physiology

faculty of medicine - JU2017

● Sheet ○ Slides

Number

7

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In the previous lectures, we have talked about how the difference in permeability for ions across the cell membrane can generate a potential. The potential that is present in normal conditions is called the **resting potential** and the membrane is said to be **polarized**.

What happens if the resting potential is changed due to a stimulus?

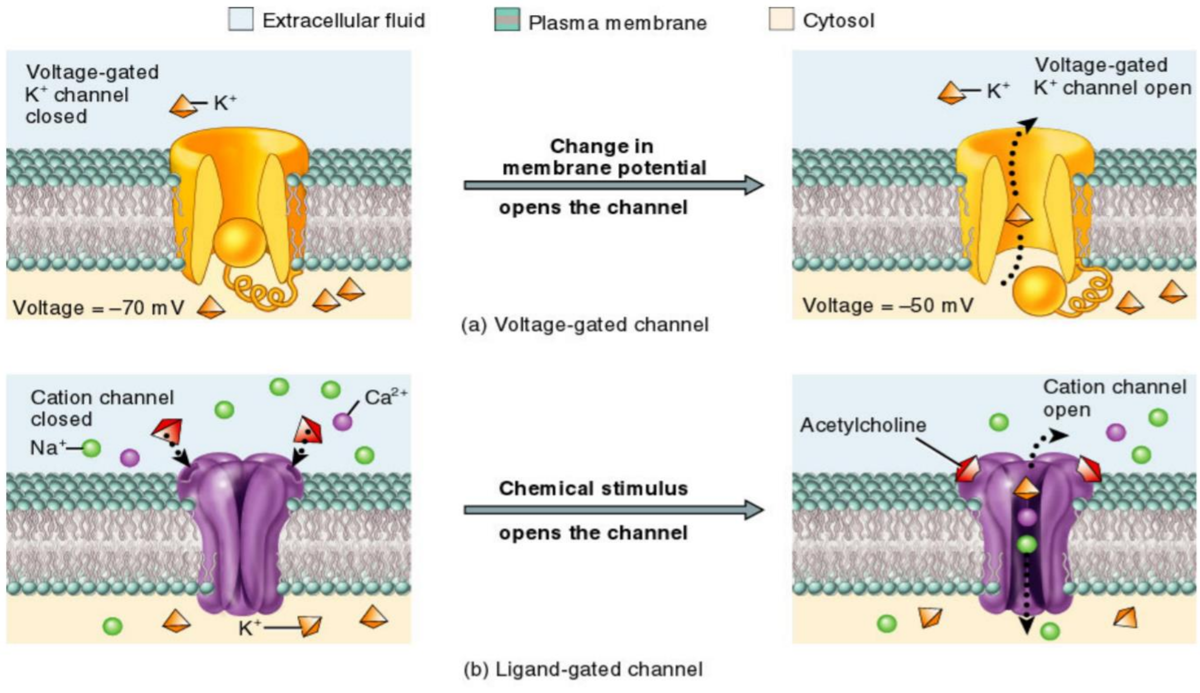
Cell membrane's permeability for ions will be altered which leads to an action potential.

Action potential:

There are two types of channels in cell membrane:

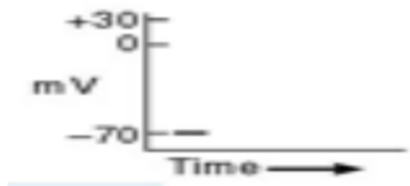
- Chemical gated channels (also called ligand gated channels): they are opened by the binding of a chemical substance (a ligand) to the channel.

- Voltage gated channels: they are activated at certain voltages and inactivated at certain voltages too.



Phases:

- Resting Phase: the normal state of membrane potential with no changes in membrane's permeability.

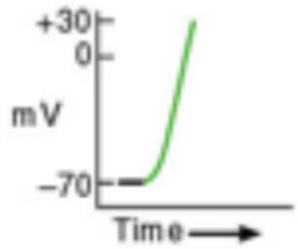


- **Depolarization Phase:**

When a stimulation occurs, the resting membrane potential is changed by activation of Na+ chemical gated channels and **some** Na+ voltage gated channels. The flow of Na+ to the inside of the cell causes the membrane potential to be **less** negative. This situation continues until the membrane potential reaches a point at which all Na+ voltage gated channels are activated. This voltage point is called the **threshold** point.

Threshold point represents a barrier that if crossed, action potential will occur and if not nothing will happen and the membrane will return to its resting state. This is known as **the all or nothing principle**; which states that under right conditions, action potential is generated and it is propagated along the entire membrane. However, if conditions were not right no action potential is generated.

