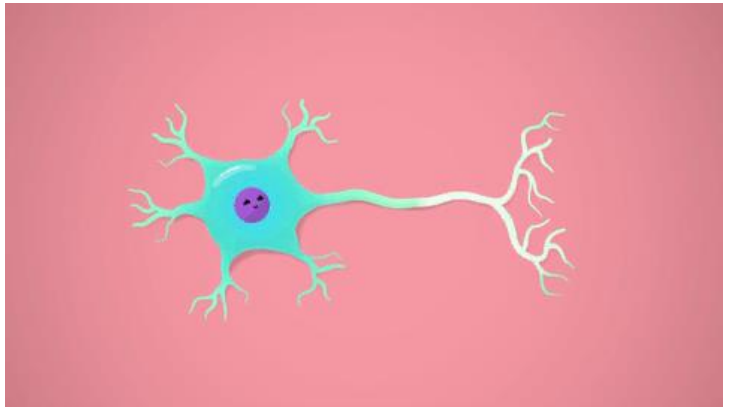

Comparison between neuronal action potential and action potentials in other cells

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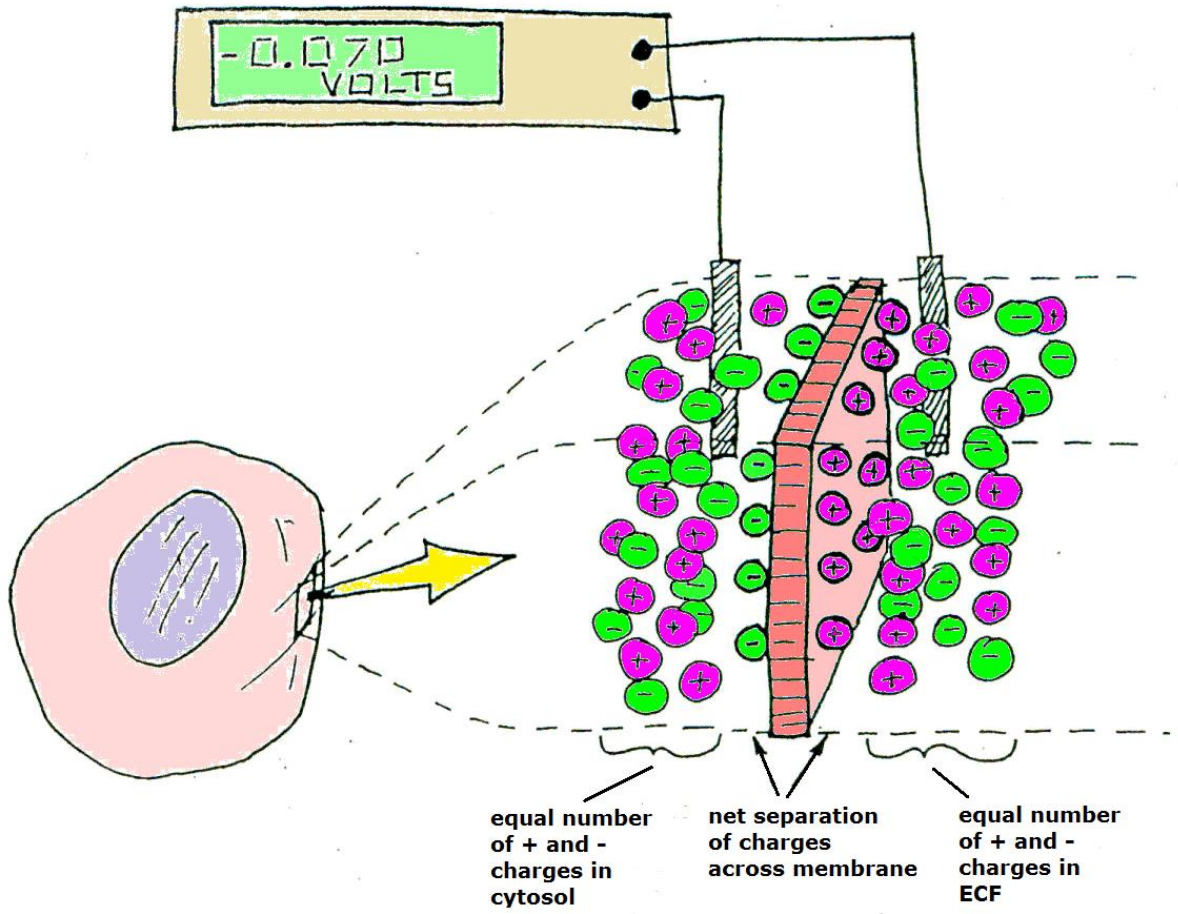
Department of Biophysics

Lecture Outline:

- Brief information about resting membrane potential
- Ionic Mechanisms of action potentials
- Propagation of the action potential
- Comparison between neuronal action potential and action potentials in other cell types

Membrane potential

- In all type of cells, there is an **electrical potential difference** between the inside of the cell and the surrounding extracellular fluid. This is termed the **membrane potential** of the cell.
- Two energetic factors influence the movement of an **ion** across a membrane.
- The concentration gradient
- The electrical potential difference

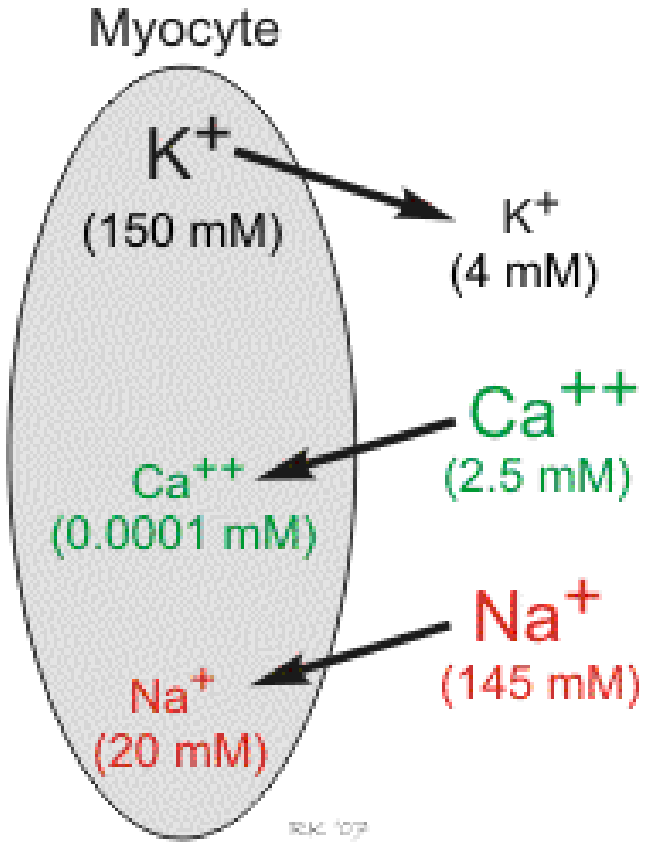


https://backyardbrains.com/experiments/heartrate

Membrane potential

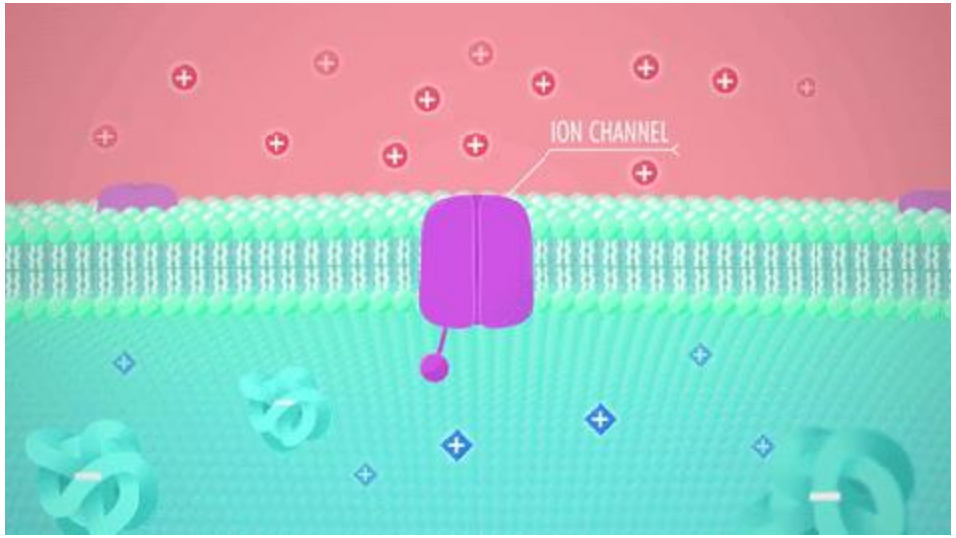
Membrane potentials in cells are determined primarily by three factors:

