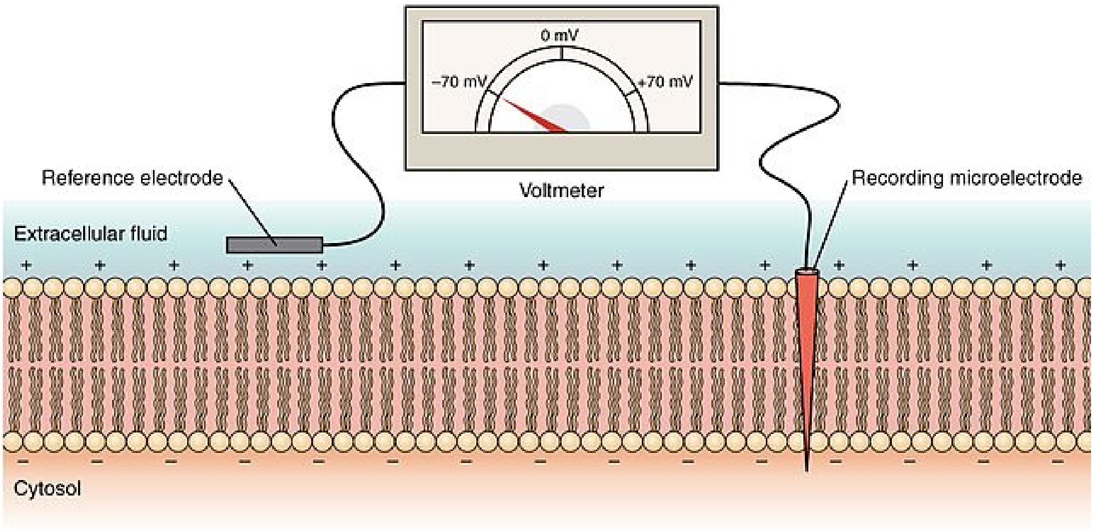
Membrane Excitability, Equilibrium Potential, and Action Potential

[See online here](#)

The cell membrane is a partially permeable membrane that allows only hydrophobic or lipid soluble molecules to move in and out freely. Ions, being polar molecules, are unable to pass freely and therefore channel proteins are responsible for carrying them across the cell membrane. These channel proteins are gated and thus open and close in response to a certain stimulus.



Membrane Potential

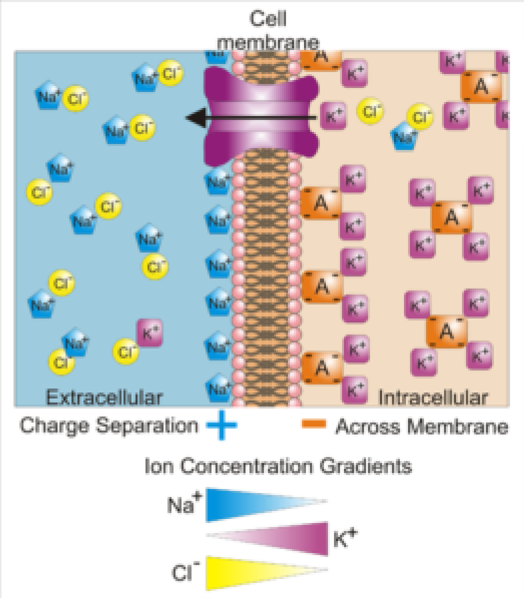


Image: “Figure 1.0: Diagram showing the ionic basis of the resting potential” by Synaptidude. License: CC BY 3.0

Membrane potential (Vm) is the difference in electrical potential between the interior and exterior of a biological cell. A typical membrane potential value ranges from +**40 mV to -70 mV**.

Figure 1.0 shows that the inside of the cell is more negative than the extracellular environment. This is because of the cell membrane’s permeability to certain ions and the numbers of those ions.

The concentrations of certain ions in the intracellular and extracellular environment are listed in the table below:

Sr. No	Ion	Extracellular concentration (mM/L)	Intracellular concentration (mM/L)
1	Sodium (Na+)	145	12
2	Potassium (K+)	4	120
3	Chloride (Cl-)	110	15
4	Calcium (Ca+2)	2.5	0.0001

Table 1.0: Concentration of ions across the cell membrane.

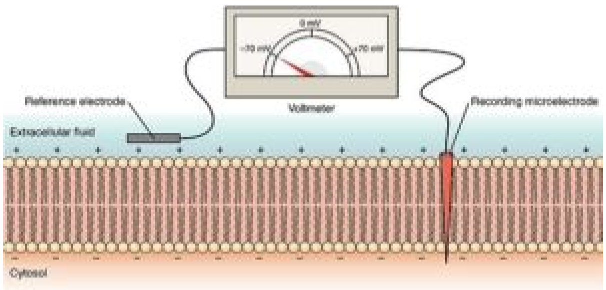


Image: “Figure 2.0: Measurement of membrane potential” by OpenStax – https://cnx.org/contents/FPtK1zmh@8.25:fEI3C8Ot@10/Preface. License: CC BY 4.0

The principal intracellular cation is potassium, while the principal extracellular cation is sodium.

