fig. 13-18 Thibodeau and Patton 8th Ed. p.396.

Changes (types) of membrane potentials



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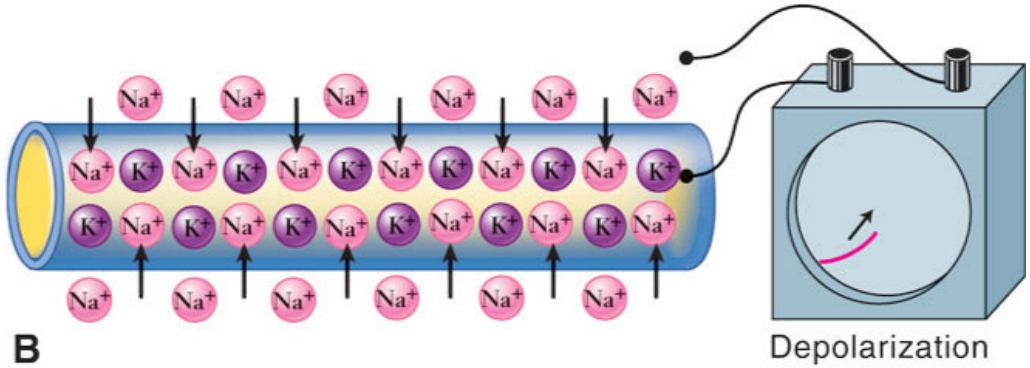


- **Na^+** channels open
- Positive charges move IN
- DEPOLARISED → e.g. –60 mV

Fig. 13-18 Thibodeau and Patton 8th Ed. p.396.

