

Name: _____

Student #: _____

BIO 3305
Cellular Physiology
Prof: John Lewis

MIDTERM #1

September 30, 2019

- **4 questions**
- **4 pages total**
- **40 marks total**

Please answer **ALL** questions.

Please write your name and student # on all pages.

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1. (8 marks) Determine whether each of the following statements is TRUE or FALSE. Please circle the correct answer.

- (a) TRUE or FALSE | A distinguishing feature of *all* active transport is the requirement of energy from the hydrolysis of ATP.
- (b) TRUE or FALSE | An active transporter is *electrogenic* if the net charge of all ions transported across the membrane is non-zero.
- (c) TRUE or FALSE | The direction of transport through membrane ion channels is determined only by the concentration gradient of the associated ion.
- (d) TRUE or FALSE | At a depolarized membrane potential, individual voltage-gated ion channels can be open or closed.

2. (8 marks) You are investigating the ionic basis of the resting membrane potential of a specialized mechanosensory cell in a crayfish. You have established that these cells are permeable to K^+ and Cl^- ions, and **only** these ions contribute to the resting potential (i.e. no other ions are involved in controlling the resting potential). The equilibrium potentials are $E_K = -100mV$, $E_{Cl} = -50mV$. Given these observations, determine whether each of the following statements is TRUE or FALSE. Please circle the correct answer.

- (a) TRUE or FALSE | The resting potential of this cell will be between $-100mV$ and $-50mV$
- (b) TRUE or FALSE | If Cl^- permeability is greater than that of K^+ , the resting potential will be more hyperpolarized than $-80mV$.
- (c) TRUE or FALSE | Blocking K^+ channels will result in a depolarization of the membrane.
- (d) TRUE or FALSE | Increasing the extracellular concentration of Cl^- will depolarize the cell.

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3. (12 marks) While recording from your favorite cell, you observe spontaneous hyperpolarization events that last about 100ms and occur about twice every second. The resting potential of this cell is -30mV and the membrane potential hyperpolarizes to -40mV during these events. You know that the resting potential of this cell is determined **only** by Na^+ and K^+ ions, and you have good reason to hypothesize that the hyperpolarization events are due to a novel channel that is permeable to both Ca^{+2} and Cl^- ions. Unfortunately, there are **no specific drugs** that block any of these channels. In the space below, describe a **set of experimental manipulations** that will allow you to test your hypothesis (hint: one manipulation should involve the membrane potential directly and the other should involve ion concentrations). Be sure to include a specific discussion of the **predicted outcomes for each of your proposed experiments**, along with any **assumptions** you are making. Note that $E_{\text{K}} = -100\text{mV}$, $E_{\text{Cl}} = -90\text{mV}$, $E_{\text{Ca}} = +30\text{mV}$, $E_{\text{Na}} = +100\text{mV}$. (You can use the back of this page if necessary)

1. *Manipulate membrane potential (V_m) above and below the equilibrium potential for the mixed channel (which we will refer to as E_c).*
2. *Systematically manipulate E_c by changing Ca and/or Cl concentrations*

We do not know what E_c is, so we must make an assumption that depends on whether the mixed channels are opening or closing during the hyperpolarization events. Since the resting potential does not involve Ca or Cl, this implies that our channels cannot be open at rest, so we can safely assume they are opening during the hyperpolarizing events (i.e. not closing). Therefore, E_c must be below -40mV (i.e. more negative than -40mV).

Now we should change V_m to find E_c . To do this, we decrease V_m gradually (using injected current) until the hyperpolarizations disappear – this potential should correspond to E_c if our hypothesis is correct. If we decrease V_m further, the events should switch to depolarizations.

In other words, when these mixed channels open, V_m will go towards E_c .

Next we must determine if this “equilibrium potential” depends on Ca and Cl. To do this, we can systematically manipulate the extracellular concentrations of these ions, using their equilibrium potentials for reference. Increasing extracellular Ca concentration will increase E_{Ca} (make it more positive) and thus should increase E_c (less negative). On the other hand, increasing extracellular Cl will decrease E_{Cl} (make it more negative) and thus should decrease E_c (more negative).

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4. (12 marks) You are making recordings from a cell with an unusually hyperpolarized resting potential of -100mV . Your initial experiments have determined that four ions K^+ , Cl^- , Na^+ , Ca^{+2} (i.e. all four, but no others) are involved in setting the resting potential of this cell. You find that when you block all Na^+ channels, the resting potential hyperpolarizes to -110mV . On the other hand, when you block all Na^+ **and** all Ca^{+2} channels, the resting potential depolarizes to -50mV .

Propose a set of equilibrium potentials for the four ions involved that would be consistent with the above observations. This is your hypothesis.

Now, block all Na^+ sodium channels again, and systematically **change the Cl^- equilibrium potential** (pick one value above and another value below your proposed value). Describe the **expected effect** on the membrane potential **assuming that your hypothesis is correct**. This is a partial test of your hypothesis. (You can use the back of this page if necessary)

The following describes one possible solution; others involving different combinations of equilibrium potentials etc are also possible:

The resting membrane potential is determined by all four ions, but there are some conditions on the equilibrium potentials due to the results of blocking Na and Ca channels.

Hypothesis:

The membrane potential depolarizes to -50mV when both channels are blocked. That means the contributions of the remaining ions (K and Cl) balance out to -50mV , so one should have an equilibrium potential above -50mV and the other below -50mV .

When only Na channels are blocked, the membrane hyperpolarizes to -110mV . That means E_K and/or E_{Ca} should be below -110mV .

So one possibility would be $E_K = -120\text{mV}$, $E_{Cl} = -20\text{mV}$, $E_{Ca} = -120\text{mV}$, $E_{Na} = +50\text{mV}$.

Test (note that this need not necessarily rule out all competing hypotheses, but merely test one aspect of the hypothesis)

- 1. Increase E_{Cl} to 0: V_m will be more depolarized than -110mV*
- 2. Decrease E_{Cl} to -40mV : V_m will be more hyperpolarized than -110mV*

As mentioned above, other combinations of equilibrium potentials are possible, but they must be consistent with all observations