Action Potential

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Lec 2

Action Potential

- In general, neurons are electrical machines. positive and negative ions can enter and exit cells through a variety of channels located in the cell membrane.
- Neurons communicate by generating electrical signals in the form of changes in membrane potential. Some of these changes in membrane potential trigger the release of neurotransmitter, which then carries a signal to another cell.

- When a cell is not stimulated, the electrical potential difference across its plasma membrane is known as its **resting membrane potential**. The resting membrane potential of neurons is approximately **–70 mV**.
- In neurons, the concentration of K is much higher inside than outside the cell, while the reverse is the case for Na. This concentration difference is established by Na–K–ATPase.

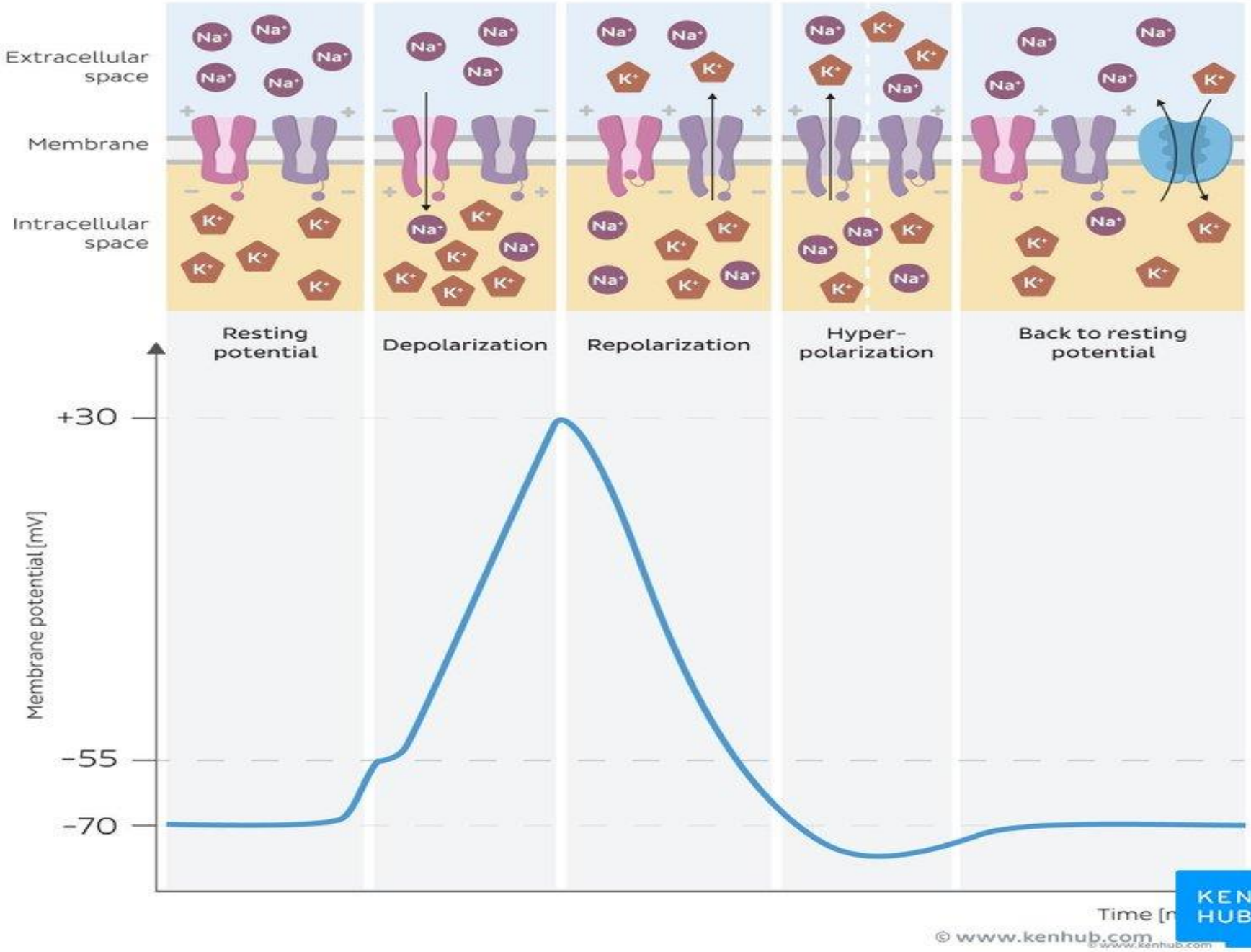
- When certain ion channels, known as **gated channels**, open or close in response to specific stimuli, changes in membrane potential occur in neurons, causing electrical impulses.
- So, an action potential is generated when a stimulus changes the membrane potential to the values of **threshold potential (It is the minimal intensity of stimulating current capable of eliciting an action potential).** The threshold potential is usually around –50 to –55 mV.

- Initiation of action potentials follows **the all-or-none principle:**
- The action potential fails to occur if the stimulus is subthreshold in magnitude, and it occurs with constant amplitude and form regardless of the strength of the stimulus if the stimulus is at or above threshold intensity.
- An action potential in a neuron consists of three distinct phases:

- **Rapid Depolarization**, the initial stage of an action potential, occurs when the membrane potential rises from -70 mV (rest) to +30 mV. This depolarization is brought on by an abrupt and significant rise in sodium permeability, which is followed by an increase in the flow of sodium ions into the cell via the electrochemical gradient of sodium. Since the permeability to sodium is higher than that to potassium

- **Repolarization**. The second phase of an action potential is a repolarization of the membrane potential during which the membrane potential returns from **+30 mV** back to resting levels **(–70 mV)**.
- Within 1 msec after the increase in sodium permeability, sodium permeability decreases rapidly, reducing the inflow of sodium.
- At approximately the same time, the opening of voltage-gated K+ channels that result in potassium permeability increases. Potassium then moves down its electrochemical gradient out of the cell, repolarizing the membrane potential to bring it back to resting levels.

