Membrane potential (voltage)

Focus Question:

Electrically excitable cells like neurons have a membrane potential (also called membrane voltage). What is membrane potential and how is it established in neurons?

Learning Goals:

Identify the factors that influence ion flux across selectively permeable membranes.

Define ion equilibrium potential.

Distinguish resting membrane potential from ion equilibrium potential.

Pre-requisite knowledge:

Principle 1:

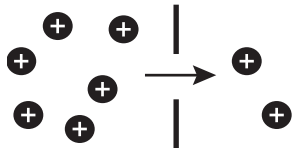
Electric charge comes in two flavors: positive (+) and negative (-). When salt dissolves in water a positively charged ion forms and negatively charged ion forms.

Principle 2:

Oppositely charged ions attract. Like charged ions repel.

Principle 3:

Ions (or any particles) diffuse from areas of high concentration to low concentration.



Model 1: Potassium equilibrium potential

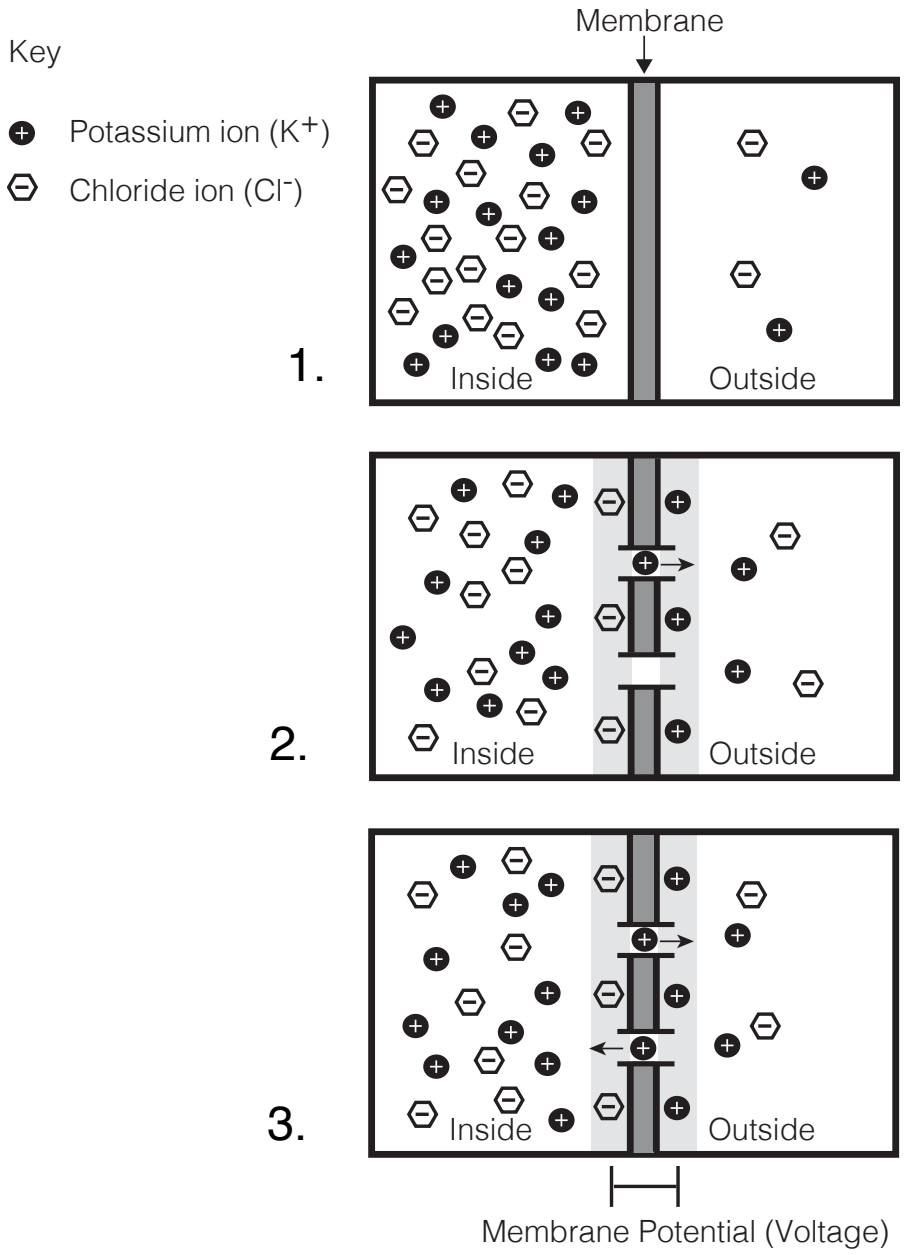


Figure 1. Model of a patch of neuronal membrane with a typical distribution of **potassium ions** inside and outside the membrane. The effect of changing membrane permeability is shown in stepwise progression.

Questions for Model 1:

1. In panel 1 are the numbers of positive and negative ions the same on either side of the membrane?

2. Describe in a complete sentence what has happened to the cell membrane in panel 2.

3. Which principle explains the outward flow the ions in panel 2?

4. Define a particular property to the membrane opening in panel 2?

5. Which principle explains why the positively charged ion in 3 flows back into the cell?

6. In panel 3 there is an unequal distribution of positive charges inside and outside the cell; **an imbalance of electrical charge across an insulator like a membrane creates a membrane potential or membrane voltage.** What do you notice about the arrangement of the ions with respect to the membrane?

7. Panel 3 depicts a special state called the equilibrium potential. Write a definition that explains the relationship between the ion that is flowing in and out of the cell and the physical principles that lead to this balanced state.

8. Predict the distribution of ions across the membrane in panel 3 **if** we started with more potassium ions outside the cell then inside the cell in panel of figure 2.