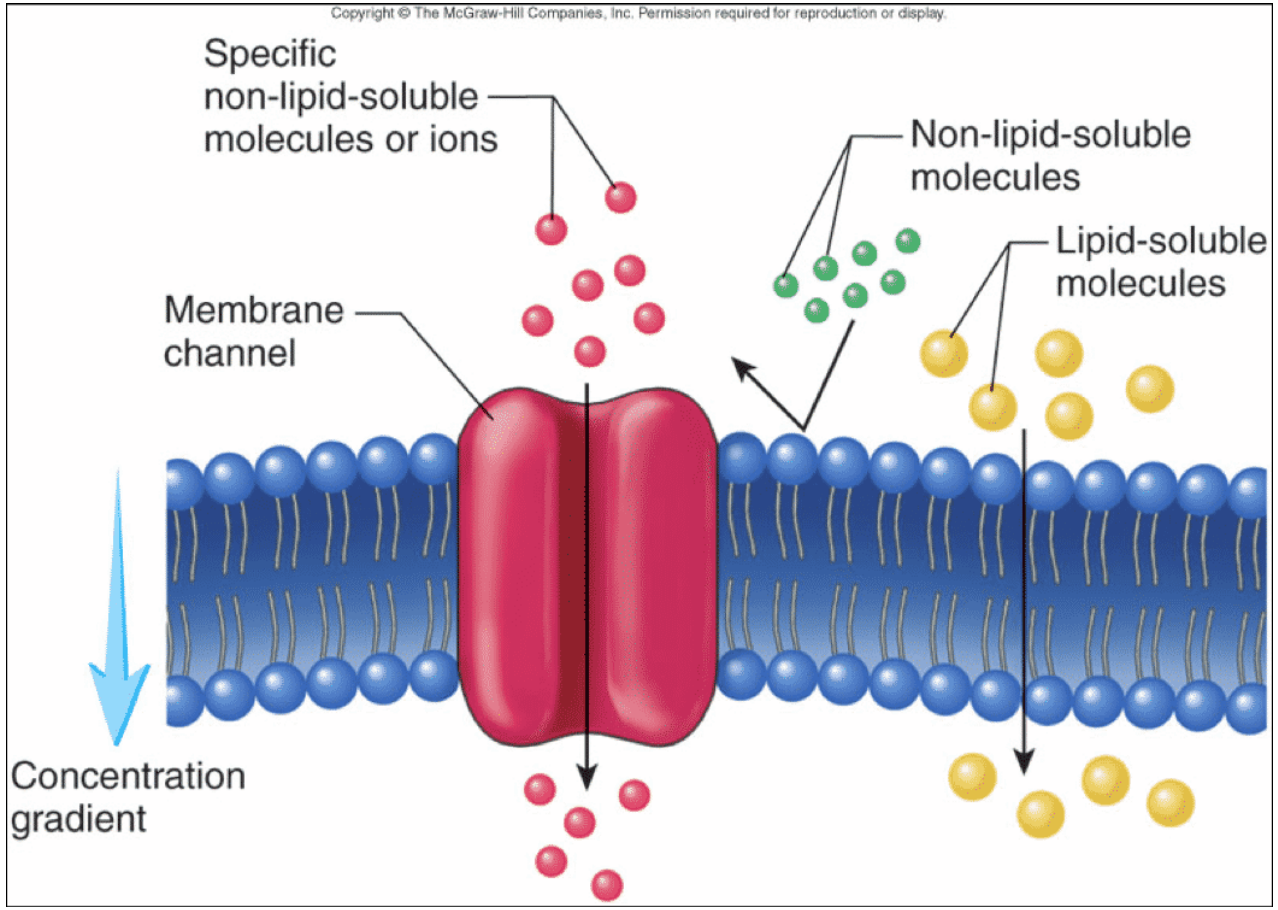
1) the concentration of ions on the inside and outside of the cell;



Membrane potential

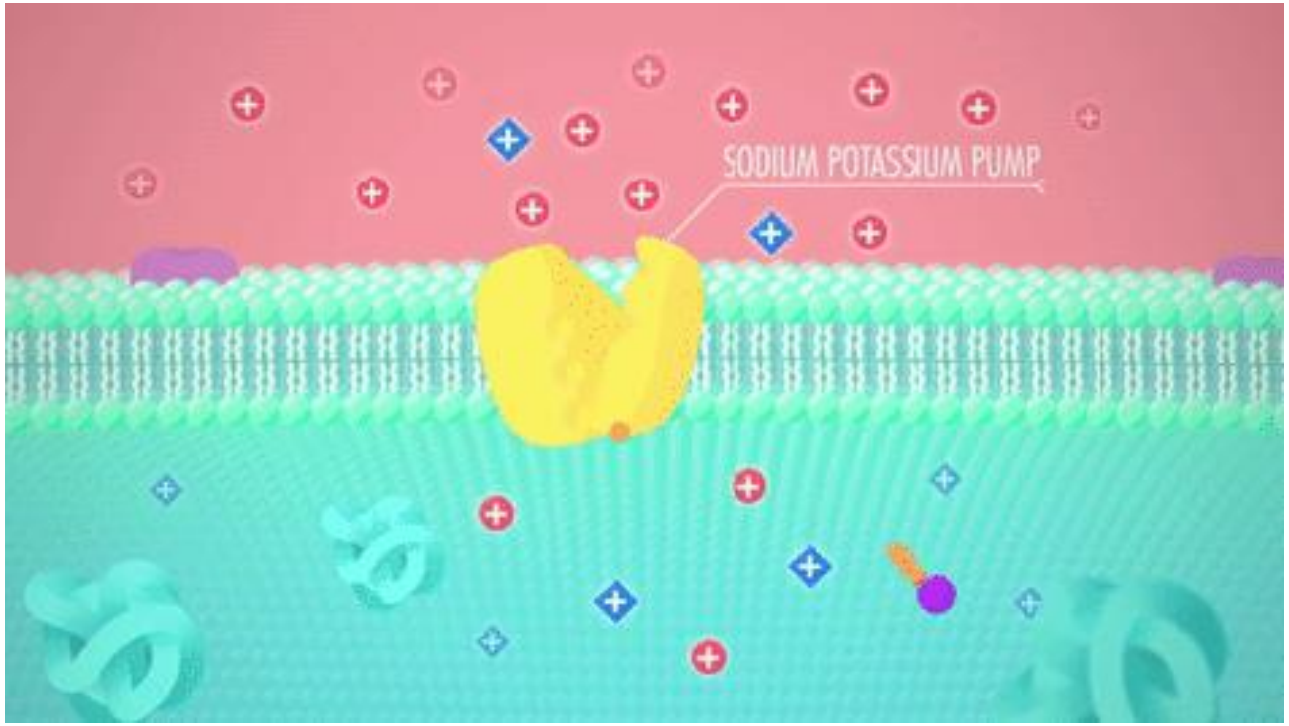
2) the permeability of the cell membrane to those ions (i.e., ion conductance) through specific ion channels;





Membrane potential

3) by the activity of **electrogenic** pumps (e.g., Na^+/K^+-ATPase and Ca^{++} transport pumps) that maintain the ion concentrations across the membrane.