- **After-Hyperpolarization:**
- The third phase of an action potential is termed after hyperpolarization. Potassium permeability remains elevated for a brief time (5–15 msec) after the membrane potential reaches the resting membrane potential, resulting in an after-hyperpolarization. During this time, the membrane potential is even more negative than at rest as it approaches the potassium equilibrium potential (-94 mV).


Extracellular space
Membrane
Intracellular space
Resting potential
Depolarization
Repolarization
Hyper-polarization
Back to resting potential
+30
-55
-70
Membrane potential [mV]
Time [m
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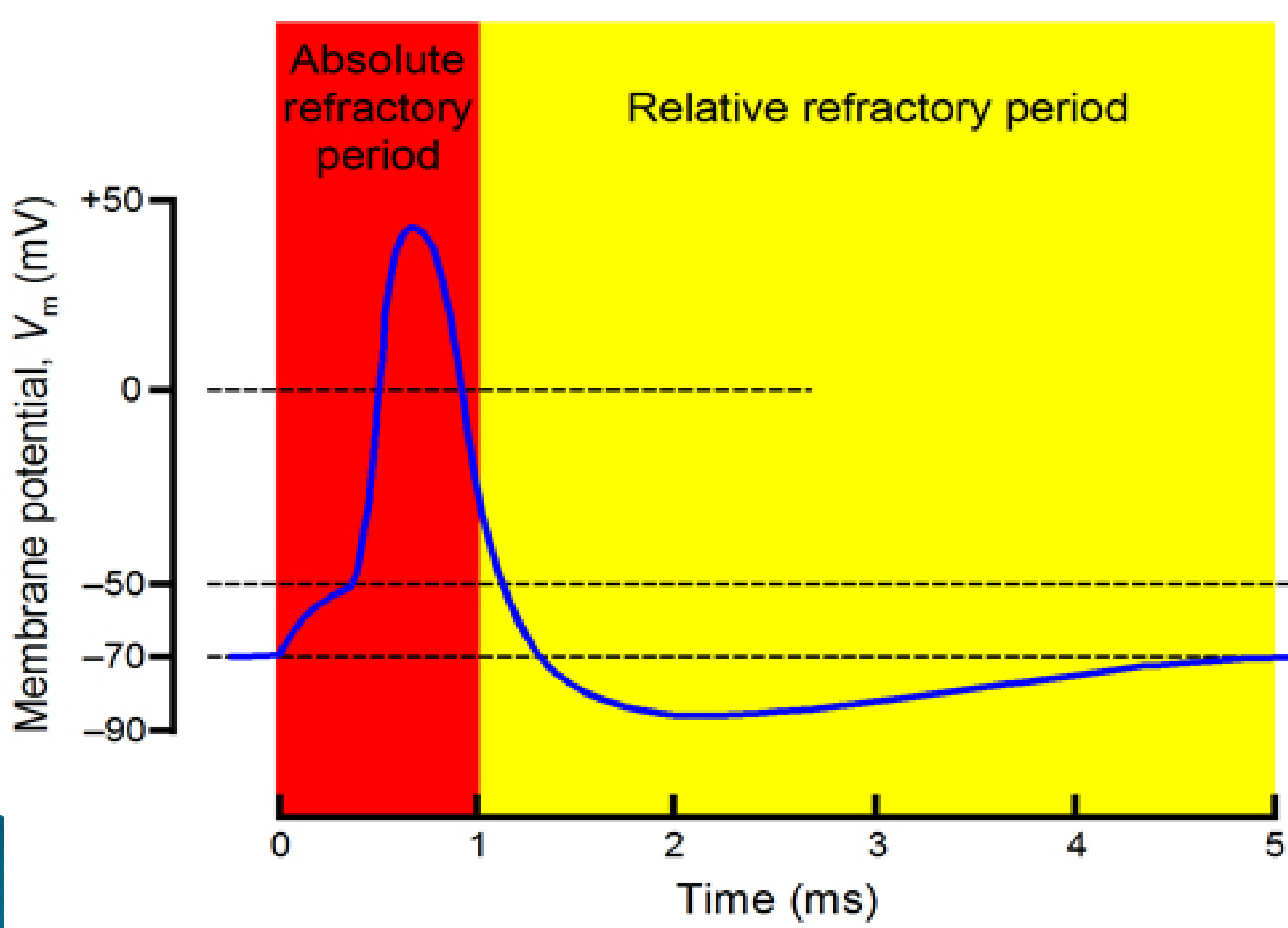
- **Refractory Periods**
- During and immediately after an action potential, the membrane is less excitable than it is at rest. **This period of reduced excitability is called the refractory period**.
- The refractory period can be divided into two phases:
- **The absolute refractory period**
- **The relative refractory period**

- **The absolute refractory period** spans all of the depolarization phase plus most of the repolarization phase of an action potential (1–2 msec).
- During this time, a second action potential cannot be generated in response to a second stimulus, regardless of the strength of that stimulus because sodium channels are in the inactive state

- **The relative refractory period** occurs immediately after the absolute refractory period and lasts approximately 5–15 msec.
- During this period, it is **possible to generate** a second action potential, but only in response to a stimulus **stronger than** that needed to reach threshold under resting conditions because of **increase potassium conductance.**


Absolute refractory period
Relative refractory period
+50
0
–50
–70
–90
Membrane potential, V_m (mV)
0
1
2
3
4
5
Time (ms)