UNCOVERING MISCONCEPTIONS ABOUT THE RESTING MEMBRANE POTENTIAL

Dee U. Silverthorn

Neurobiology Section, University of Texas, Austin, Texas 78712

10.1152/advan.00012.2002.

Resting membrane potential is one of the most difficult physiological concepts that students must master. Although the upper-division undergraduates in my physiology course have completed a semester of neurophysiology in which they worked problems using the Nernst and Goldman equations, they often fail to retain conceptual understanding of the underlying phenomena. I developed the following question to show them (and myself) what they don’t understand.

If the ECF $K^+$ concentration increases from 3 to 5 mM, what happens to the resting membrane potential of an adipose cell? (Circle all that are correct)

a) it decreases
b) it increases
c) it doesn’t change
d) it becomes more negative
e) it becomes less negative
f) it depolarizes
g) it hyperpolarizes
h) it repolarizes
i) it fires an action potential

(Correct answers: a, e, and f)

The student answers to this question are highly varied and often include such a mix of correct and incorrect choices that it is impossible to figure out why the students are missing the answers. This semester, I changed the question to see whether I could elicit the misconceptions underlying their incorrect answers. The revised question was:

What happens to the membrane potential of a cell when the extracellular potassium concentration goes from 3 to 5 mM? Explain.

The students were asked to answer the question on an index card. They were told that the activity was not graded and that it was acceptable to answer “I don’t know” if they had not had a neurophysiology class (9/105 students). These students were eliminated and the remaining answers and explanations compiled to see whether there were patterns to the wrong answers or to the reasoning that students used to get to the correct answers.

Answer pattern 1: The membrane potential becomes more positive (correct) = 36/96 students.

However, only 8 of the 36 were able to state a coherent reason for their answer and only 2 of these students used the Nernst equation in their reasoning. The most common incorrect reason given was that the increase in extracellular potassium would cause $K^+$ to rush into the cell down its concentration gradient. This suggests that students do not know that the normal $K^+$ concentration is $\sim 150$ mM inside the
cell and 3.5–5 mM outside, and that a 2 mM change will not reverse the gradient. This misconception is similar to one that appears during student descriptions of the action potential, where they assume that Na\(^+\) entry into the axon reverses the Na\(^+\) gradient.

**Answer pattern 2:** The membrane potential becomes more negative (incorrect) = 36/96. Reasoning for this was almost evenly split among three answers.

a) . . . because K\(^+\) moves out of the cell. Students who explained this reasoning said that if plasma K\(^+\) concentration increases, K\(^+\) must have moved from the cells to the extracellular fluid. They failed to recognize that the body is not a closed system and that K\(^+\) can come from the external environment.

b) . . . because the membrane potential will approach the equilibrium potential for K\(^+\). These students seem to be confusing concentration equilibrium with equilibrium potential. When questioned further, several of these students were not able to explain the concept of equilibrium potential correctly.

c) . . . because more K\(^+\) outside makes the inside more negative. These students do not understand the principle of electrical neutrality and think that it is possible to add cations to the body without adding corresponding anions. Because the question does not explicitly state that the added K\(^+\) was accompanied by anions, students assumed that only cations were added.

**Answer pattern 3:** Thirteen students said incorrectly that the membrane potential difference increased, but they had no further explanation. An additional two students correctly said that membrane potential decreased, and they had no explanation for their answer. It was impossible to tell from these answers whether students actually understood what was happening.

We suspected from results of the multiple-choice question described at the beginning that students do not understand what it means to say that membrane potential has increased or decreased, and the answers on this quiz supported that suspicion. Twenty-nine students in patterns 1 and 2 had answers that explained the change in membrane potential with both types of descriptors: more positive/more negative and increased/decreased. Of these 29, 23 incorrectly matched the “increased/decreased” modifiers with membrane potential becoming more negative or positive.

To confirm the existence of this misconception, the entire class was asked this question on the following day:

*If the membrane potential of a cell increases, has the potential become more positive or more negative?*

Over 75% of the class (82/108) answered this incorrectly, suggesting that students do not remember that membrane potential is not an absolute number, but the difference between the inside of the cell and the outside ground. Thus a decrease in the membrane potential difference means that the voltage has moved closer to ground or become more positive. Most students take the modifier “decrease” to mean that the potential has become more negative.

**Answer pattern 4:** Students in this group (9/96) included Na\(^+\) in their answers, reasoning that increasing extracellular K\(^+\) will cause other cations such as Na\(^+\) to enter (or leave) the cell “to preserve the electrical state.” Two students stated that the cell will fire action potentials. These students were extrapolating from what they had learned about action potentials in nerve and muscle and were linking changes in potassium permeability to changes in sodium permeability. They did not understand that all living cells have resting membrane potentials. This confusion may arise partly from the fact that some physiology and biology textbooks introduce the concept of resting membrane in the chapter on neurophysiology, leading students to believe that only neurons and muscles have membrane potentials.

A number of serious misconceptions appeared in individual answers, including one statement that moving K\(^+\) into the cell makes the cell more negative and another assertion that “K\(^+\) is negatively charged.” A third student described the cell’s “resting potential of potassium.”
Analysis of the answers suggests that students come to the class with only a superficial understanding of membrane potentials despite having had a semester of neurophysiology. The misunderstandings are so varied that we simply reteach resting membrane potential with an emphasis on those areas where we know students have problems. Going into this session, the students know from the multiple-choice question what they do not understand and are therefore more active about correcting their misconceptions.

Address for reprint requests and other correspondence: D. Silverthorn, Neurobiology Section, Univ. of Texas, Austin, TX 78712 (E-mail: silverth@utxvms.cc.utexas.edu).

Received 8 March 2002; accepted in final form 8 March 2002.