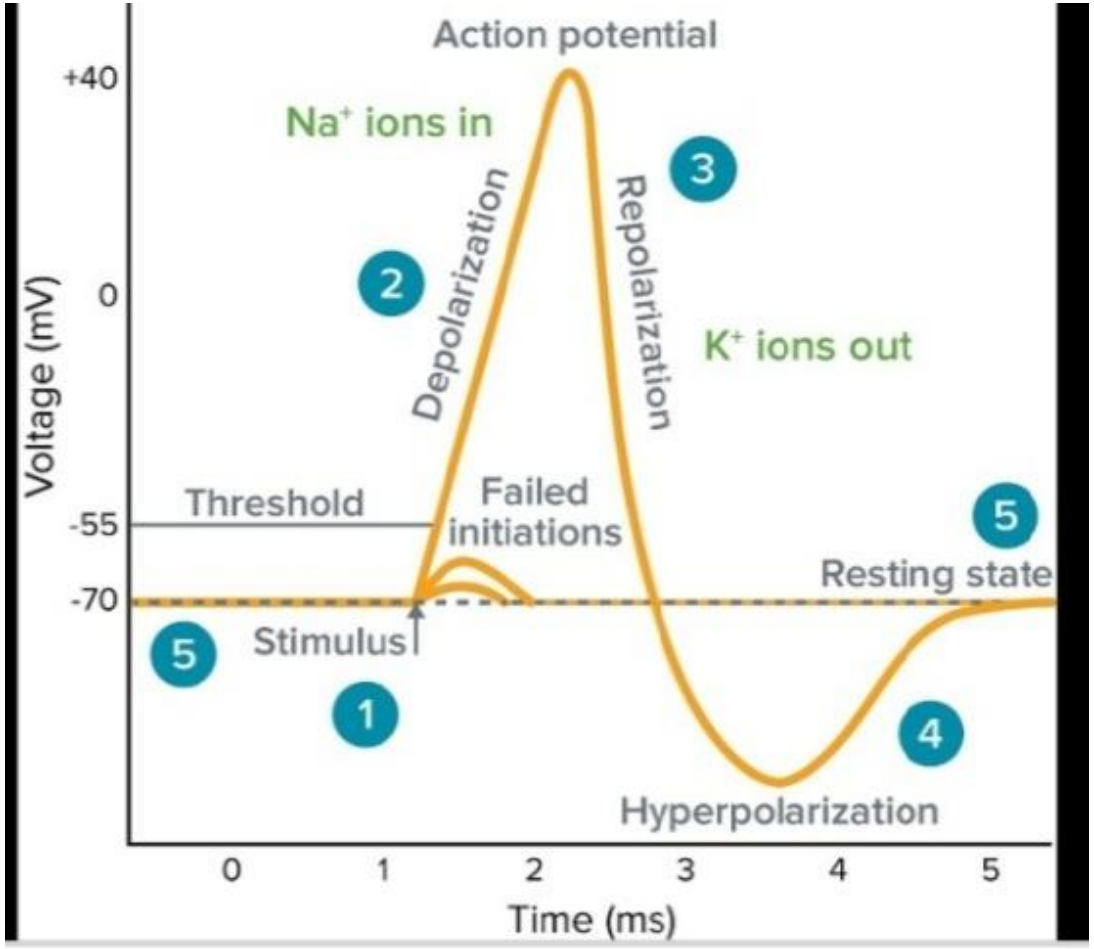
Sodium potassium pump maintains an electrochemical gradient inside neurons

What is an excitable cell?

- Excitable cells are those capable of developing action potentials across their plasma membranes. They can do this because they express voltage-gated cation channels in specific membrane domains. Muscle is considered a type of “excitable cell” and the majority of muscle types will produce action potentials along their plasma membranes (or sarcolemma).

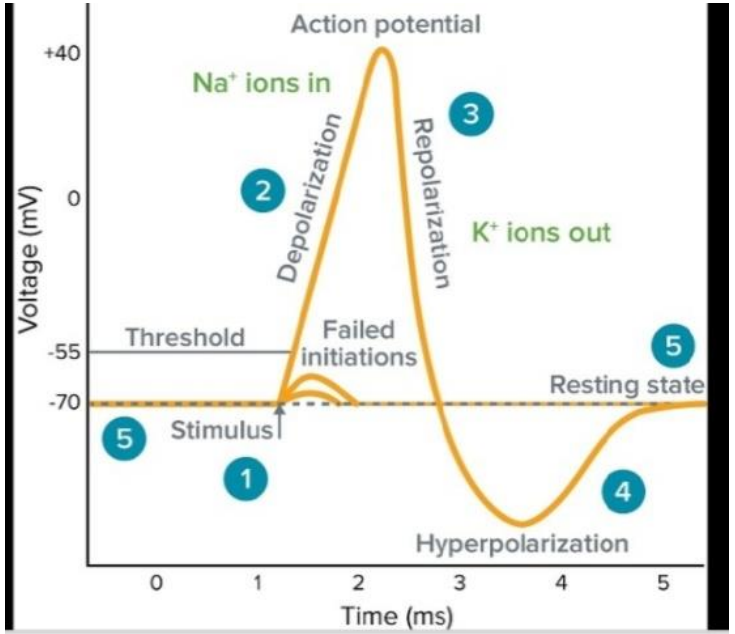
What is action potential?

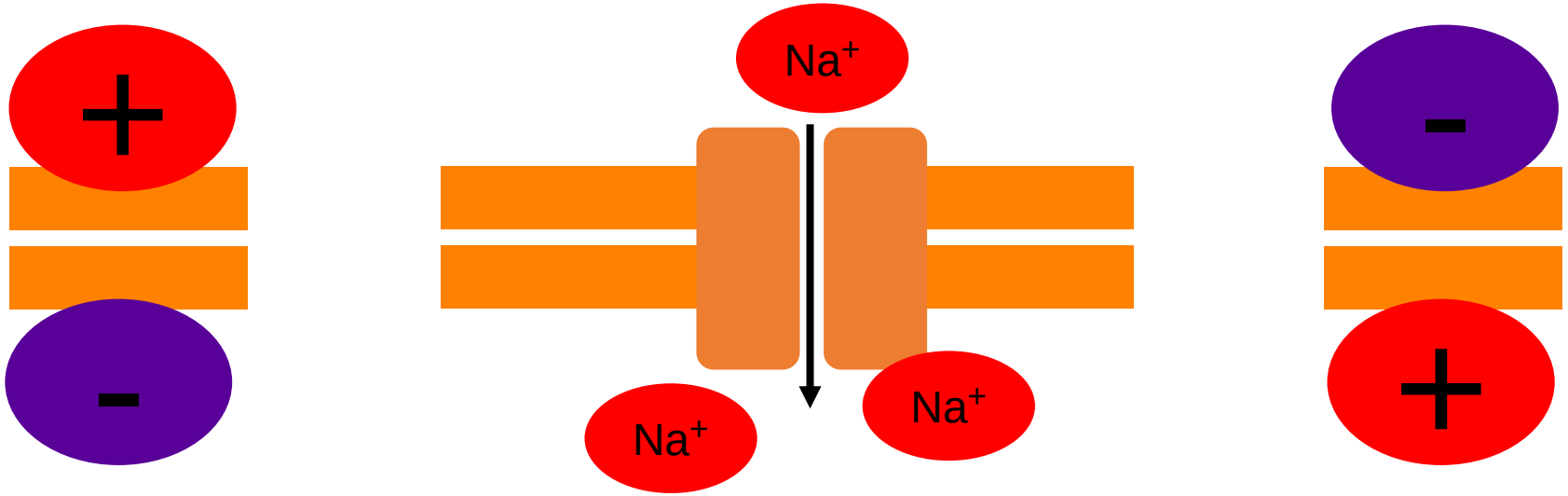
- An action potential is a predictable change in membrane potential that occurs due to the open and closing of voltage gated ion channels on the cell membrane.



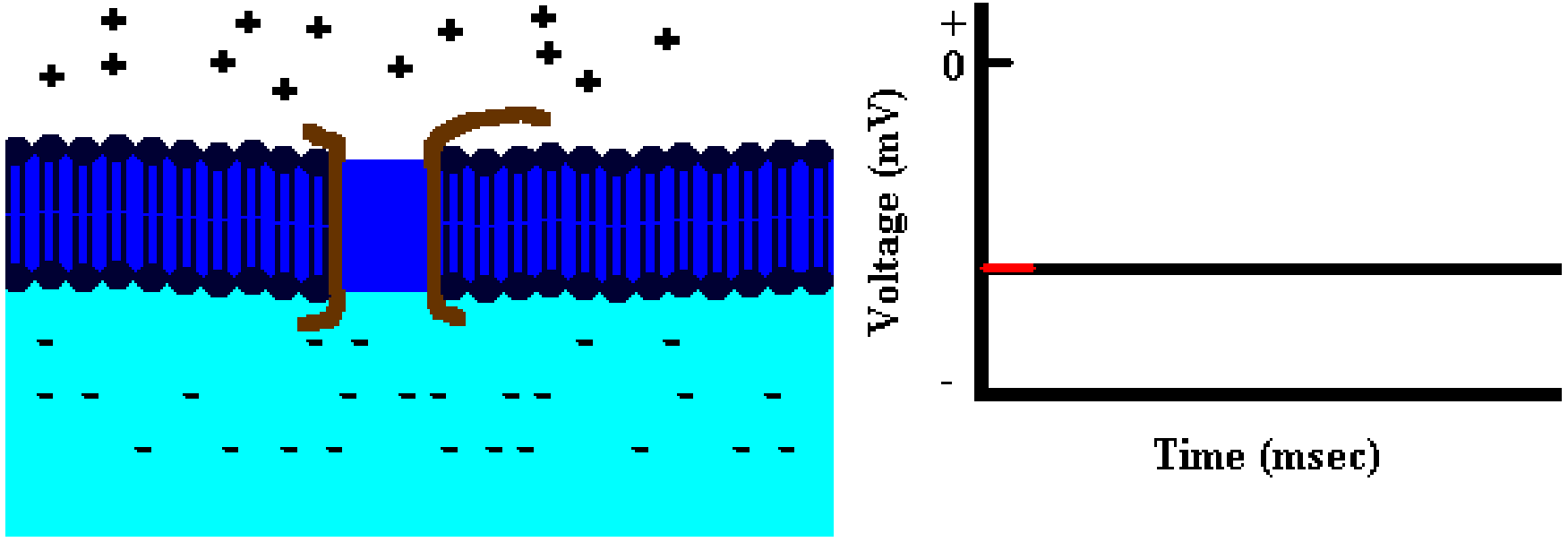
Action potentials: Rapid depolarization

- When partial depolarization reaches the **activation threshold, voltage-gated sodium ion channels** open.
- Sodium ions rush in.
- The membrane potential changes from -70mV to +40mV (2).



