B2. Transmembrane Potentials

Several questions arise about the distribution of ions and the magnitude of the transmembrane potential.

1. How are the ion gradients established?
2. How does the transmembrane ion distribution contribute to the membrane potential?
3. How can the resting electrochemical potential and the ion distribution be maintained?

The answer to these questions will be illustrated using studies on two types of brain cells, glial cells (which function as protectors, scavengers, and feeder for brain neurons) and neurons. Both types of cells have transmembrane potentials.

Glial Cells

1. The transmembrane ion gradients for ions can be established by different mechanisms. One uses ion-specific ATPases (P-type ion transporters), such as we discussed with the Na/K ATPase. This transporter ejects 3 sodium ions from the inside of the cell for every 2 potassium ions it transports in, all against a concentration gradient. Since it is an electrogenic antiporter, it helps generate the potential. Additionally, specific ion channels also contribute (as described below) to the transmembrane gradients and potentials.

2. The harder question is how the ion distribution contribute to the membrane potential. Two things must occur for a membrane potential to exist: First, there must be a concentration gradient of charged ions (for example, sodium, potassium, or chloride) across the membrane. Second, the membrane must be differentially permeable to different ions. If the membrane were completely impermeable to ions, then no movement of ions across the membrane could occur, and no membrane potential would arise. If, however, membranes are differentially permeable to the ions, an electrical potential across the membrane can arise. Remember, synthetic bilayers are quite impermeable to ions, given the hydrophobicity of the internal part of the bilayer. Likewise it is quite impermeable to glucose. It turn out that glial cells
appear to have only a non-gated potassium channel, which allows the outward flow of potassium ions down the concentration gradient. The inside will then have a net negative charge since impermeable anions remain. The chemical potential gradient causes this outward flow of potassium ions. As more ions leave, the inside gets more negative, and a transmembrane potential develops which resists further efflux of potassium. Eventually they balance, and the net efflux of potassium stops. The resting transmembrane potential reaches -75 mV which is exactly the value obtained from the equations we will derive below. Since glial cells appear to only express a nongated potassium channel, their resting potential is equal to the potassium equilibrium potential.

Figure: Visualizing the transmembrane potential in K+ loaded vesicles ± a nongated K+ channel.

(Note: above figure has mistake. Cl⁻ ion, assuming that is not permeable, will not change across the membrane at equilibrium.)

Contributors

- Prof. Henry Jakubowski (College of St. Benedict/St. John's University)