EPFL

Mock MSc exam

BIO-482 Neuroscience: Cellular and circuit mechanisms

Carl Petersen and Sylvain Crochet

Time: Wednesday 6th November 2024
Start: 13:15
End: 16:00

Location: CM 1105

Please answer ALL questions.

Write your name in the indicated location at the top of every page.

For Multiple Choice questions – only one answer is correct.

Use the space provided to answer the questions.
If you need more space, then continue writing overleaf.

The maximal number of attainable points for each question is indicated in square brackets [x marks].

There are 7 pages of questions, each with 7 marks.

Total number of marks for the exam is 49.

Some constants:

Elementary charge:	$e = 1.6 \times 10^{-19}$ C
Avogadro's constant:	$N_A = 6 \times 10^{23}$ mol^{-1}
Gas constant:	$R = 8$ J K^{-1} mol^{-1}
Faraday constant:	$F = 10^5$ C mol^{-1}

Week 1 – Cell membranes [7 marks]

1. Consider an ion channel with a single-channel conductance of 10 pS. Approximately, how many monovalent ions would flow through this channel per second if it was open and the electrical driving force was 100 mV? [**1 mark**]

A, ~5,000 **B**, ~100,000 **C**, ~5,000,000 **D**, ~100,000,000

2. Which of the following best describes intracellular concentrations of sodium, potassium and calcium in a typical mammalian neuron? [**1 mark**]

A, Sodium 10 mM	Potassium 10 mM	Calcium 100 mM
B, Sodium 10 mM	Potassium 150 mM	Calcium 100 µM
C, Sodium 150 mM	Potassium 10 mM	Calcium 1 mM
D, Sodium 10 mM	Potassium 150 mM	Calcium 100 nM

3. Describe an electrical equivalent circuit representing a small (i.e. isopotential) cell. Include diagrams. [**5 marks**]

Week 2 – Excitability [7 marks]

1. What is the typical resting membrane potential of a neuron (i.e. in the absence of synaptic input) and what is the typical threshold for action potential initiation? [**1 mark**]

A, V_m rest -75 mV, V_m thresh -50 mV **B**, V_m rest : -50 mV, V_m thresh +50 mV

C, V_m rest -50 mV, V_m thresh -25 mV **D**, V_m rest : -100 mV, V_m thresh -75 mV

2. Where are action potentials typically initiated? [**1 mark**]

A, Soma **B**, Distal dendrite **C**, Proximal dendrite **D**, Axon initial segment

3. Describe mechanisms controlling the speed of action potential propagation. Include diagrams. [**5 marks**]

Week 3 – Synaptic transmission [7 marks]

1. What is the approximate diameter of a synaptic vesicle? [**1 mark**]

A, 4 nm **B**, 40 nm **C**, 400 nm **D**, 4 µm

2. Some synapses exhibit short-term synaptic facilitation. What presynaptic signals are preferentially transmitted at such synapses? [**1 mark**]

A, High frequency action potentials **B**, Low frequency action potentials
C, Single isolated action potentials **D**, Extrasynaptic signals

3. Describe the electrical and molecular sequence of events underlying synaptic transmission. Include diagrams. [**5 marks**]

Week 4 – Glutamatergic excitation [7 marks]

1. What is a typical amplitude and duration of an EPSP measured at the soma and evoked by a single action potential in a single presynaptic neuron? [**1 mark**]

A, 10 mV; 1 s **B**, 100 mV; 100 ms **C**, 1 mV; 10 ms **D**, 10 µV; 1 s

2. What does <u>not</u> contribute importantly to postsynaptic long-term potentiation? [**1 mark**]

A, Calcium/calmodulin-dependent kinase 2 **B**, Calcium

C, AMPA receptor insertion **D**, Sphingosine kinase

3. Describe key differences between AMPA and NMDA receptors, as well as their respective key functional roles. Include diagrams. [**5 marks**]

Week 5 – GABAergic inhibition [7 marks]

1. What drives the developmental change in GABAergic synaptic transmission from excitation to inhibition? [**1 mark**]

A, KCC2 **B**, $GABA_B$ receptors **C**, VGAT **D**, Gephyrin

2. Which feature best describes neocortical parvalbumin-expressing GABAergic neurons? [**1 mark**]

A, Facilitating excitatory synaptic input **B**, Fast action potential waveforms

C, Axonal projections to subcortical targets **D**, Volume transmission

3. Describe distinct mechanisms of $GABA_A$-mediated and $GABA_B$-mediated inhibition. Include diagrams. [**5 marks**]

Week 6 – Measuring and controlling brain function [7 marks]

1. What is channelrhodopsin-2? [**1 mark**]

A, light-activated kinase
B, light-activated anion channel
C, light-activated cation channel
D, light-activated G-protein coupled receptor

2. What signal cannot be recorded by extracellular electrophysiology? [**1 mark**]

A, local field potentials
B, membrane potential
C, action potential firing
D, correlated neuronal activity

3. Describe how brain function can be imaged by optical methods. Include diagrams. [**5 marks**]

Week 7 – Mechanisms of brain (dys)-function [7 marks]

1. Which virus can be used to trans-synaptically label presynaptic neurons? [**1 mark**]

A, Rabies virus **B**, Adenovirus **C**, Lentivirus **D**, Sindbis virus

2. Which brain region is typically targeted in deep brain stimulation treatment of Parkinson's disease? [**1 mark**]

A, Dorsal thalamus **B**, Subthalamic nucleus

C, Hypothalamus **D**, Lateral geniculate nucleus

3. Describe a possible mechanism for reward-based goal-directed sensorimotor learning. Include diagrams. [**5 marks**]