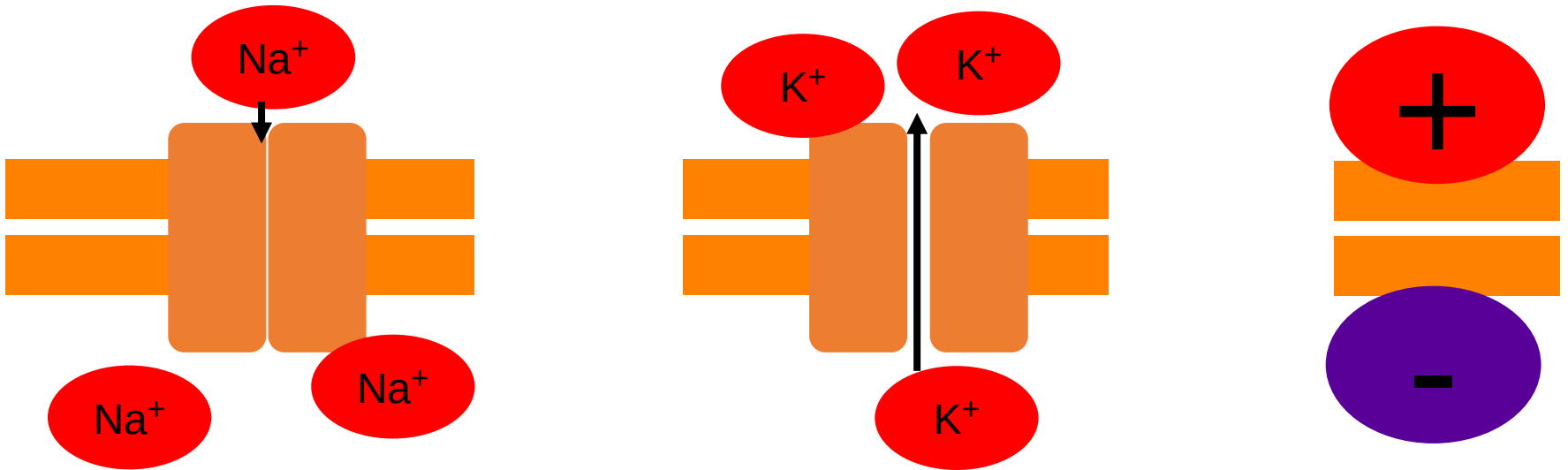


Depolarization

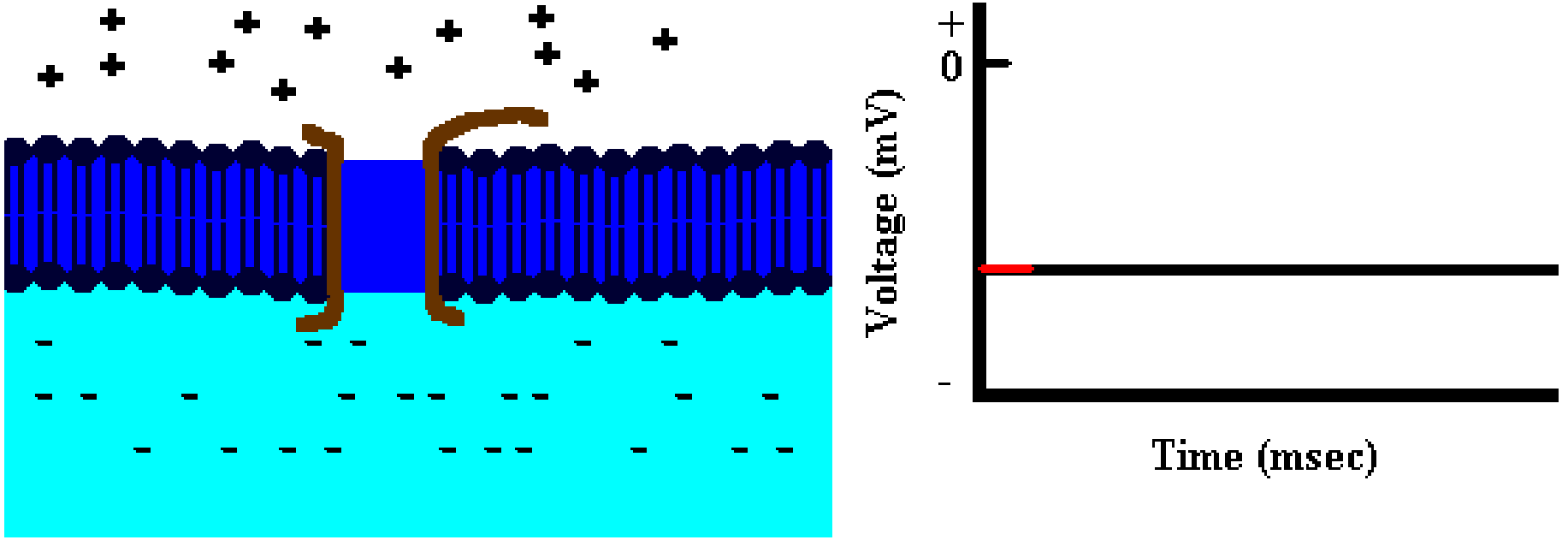


Action potentials: Repolarization

- Sodium ion channels close and become **refractory**.
- Depolarization triggers opening of **voltage-gated potassium ion channels.**
- **K+** ions rush out of the cell, repolarizing and then hyperpolarizing the membrane.

