EPFL

MSc mock exam

BIO-482 Neuroscience: Cellular and circuit mechanisms

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Time: Wednesday 5th November 2025
Start: 13:15
End: 16:00

Location: CM1105

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

A, Sodium 5 mM	Potassium 5 mM	Calcium 100 mM
B, Sodium 150 mM	Potassium 150 mM	Calcium 100 µM
C, Sodium 150 mM	Potassium 5 mM	Calcium 1 mM
D, Sodium 5 mM	Potassium 150 mM	Calcium 100 nM

2. What equation best describes the 'length constant', λ, of the spatial distribution of voltage along a passive cable at steady state (R_m, membrane resistance; R_{Axial}, axial resistance; C_m, membrane capacitance)? [**1 mark**]

A, $\lambda = \sqrt{(R_m / R_{Axial})}$ **B**, $\lambda = \sqrt{(R_m \times C_m)}$

C, $\lambda = \sqrt{(C_m / R_m)}$ **D**, $\lambda = \sqrt{(R_{Axial} / R_m \times C_m)}$

3. Describe in words and diagrams key aspects of passive cell membranes including discussion of electrical properties and molecular components. [**5 marks**]

Week 2 – Excitability [7 marks]

1. Which one of the following changes with membrane potential for a voltage-gated ion channel? [**1 mark**]

A, single channel conductance **B**, open probability

C, ionic selectivity **D**, reversal potential

2. What best describes the propagation velocity of an action potential in a typical unmyelinated axon in the mammalian brain? [**1 mark**]

A, 1 mm/s **B**, 1 m/s **C**, 1 m/ms **D**, 1 μm/s

3. Describe the biophysical mechanisms underlying the action potential. [**5 marks**]

Week 3 – Synaptic transmission [7 marks]

1. What is the approximate relationship between vesicle release rate (R) and cytosolic calcium concentration ($[Ca^{2+}]$)? [**1 mark**]

A, $R \propto \sqrt{[Ca^{2+}]}$ **B**, $R \propto [Ca^{2+}]^2$ **C**, $R \propto [Ca^{2+}]^4$ **D**, $R \propto \text{Log}[Ca^{2+}]$

2. The calcium sensor driving exocytosis of synaptic vesicles is [**1 mark**]:

A, Syntaxin **B**, SNAP-25 **C**, Synaptobrevin **D**, Synaptotagmin

3. Describe in words and drawings evidence for the quantal nature of synaptic transmission. [**5 marks**]

Week 4 – Glutamatergic excitation [7 marks]

1. What is the approximate reversal potential of a glutamatergic EPSC [**1 mark**]?

A, -100 mV **B**, -50 mV **C**, 0 mV **D**, +50 mV

2. What key molecule contributes to dendritic spine motility? [**1 mark**]

A, Actin **B**, Spectrin **C**, Ferritin **D**, Prestin

3. Describe in words and drawings the key mechanisms underlying postsynaptic long-term potentiation and how it can be induced experimentally. [**5 marks**]

Week 5 – GABAergic inhibition [7 marks]

1. Postsynaptic inhibition mediated by metabotropic $GABA_B$ receptors acts primarily via: [**1 mark**]

A, activating K^+ channels
B, activating Cl^- channels
C, inhibiting Na^+ channels
D, activating Ca^{2+} channels

2. Which of the following molecularly-defined neocortical classes of GABAergic neurons primarily targets distal apical dendrites of pyramidal neurons? [**1 mark**]

A, Parvalbumin-expressing
B, 5HT3A-receptor-expressing
C, Vasoactive intestinal peptide-expressing
D, Somatostatin-expressing

3. Describe the action of benzodiazepines using words and diagrams, including discussion of mechanisms and experimental evidence. [**5 marks**]

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

1. Approximately, how many times larger is the volume of the human brain compared to the mouse brain? [**1 mark**]

A, 10 **B**, 1,000 **C**, 100,000 **D**, 10,000,000

2. In the '*Cre-LoxP'* system, what is '*Cre*' and what is '*LoxP*'? [**1 mark**]

A, *LoxP* is a ligand of the membrane *Cre* receptor

B, *LoxP* is a DNA-binding protein controlling expression of *Cre*

C, *LoxP* is a DNA sequence which is cut by the *Cre* enzyme

D, *LoxP* is an amino acid which polymerises to form *Cre*

3. Describe in words and diagrams the principles of two-photon microscopy and how this method can be used to image the activity of individual neurons *in vivo*. [**5 marks**]

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

1. What medication is typically given to patients with Parkinson's disease? [**1 mark**]

A, Acetylcholinesterase inhibitors **B**, L-DOPA

C, Corticosteroids **D**, Fluoxetine

2. Some striatal neurons express dopamine type 1 receptors. i) To where do these neurons strongly project; and ii) what neurotransmitter do they release? [**1 mark**]

A, i) zona incerta; ii) dopamine **B**, i) thalamus; ii) glutamate

C, i) cerebellum; ii) acetylcholine **D**, i) substantia nigra; ii) GABA

3. Why is sensory perception considered an active process? Give examples and describe experiments probing causal mechanisms of sensory perception? [**5 marks**]