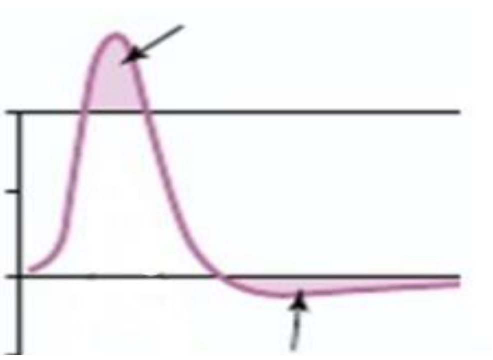
After the voltage reaches the threshold point, all of the Na+ voltage gated channels are activated. This causes rapid change in the membrane potential from the negative state towards the equilibrium potential for Na+ (positive state). This phase is called the **depolarization phase**. In most cells, Na+ ions continue to diffuse into the cell until the inside of the membrane is positive compared to the outside (membrane potential is above zero). The state at which we have a positive membrane potential is called **overshoot**. In some small fibers, as well as in many central nervous system neurons, the potential merely approaches the zero level and does not overshoot to the positive state.



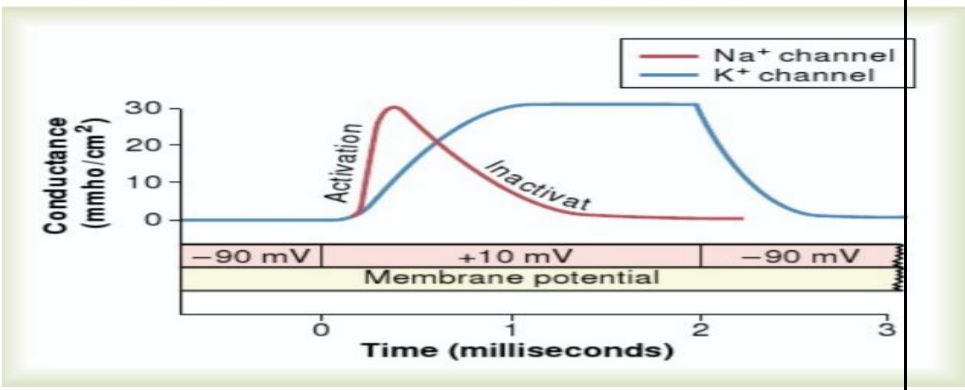
Within a few 10,000ths of a second after the activation of Na+ voltage gated channels, they begin to close. This means that fewer Na+ are diffusing from outside to inside and thus membrane potential is not being **depolarized**.

In the following figure:

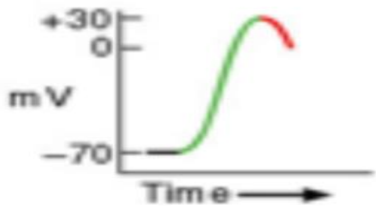
The upper arrow represents the overshoot condition. Whereas the lower arrow represents the undershoot condition (it will be mentioned later). Also called, positive after potential or after hyperpolarization.



Important note: depolarization phase includes two events. First, the change in membrane potential before reaching the threshold point. Second, the "firing" event (its name indicates the rapid diffusion of Na+ ions), which occurs after reaching the threshold point.

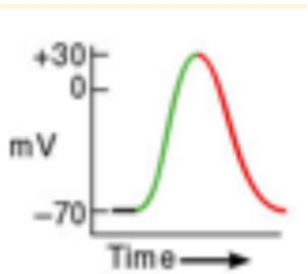


- **Repolarization Phase:** Let's go back in time to the threshold point. When the membrane potential reaches the threshold, not only Na+ channels are activated, but also K+ voltage gated channels are activated. But they open slower than Na+ channels that's why they are called **slow channels** while Na+ channels are called **fast channels**.



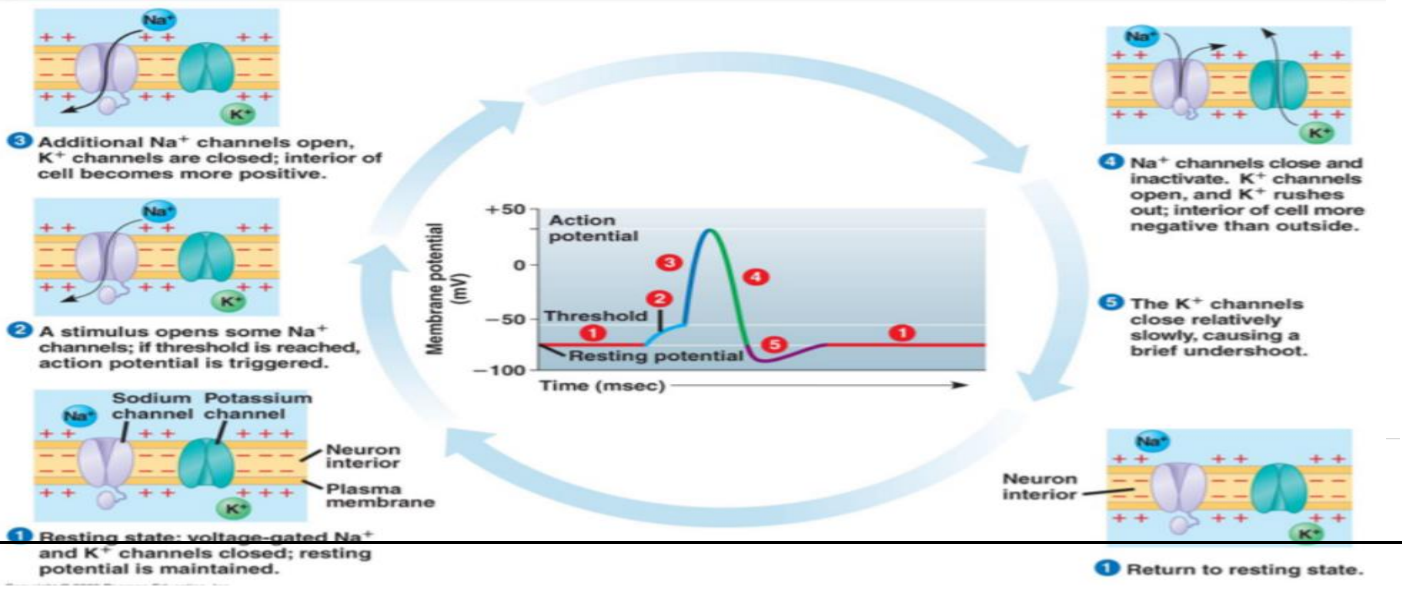
K+ channels continue opening and they are not fully opened until Na+ channels are completely closed. At this point, Na+ channels are closed and Na+ cannot enter the cell while K+ channels are completely opened and diffusion of K+ from inside to outside is allowed. Since K+ ions are positive particles and they are diffusing from inside to outside this makes the membrane potential more negative inside. This process is called **repolarization**.