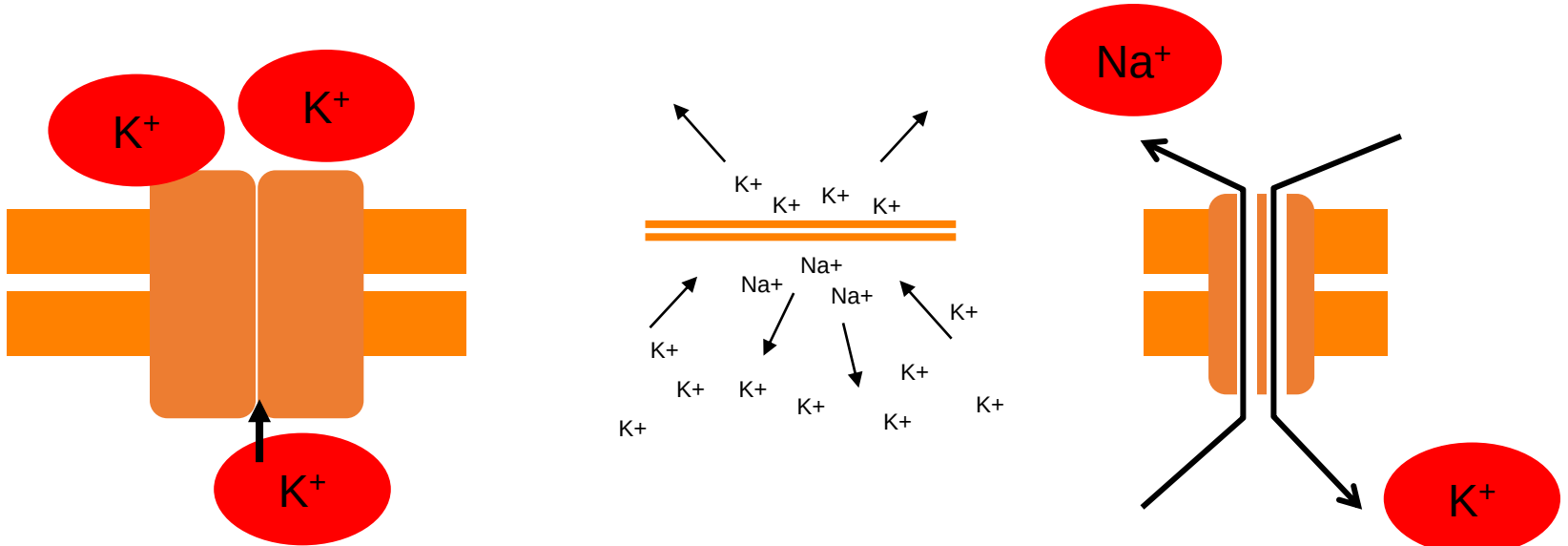


Repolarization



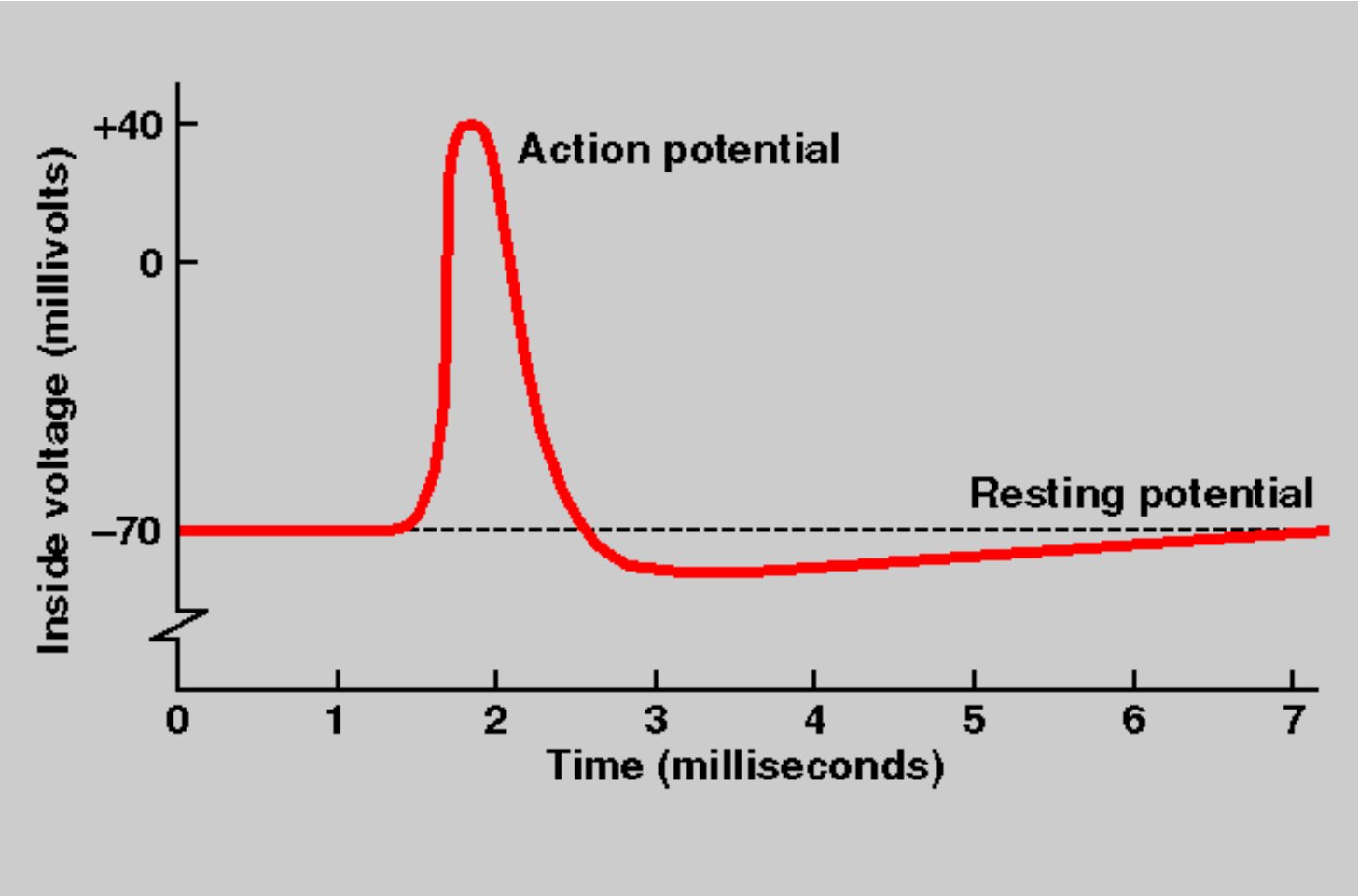
Action potentials: Resuming the Resting Potential

- Potassium channels close.
- Repolarization resets sodium ion channels.
- Ions diffuse away from the area.
- Sodium-potassium transporter maintains polarization.
- The membrane is now ready to “fire” again.