Model 2: Sodium equilibrium potential

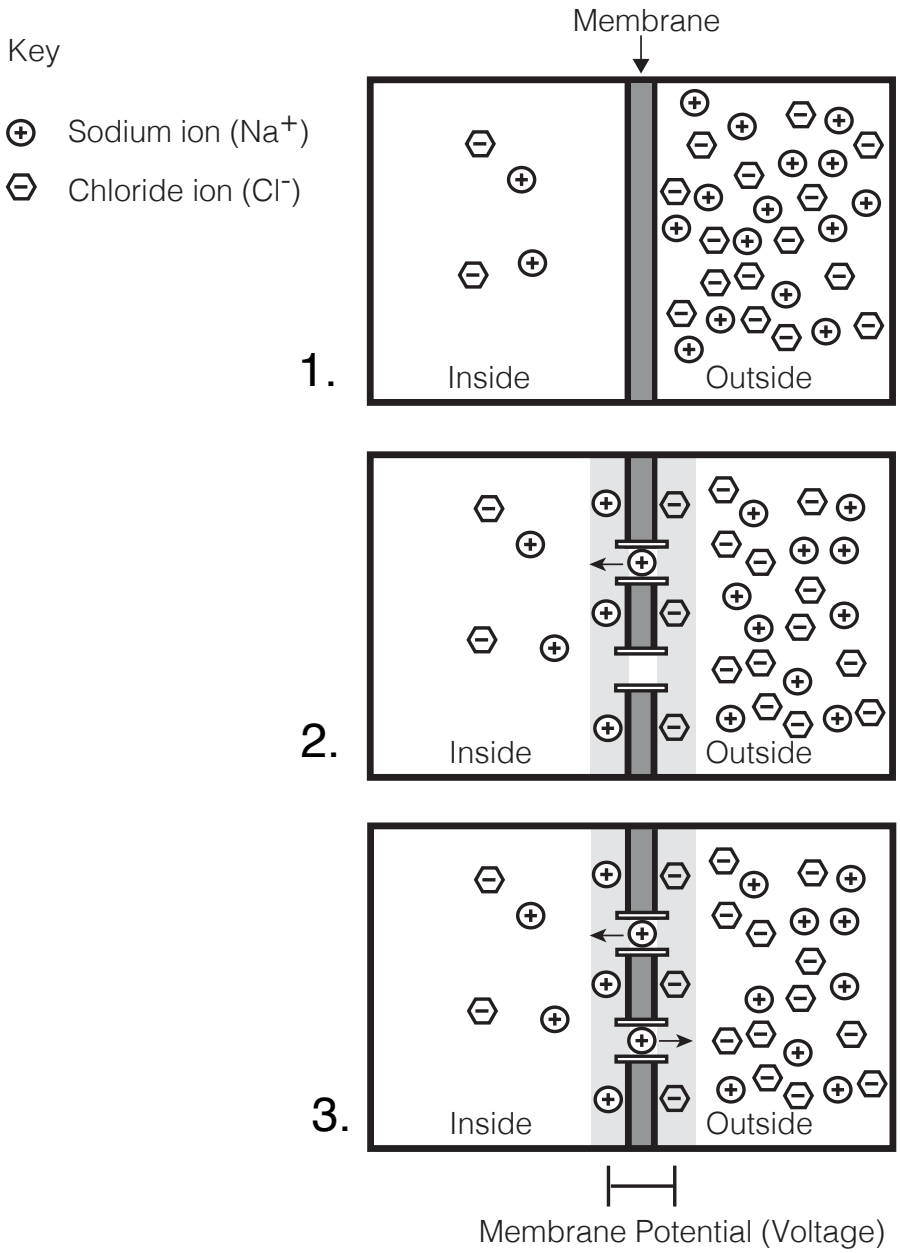


Figure 2. Model of a patch of neuronal membrane with a typical distribution of **sodium ions** inside and outside the membrane. The effect of changing membrane permeability is shown in stepwise progression.

Questions for Model 2:

9. Which principle explains the inward flow of ions in panel 2 (figure 2)?

10. How does the opening in Model 2 differ from the opening in Model 1?

11. Which principle explains why the positively charged ion in 3 flows out of the cell?

12. Panel 3 in Model 2 (Figure 2) depicts the sodium equilibrium potential. Compare and contrast the equilibrium depicted in Model 1 and Model 2.

13. Electrochemical equilibrium is the “preferred” state in any system. Predict the charge distribution of ions across the membrane if the membrane is 90% more permeable to sodium ions than potassium ions.

Model 3: Resting Membrane Potential

Key

- Sodium ion (Na^+)