Changes (types) of membrane potentials

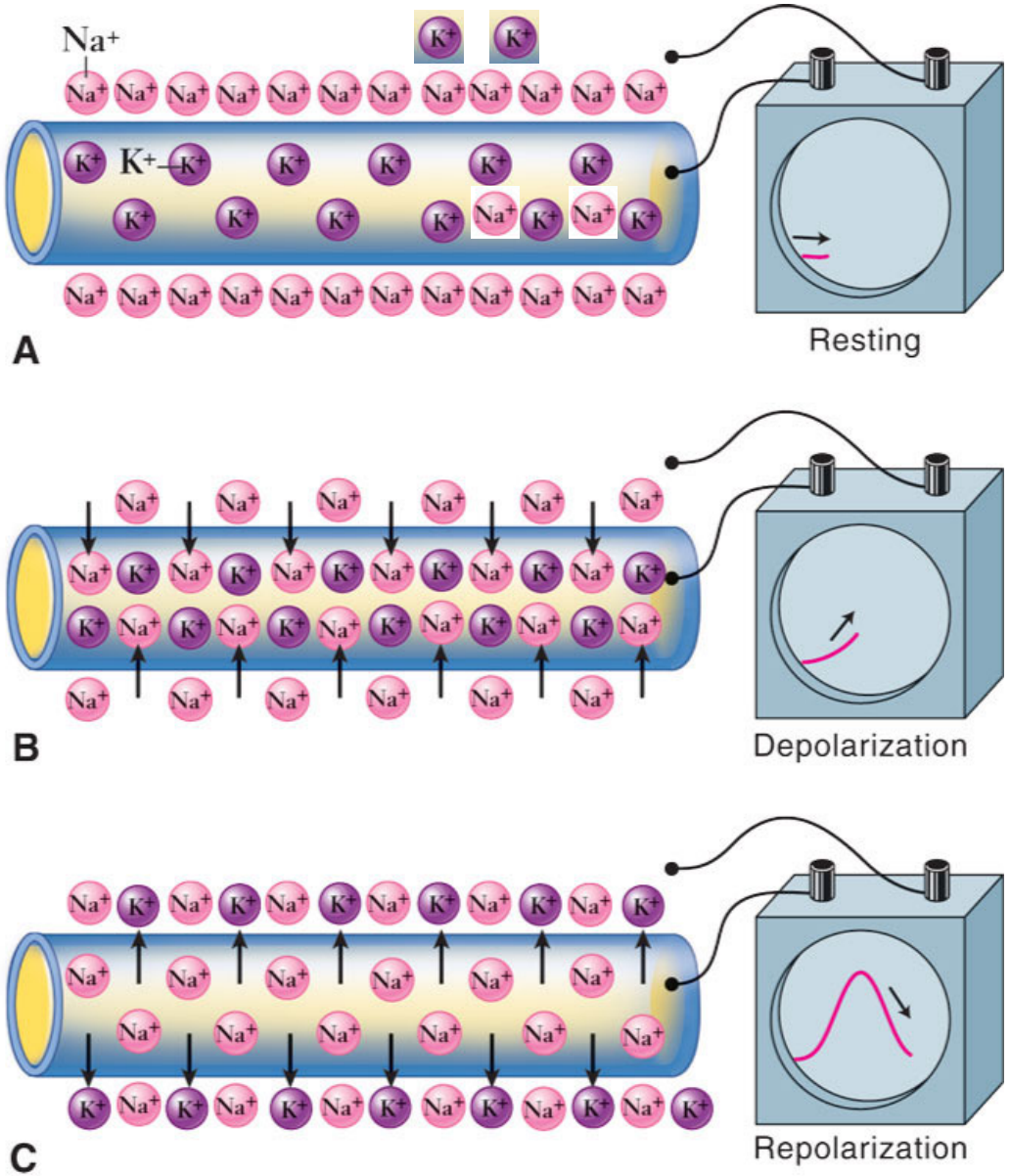


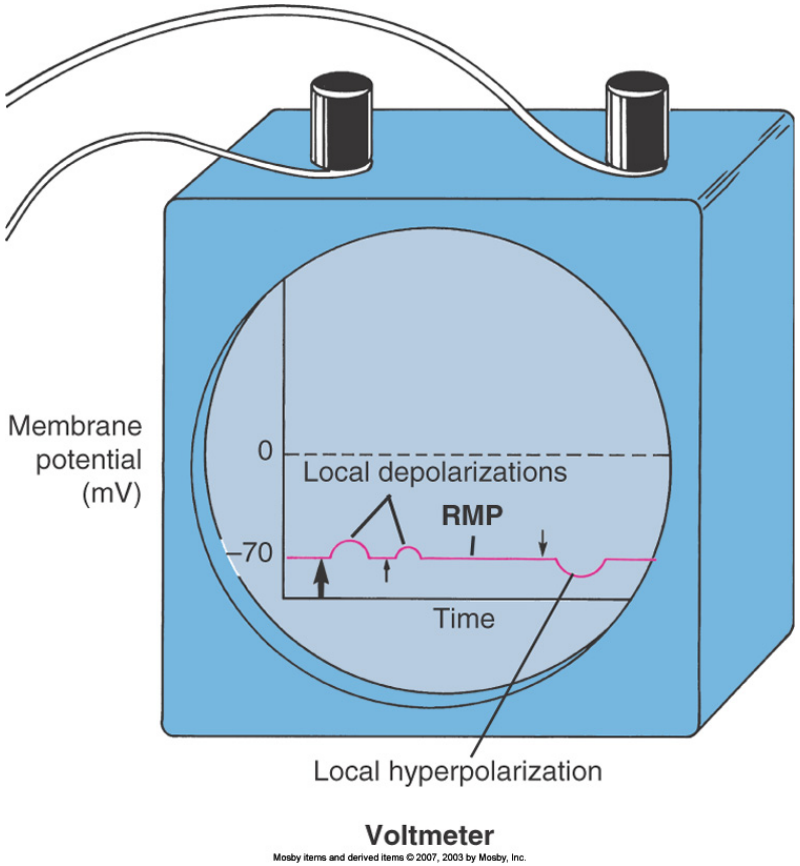
Fig. 13-18 Thibodeau and Patton 8th Ed. p.396.

- RESTING
- Low Na^+ inside and high K^+ inside
- Na^+ inflow = K^+ outflow
- **–70 mV**

- **Na^+** channels open
- Positive charges move IN
- DEPOLARISED → e.g. –60 mV

- **K^+** channels open
- Positive charges move OUT
- **REPOLARISED** → negative again
- **HYPERPOLARISED** → e.g. **–80 mV**

LOCAL POTENTIALS – constant change



DEPOLARISED – EXCITATORY

HYPERPOLARISED – INHIBITORY

At 'Rest'

→ most Na^+ channels are closed

→ some K^+ channels are open

→ Na^+/K^+ ATPase is operating

Classical HOMEOSTASIS

Fig 13-17 p. 395 *Thibodeau and Patton 8th Ed.*

Types of Potentials

Type of Potential	Polarisation	Typical value	Description
Resting	Balanced	-70 mV	Neuron is at rest, not excited not conducting an impulse, Some K^+ channels open.
Local	**DEpolarised** **EXCITATORY** **HYPERpolarised** **INHIBITORY**	**Varies**	Temporary fluctuation in a local region of the membrane Na^+ and K^+ channels open ACTIVE neurons
Threshold	Depolarised	**-59 mV**	Minimum local depolarisation that triggers an action potential
Action	**DEpolarised** **REpolarised**	+30mV	Temporary max depolarisation propagates along the axon without losing amplitude

See Table 13-3 *Thibodeau and Patton 8th Ed p. 397*

Which ion makes the legs twitch? How does it do that?

Except from YouTube **Frog Legs Dancing With A Little Salt**
Uploaded by thearchipelagos on 2 Jun 2009

HUBS191