Ragnar Granit Institute
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71210 Bioelektroniikka - Bioelectromagnetism
Laskuharjoitus 5 – Exercise 5, 13.10.2004

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1. Derive the equation of sodium conductance in voltage clamp measurement (with chemical clamping) using the Hodgkin-Huxley model.

2. Cell membrane was studied with the voltage clamp measurement with a 56 mV positive voltage step. 2.5 ms after the step the membrane current is 0.6 mA/cm^2. When the sodium current was blocked with pharmaceutical the current was 1 mA/cm^2 (again, t = 2.5 ms after the step). Also, it was observed that the flow of sodium ions could be stopped with 117 mV increase in resting membrane potential.

   What is the sodium ion conductance G_{Na} (stimulation 56 mV, 2.5 ms)? (*Answer: 65,6 S/m^2*)

3. Propagation speed of the action pulse in a 4 µm thick mammalian myelinated nerve axon is about 24 m/s. Approximate the speed in a 14 µm thick myelinated nerve. Propagation speed is

$$\Theta = \sqrt{\frac{Kr}{2\rho C_m}}$$

   (*Answer: 87,5 m/s*)

4. a) Describe a Hodgkin-Huxley type electrical model of a myelinated nerve membrane.

   b) In an unmyelinated axon with radius r = 50 µm and 1 µm thick membrane, the propagation speed is 20 m/s. Similar axon with an additional myelin covering the speed is 80 m/s. How thick is the myelin if it covers about 80 % of the axon surface? (difficult – you need an equation for capacitance of a cylindrical object…) *(Answer: 13 µm)*

5. In the right arm patient's myelinated nerve has been damaged. The propagation speed has decreased to 75 % of the original. Damaged and healthy nerves are stimulated with similar stimulus current. If the rheobasic current is considered to remain unchanged, how much longer stimulus is needed with the damaged nerve? The propagation speed is inversely proportional to the square root of the membrane capacitance ($\Theta \propto (C_m)^{-½}$) (*Answer: 1,78 times longer*)

6. A motor nerve was stimulated with an electrical current stimulus in two places, 310 and 60 mm from the generated action pulse monitoring site. In these sites the action pulse was observed 9 ms and 4 ms after the stimulus respectively. What is the propagation velocity in the nerve and what is the time delay in the neuromuscular junction if the latency of the stimulus is 1 ms. (*Answer: 50 m/s and 1,8 ms*)