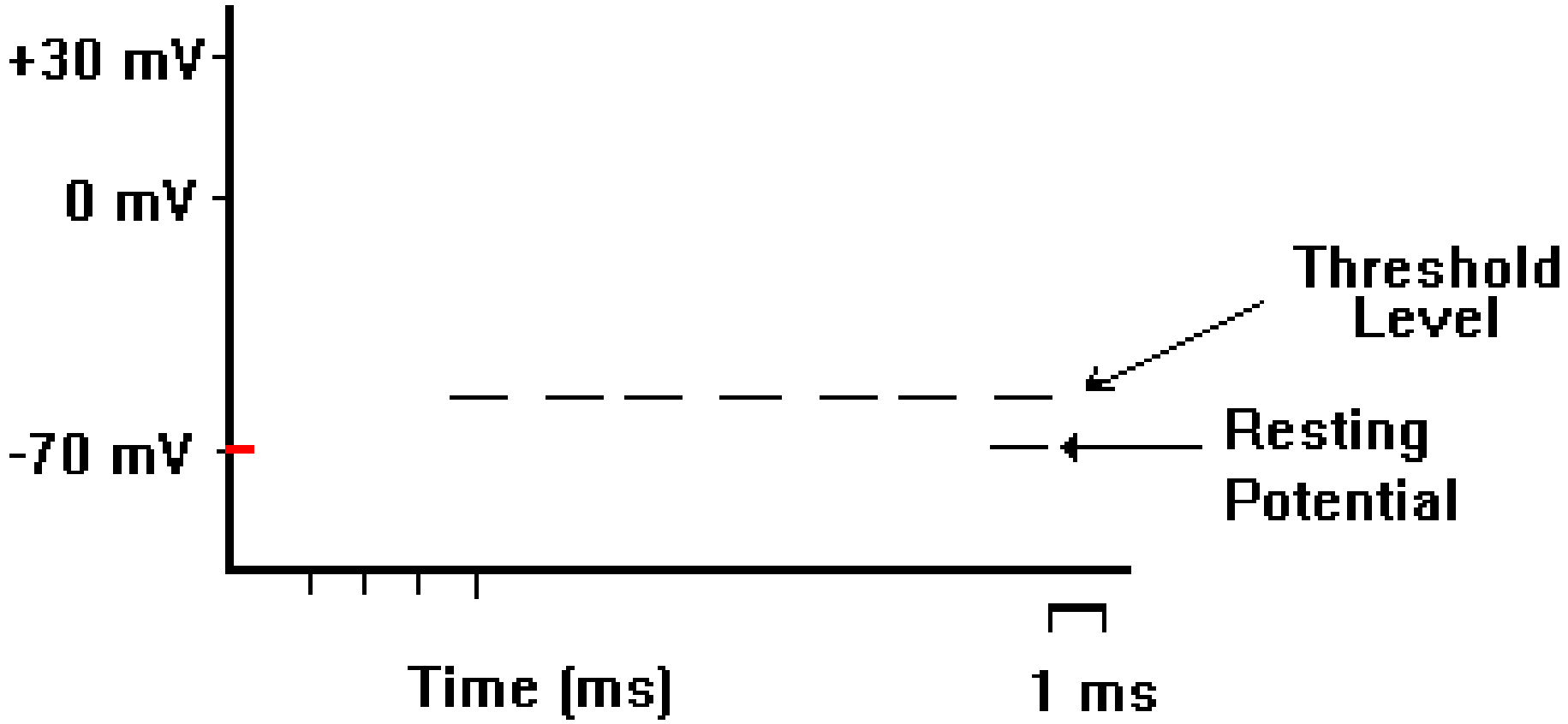


Action potential

Action Potential = ALL x NOTHING

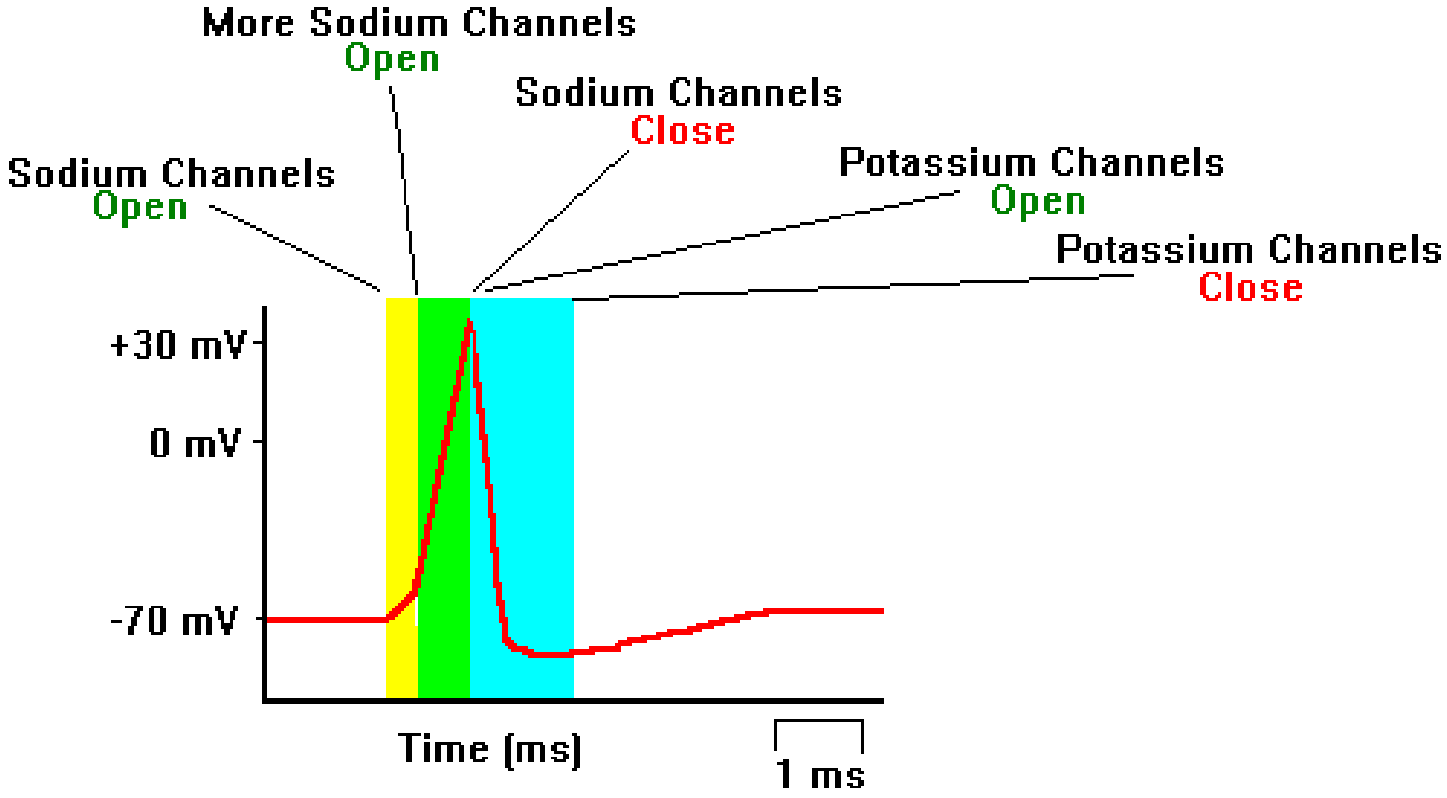


Action potential

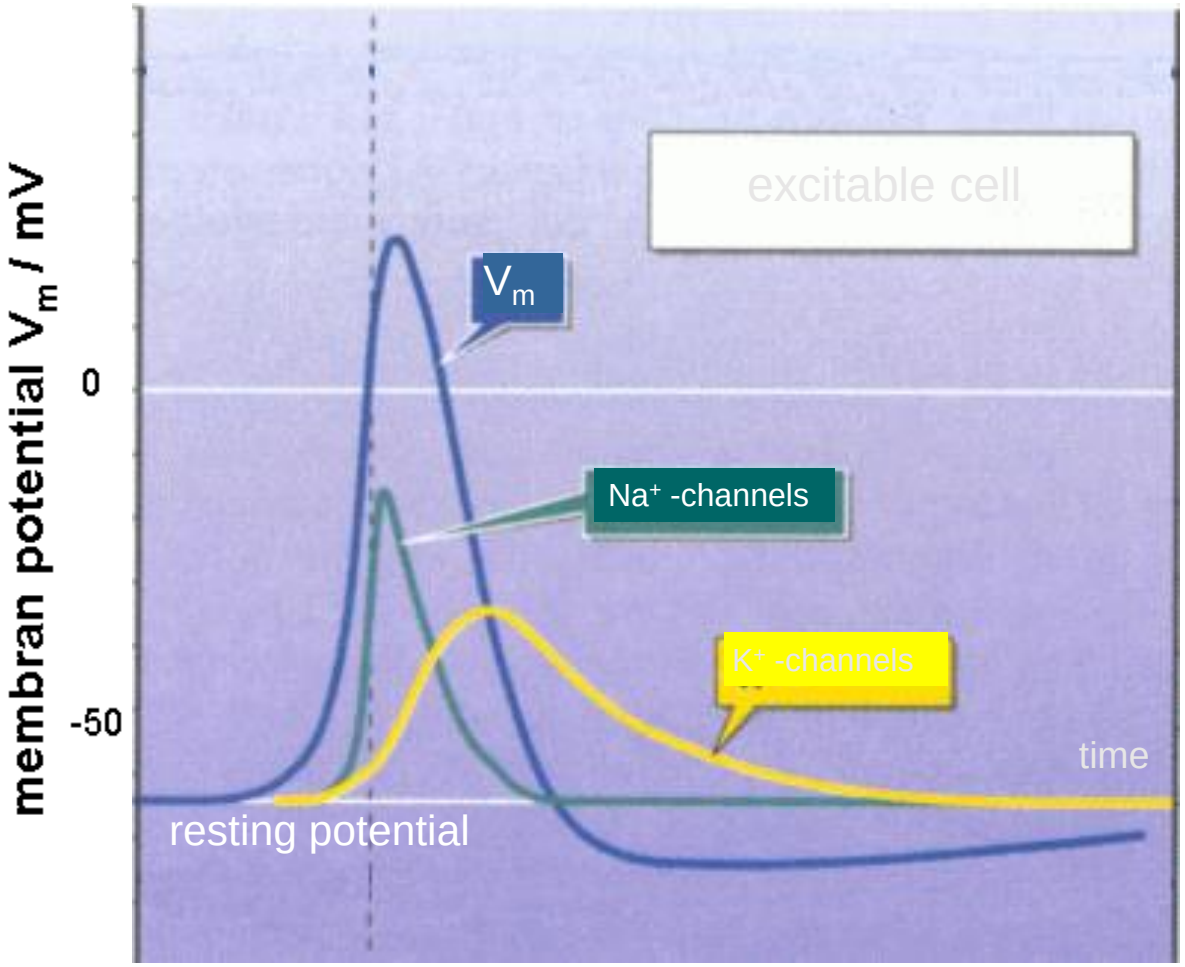


Action potential

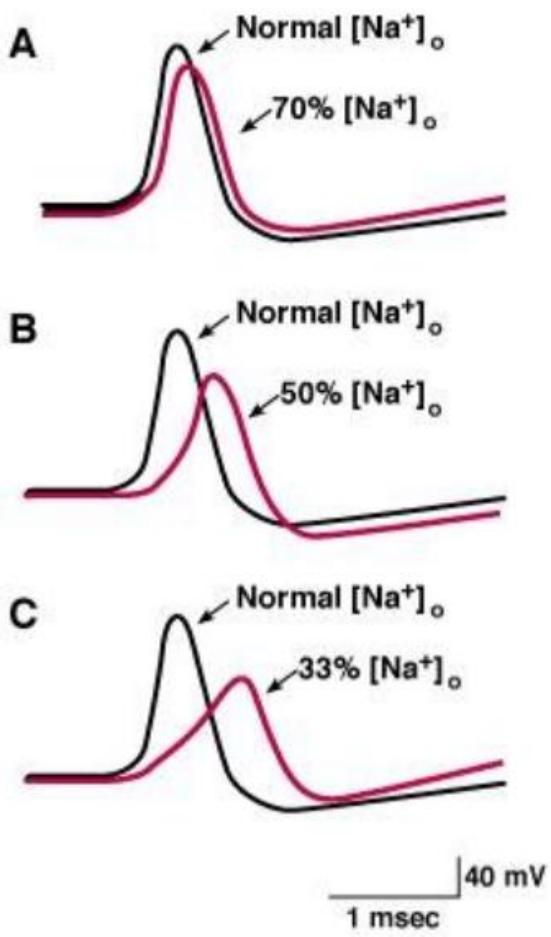
Action Potential = opening of sodium and potassium channels

