Lab Protocols

Membrane Potential, model

v. 0.2

physiology.lf1.cuni.cz

Labs aim: Explore biology in context through brain and hands

LAB: Membrane Potential
Computational Model (Metaneuron)

WHAT

1. Membrane potentials definition:
    - *PubMed MeSH:* Ratio of inside versus outside concentration of potassium, sodium, chloride and other ions in diffusible tissues or cells. Also called transmembrane and resting potentials, they are measured by recording electrophysiologic responses in voltage-dependent ionic channels of (e.g.) nerve, muscle and blood cells as well as artificial membranes.
    - *Easy words:* MP is a difference in charges across biological (e.g. cellular) membrane

AIM of the lab

- Understand core principles of membrane potential generation, its maintenance and changes
- Help to explain the effect of certain drugs interfering with MP (e.g. anesthetics)
- See the mechanisms influencing MP through interactive simulation

REQUIRED KNOWLEDGE (major topics)

- Cellular membrane, selective permeability, concentration gradients (Na, K, Ca, Cl), resting membrane potential, action potential, pos-synaptic potential, equilibrium potential (Nernst eq.), ionic channels, channel gating, all or none law

TASKS - overview

1. Resting membrane potential
    1.1. Basics

2. Action potential
    2.1. Threshold stimulus, summation
3. Effect of changes in conductivity – channel blockers (Na, K)
4. Effect of changes in extracellular ionic concentrations (Na, K)

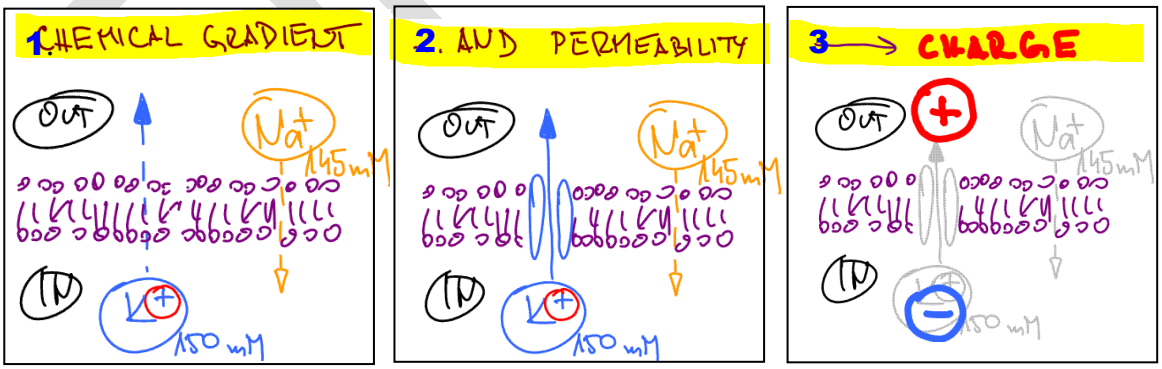
WHY …

1. … do cells maintain membrane potental?
    a. Homeostasis
    b. Transmembrane processes
    c. Energy store
    d. Signal processing/conduction

2. … do we perform the lab
    a. Clinical relevance:
        i. Demonstrate effect of ionic dysbalances
        ii. Drugs action explanation - Some common drugs are channel-blockers (e.g. anesthetics, antiarrhytmics, Ca antagonists…)
    b. Physiology – principle of
        i. Neural activity, receptor sensing,
        ii. Muscle control
        iii. Cardiac rhythm generation and propagation
        iv. Many others

HOW does that work?

