Tfy-99.263 Living state physics II (electrophysiology)   Exam 13.12.2004

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Give your name and student number in each paper. You may answer in Finnish.

Tehtävä 1
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$T = 20\ °C$

$0\ °C = 273,15\ K$

$R = 8,315\ \frac{J}{mol \cdot K}$

1. The relative conductances for K^+, Na^+ and Cl^- of the plasma membrane of an invertebrate photoreceptor cell are:
   In darkness: $g_K : g_{Na} : g_{Cl} = 1 : 0,005 : 0,1$
   In constant light: $g_K : g_{Na} : g_{Cl} = 1 : 20 : 0,1$
   The equilibrium potentials of these ions are $E_K = -90$ mV, $E_{Na} = +50$ mV and $E_{Cl} = -50$ mV.
   a) What are the resting potentials of the photoreceptor in darkness and under constant light?
   b) The photoreceptor receives a synaptic input from a feedback interneuron in the retina. Stimulation of the interneuron in darkness results in a sustained depolarisation of 10 mV in the photoreceptor membrane potential altering the chloride conductance of the photoreceptor. If the input resistance of the photo-receptor is ohmic with a value of 10^8 Ω, what is the value of the change in g_{Cl}?

2. Briefly describe the basic assumption of the single energy barrier model for ion permeation. How does the membrane potential affect ion permeation? What factor is responsible for inward and outward rectification of ion currents? What physical entity in the channel constitutes the energy barrier?

$\beta(V)$

$open \underset{\alpha(V)}{\overset{\beta(V)}{\rightleftharpoons}} closed$

3. A neuron contains N voltage-sensitive Na^+ channels. The Nernst potential for sodium E_{Na} is +50 mV. The Na^+ channels have only two states, open and closed, and they follow the reaction scheme:

   $$open\ \underset{\alpha(V)}{\overset{\beta(V)}{\rightleftharpoons}}\ closed,$$
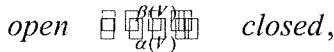
   where the rate constants $\alpha(V) = 500e^{-\frac{V}{50(mV)}}\ s^{-1}$ ja $\beta(V) = 50e^{\frac{V}{25(mV)}}\ s^{-1}$

   a) What is the steady-state probability of each of these channels being open with the cell voltage clamped at -100 mV, -50 mV and 0 mV?
   b) The single channel conductance is 25 pS. If the steady-state current of the whole cell is -100 nA at -50 mV, what is the total number of channel in the cell?
   c) What is the variance of the whole-cell Na^+ current at membrane potential 0 mV?

4. You would like to record the amplitude of <u>fast</u> changes in the membrane potential of a photoreceptor cell by intracellular recording. You penetrate the cell membrane by a glass microelectrode filled with salt solution. The resistance of the electrode is 300 MΩ. Describe very briefly three possible sources of error (there could be more; use your imagination) in your recording.

5. a) Describe how Traub modelled the functional properties of single neurons in his model(s) (general features, no values or that kind of details).
   b) In the neural networks of hippocampus there exist transient high-frequency (> 70 Hz) oscillations, that can be abolished by gap junction blockers. What kind of structures in neural networks may produce these oscillations according to Traub?