- **Returning to the resting state:**



Repolarization continues until the resting membrane potential is restored then K+ channels close slowly. The slow closing of K+ channels make the membrane potential slightly more negative than the resting state. This condition is called **positive after potential** or **after hyperpolarization**. Also, it may be called: **undershoot** (refer to the last figure in page 2). After K+ channels are closed, another action potential can begin repeating the same cycle.

Summary:



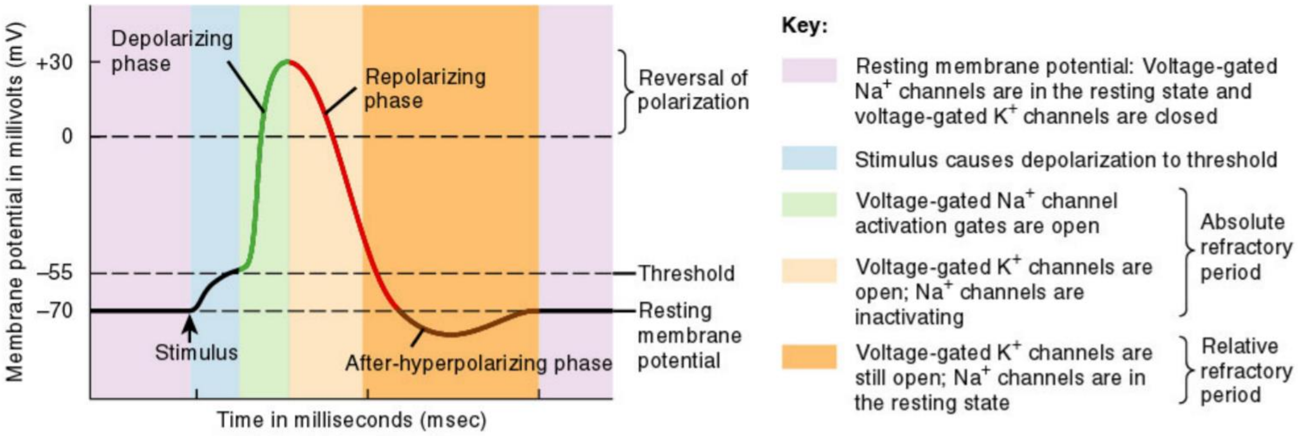
Cellular membrane has different permeability for ions which leads to a potential across the membrane that is called the **resting membrane potential**. When a stimulus is applied, chemical gated Na+ channels (opened by a ligand that is typically a neurotransmitter or a hormone) along with some voltage gated Na+ channels are opened. Na+ ions start flowing to the interior of the cell changing the membrane potential and making it less negative. After some time, threshold point is reached and the remaining Na+ channels are opened leading to the "firing" event. Within some time, Na+ channels close and K+ channels are opened but slowly. This diffusion of k+ ions to the outside of the cell make the membrane more negative and even more negative than the resting state (undershoot). K+ channels close and resting potential is restored. Then the cycle can occur again.

Refractory Periods:

There are two types of refractory periods:

- Absolute refractory period: the period during which a second action potential cannot be elicited even with a strong stimulus.

- Relative refractory period: the period during which a stronger than normal stimulus is needed in order to elicit an action potential.



The doctor mentioned a clinical condition, called **hyperkalemiea (hyper=more, kalem: Latin for potassium, iea: relating to blood). In this condition, there is higher concentration of K+ ions in blood than would be in normal conditions which causes disturbances in neural functions and other functions as well.

For better understanding, watch this video:

https://www.youtube.com/watch?v=BbUcWbtVjT4