1. potential implies unequal distribution of ions and charges, thus it must be powered and maintained in quite sophisticated manner
2. membrane potential (of biological membranes, e.g. cells) depends chiefly on:
    - **concentration (chemical) gradient across the membrane for different ions**
        - force that makes ions to move across the membrane. Otherwise no ions (charges) flux would occur thus no potential would be generated.
    - **membrane selective permeability for ions**
        - though forced, the ions must be allowed to cross the membrane. Otherwise no charge can be generated
        - if all the ions could pass through at the same time, all charges would equilibrate since concentration



    - **what is equilibrium potential?**
        - if ion follows its concentration (chemical –CH) gradient, it generates electrical gradient (by movement of its charge).
        - The more ions move, the greater the developed charge is
        - Electrical (E) and chemical (CH) gradients are opposite direction
        - Once electrical gradient (force) equals chemical one, ionic flow stops (more accurately ie equal both directions. THIS IS EQUILIBRIUM POTENTIAL Simply we can say:

E = CH

This is Nernst equation - in principle ☺

E is electrical force (determined by potential)
CH is chemical force determined by conc. gradient which depends on the (logarithm of the) ratio between concentration outside (OUT) and inside (IN) the cell, co:

$$E = k \cdot \log \frac{con_{[OUT]}}{con_{[IN]}}$$

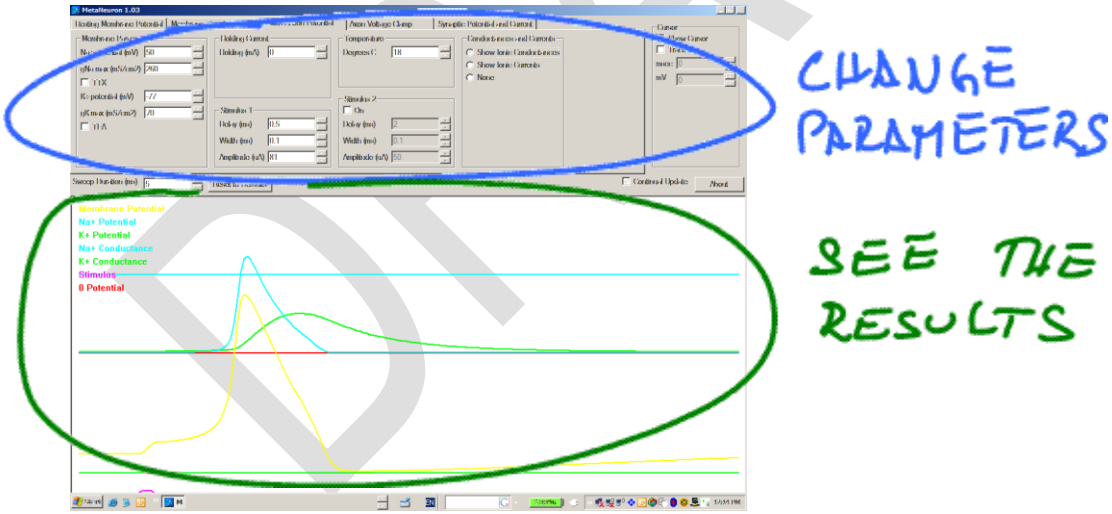
k stands for some constants ($\frac{R \cdot T}{z \cdot F}$).

Thus electrical (equilibrium) potential for given ion depends just on its concentration gradient.

- Surprisingly, concentration almost does not change !!!!
- Each ion, if allowed (i.e. if having channel open) tends to reach its equilibrium.

SETUP

1. **Simualtion software – Metaneuron** (google for it)
   a. simulates membrane processes based on Hodgkin-Huxley model (Nobel Prize 1963).
   b. Intuitive interface allowing control of ionic concentration and permeabilities (conductances) and more
   c. The graph to show the results
2. The screenshot:



TASKS - detailed

1. Resting membrane potential
   1.1. Basics – read the graph, notice RMP, E_K, E_{Na}
   1.2. explore the effect of changes in ECF ions concentrations
      1.2.1. change the values in a meaningful way
      1.2.2. explain how the finding is different for each ion and why?
   1.3. see the effect of changed conductivity

2. Action potential

2.1. basics
    2.1.1. read the graph, notice stimulus trace, MP trace, conductivities (turn them on)
    2.1.2. find threshold stimulus
    2.1.3. explore summation of two stimuli

2.2. Effect of changes in conductivity - demonstration of effects of channel blockers (Na, K)
2.3. Effect of changes in extracellular ionic concentrations (Na, K)

MORE QUESTIONS:

Q1: what is the effect of increasing amplitude of a stimulus?