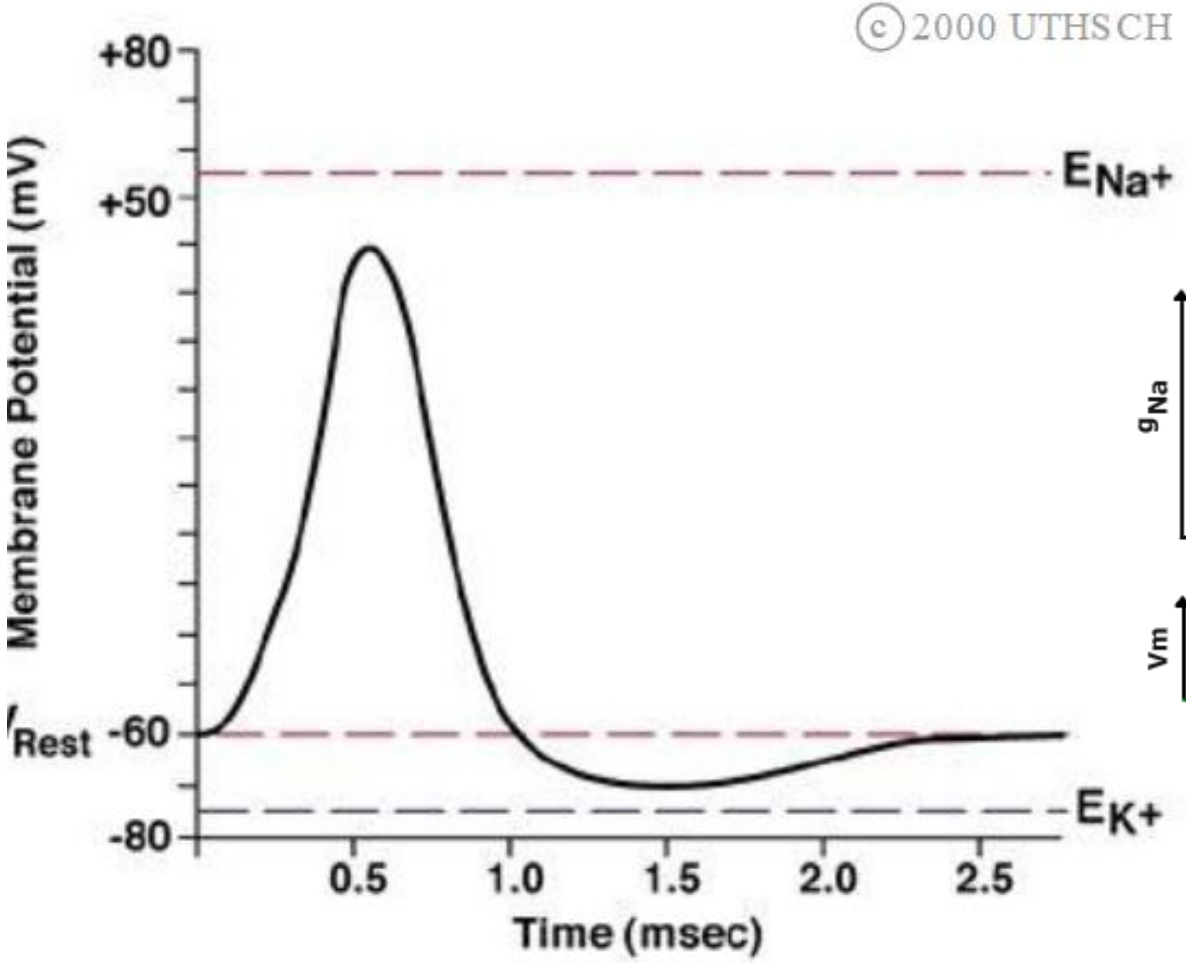


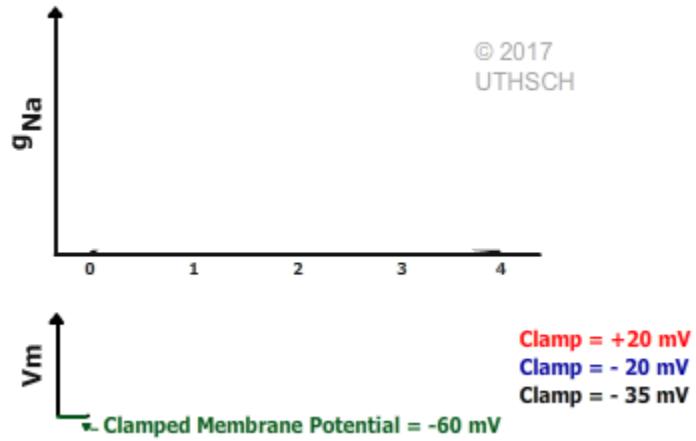
Action potential



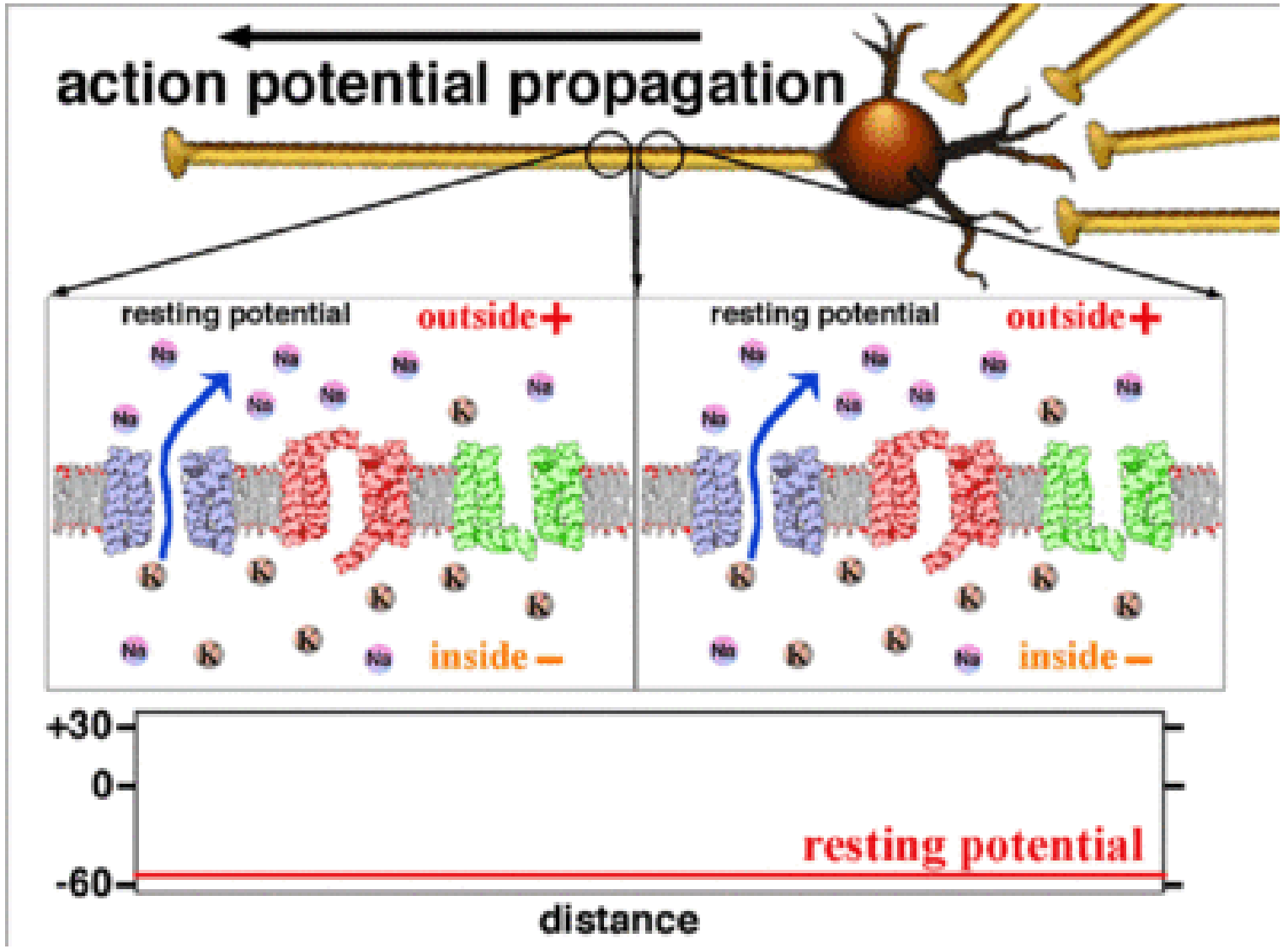
Ionic Mechanisms of Action Potentials





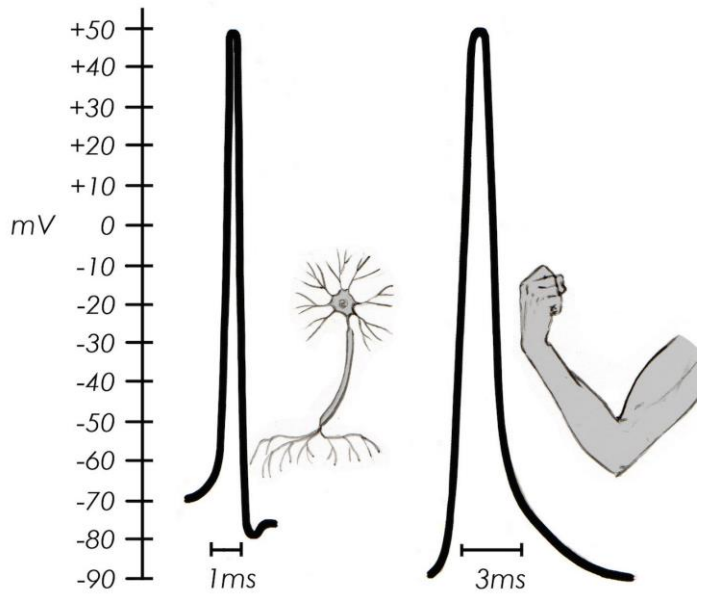


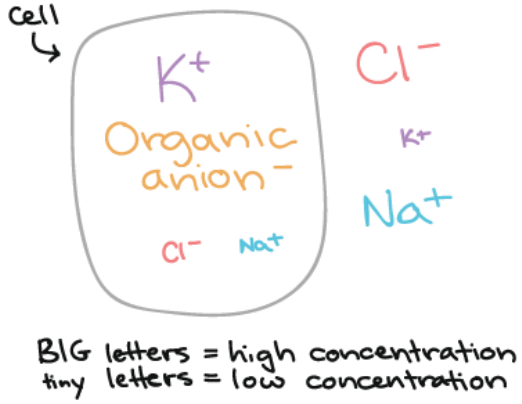
Propagation of the Action Potential



Is there any difference between skeletal muscle and neuronal membrane potentials?

- Skeletal muscle membrane potential maintains more negative membrane potential then the neuronal membrane potential.
  - The more negative Vm due to
    - Increased K+ gradient