The principal anion is chloride, which is mainly extracellular.

Therefore, the environment inside the cell is more negative than the outside because there are more negative ions inside the cell. This state is also known as the resting membrane potential since there is no active stimulus, as shown in Figure 1.0.

The membrane potential is measured with the help of a **microelectrode,** as shown in Figure 2.0.

Equilibrium Potential

Equilibrium potential/ reversal potential is the membrane potential where the net flow of specific ions through an open channel across the cell membrane is zero. Thus, the equilibrium potential across the cell membrane is **0 mV**. It is the state at which the chemical and electrical forces are in balance. It is calculated using the Nernst equation. In mammalian neurons, the equilibrium potential for Na is +60 mV, while that of K is -88mV.

Resting Membrane Potential

Without a stimulus, the cell's membrane potential is called the resting membrane potential.

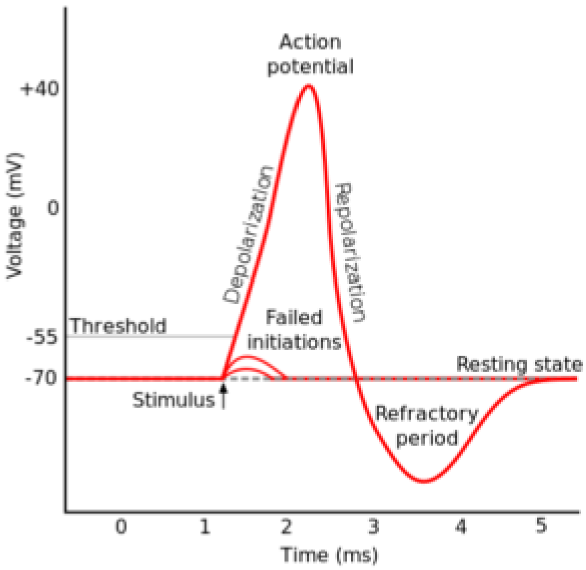


Image: "Figure 3.0: Schematic of an action potential" by Original by en:User: Chris 73, updated by en:User: Diberri, converted to SVG by tiZom – Own work. License: CC BY-SA 3.0

During the resting membrane potential, the **sodium-potassium pump** uses adenosine triphosphate (ATP) to move three sodium ions out of the cell and two potassium ions into the cell. This creates negativity inside the cell. In addition, there are leaky potassium channels that allow K+ to diffuse out of the cell. The cell membrane is said to be **polarized,** as shown in Figure 3.0.

- The **resting membrane potential is -70 mV**.

Action Potential Generation

Action potential is generated in the presence of a **stimulus**. The nerve endings are stimulated by a change in the environment, which results in the **opening of sodium channels**. Sodium ions move into the cell, and the membrane is said to be depolarized.

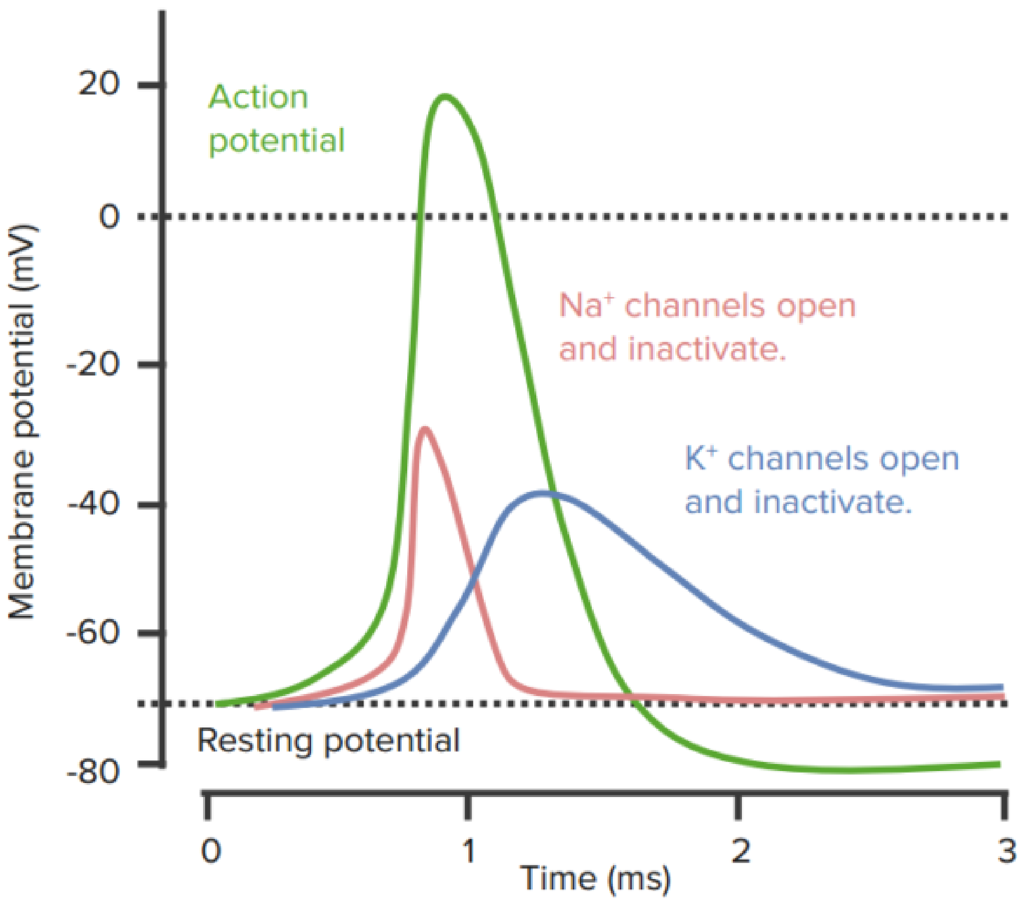
The membrane potential changes **from -70 mV to +40 mV**.