- Chloride ion (Cl^-)
- Potassium ion (K^+)
- Impermeant Anions (A^-)

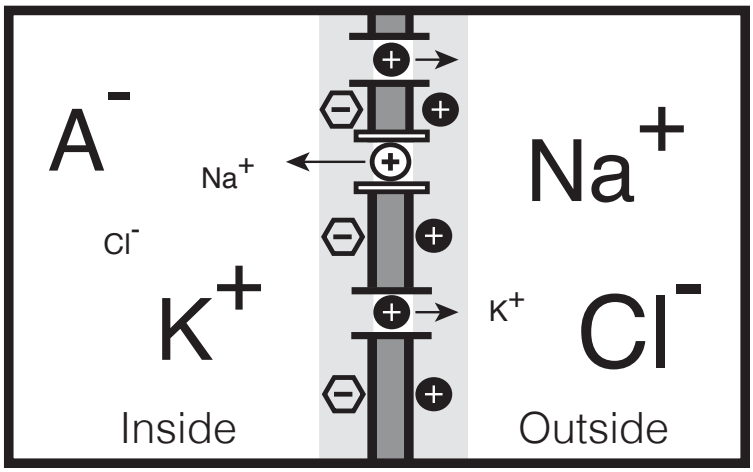


Figure 3. Model of a patch of neuronal membrane with typical relative membrane permeabilities to sodium and potassium ions. The size of the ion abbreviations corresponds to the relative quantity of ions on either side of the cell membrane. The size of the arrows corresponds to the rate at which different ions flow out of the cell.

Questions for Model 3:

14. In the resting neuron, which ion is more permeable?

15. Compare and contrast the arrows that represent the flow rate of ions in or out of the cell.

16. At rest, the membrane potential is in steady-state, a constant membrane voltage. Is the membrane in equilibrium for either ion?

17. What would happen the membrane potential if we increased the amount of potassium ions on the outside of the membrane?

18. What would happen if the membrane became more permeable to sodium ions than potassium ions?