It is important to note that not every stimulus can generate an action potential. The amount of potential change required to generate an action potential is known as the **threshold potential**.

A stimulus opens some sodium ion channels, which decrease the negativity inside the cell slightly. If the threshold potential is reached, all sodium channels open, and more sodium ions move into the cell.

Once generated, the action potential moves along the entire length of the membrane until the entire membrane is depolarized.

Example: Action Potential



The points where the voltage-gated channels open is called the threshold.

Increasing Vm past the threshold can cause an action potential in certain tissues like nerves.

Repolarization

Once an action potential is generated and the cell membrane is depolarized, the sodium channels close and the potassium channels open. This allows the **potassium ions to move out of the cell** and recreates **negativity inside the cell**. The cell membrane is said to be repolarized.

If the membrane potential becomes more negative than the resting membrane potential, it is known as **hyperpolarization**. During this state, a new action potential cannot be generated. Therefore, it called the **refractory period** or resting state, as shown in Figure 3.0.

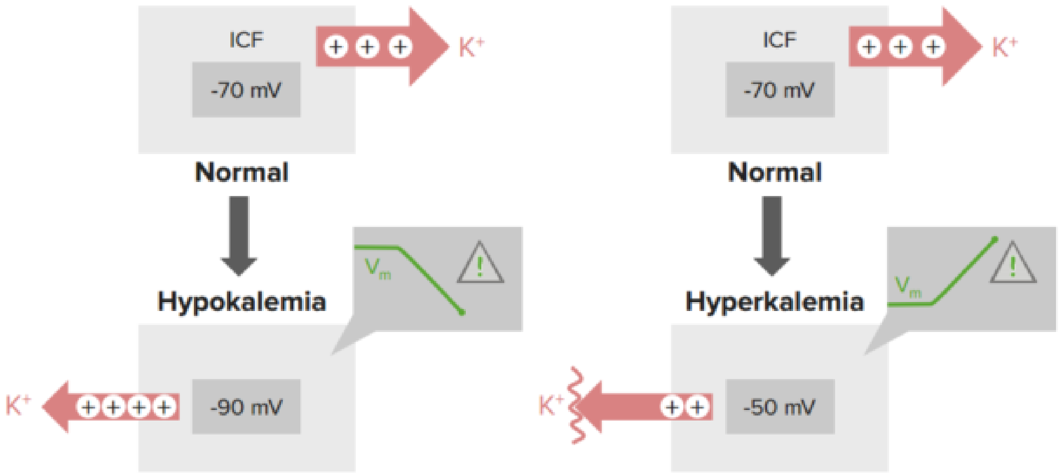
The cell membrane retains its polarized state by the sodium-potassium pump, which realigns the ions. Sodium ions, which moved into the cell during the action potential, are expelled against the concentration gradient. Similarly, potassium ions are moved into the cell. The cell membrane regains the potential of -70 mV.

If another stimulus arrives, the membrane will be depolarized again, and the action potential will be generated.

Effect of Ion Manipulation on Membrane Potential

Under normal physiological conditions, the membrane potential remains in a relatively **constant range**. However, if there is an **electrolyte imbalance**, the equilibrium potential, as well as the membrane potential, change.

In case of **hypokalemia**, more potassium ions leak out of the cell during the resting state, which changes the membrane potential to a more negative value of **-90 mV**. Similarly, if **hyperkalemia** occurs, fewer potassium ions will move out of the cell through leaky potassium channels, and the resting membrane potential will become less negative.



Effect of Current on Membrane Potential

The direction of the current decides the membrane potential. If there is an **efflux of positive ions**, the cell membrane will become **hyperpolarized**. If there is an **influx of positive ions**, the cell membrane may become **depolarized** and generate an action potential.

References

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Notes