    - Increased Cl- gradient
    - Greater resting Cl- permeability
  - The T-tubule membranes contains chloride chnnel that cotributes to the resting Vm potential together with leaky K channel.





Comparison between neuronal action potential and action potentials in other cell types

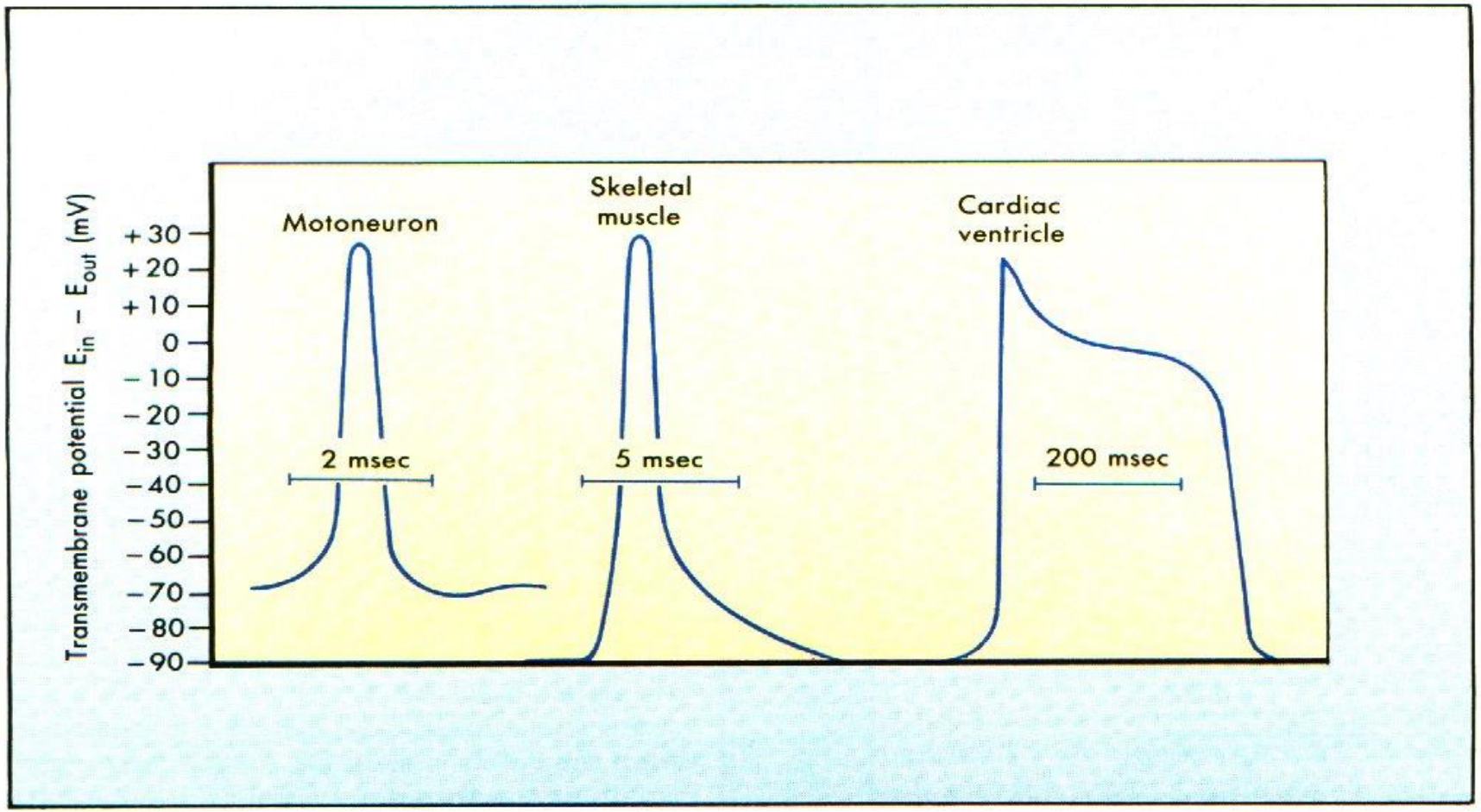


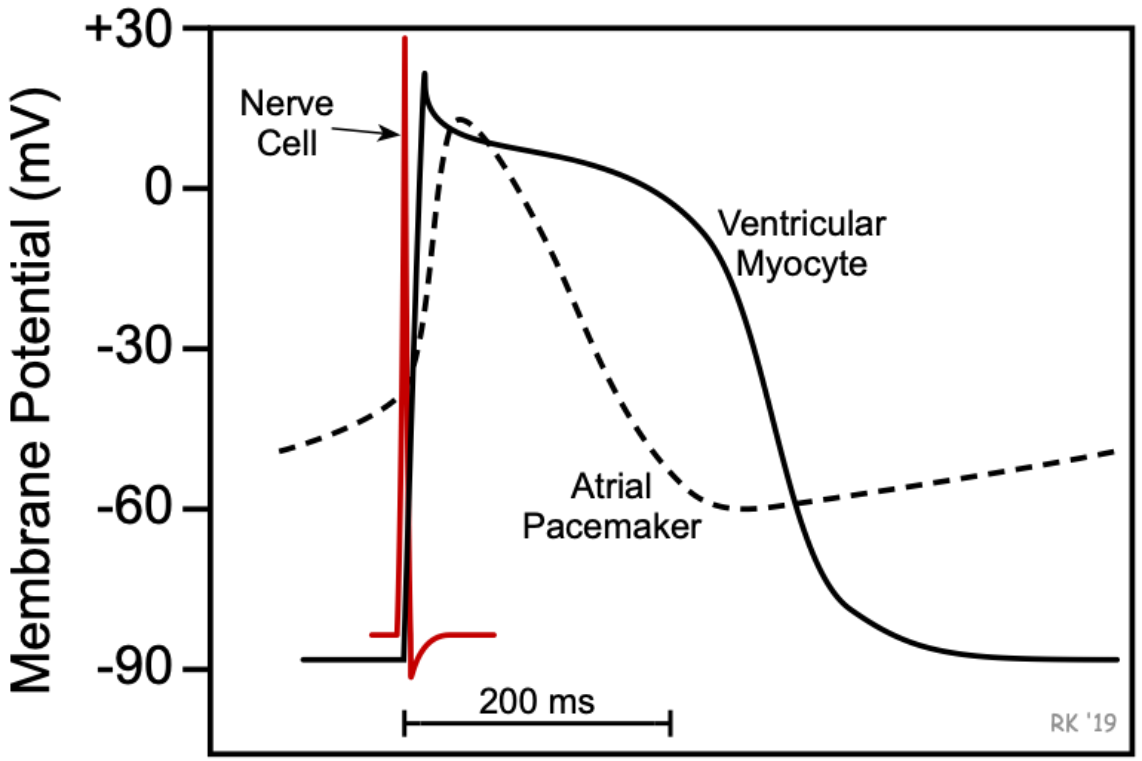
FIGURE 3-1 Action potentials from three vertebrate cell types. Note the different time scales. (Redrawn from Flickinger CJ et al: Medical cell biology, Philadelphia, 1979, WB Saunders Co.)

Action potentials in the heart

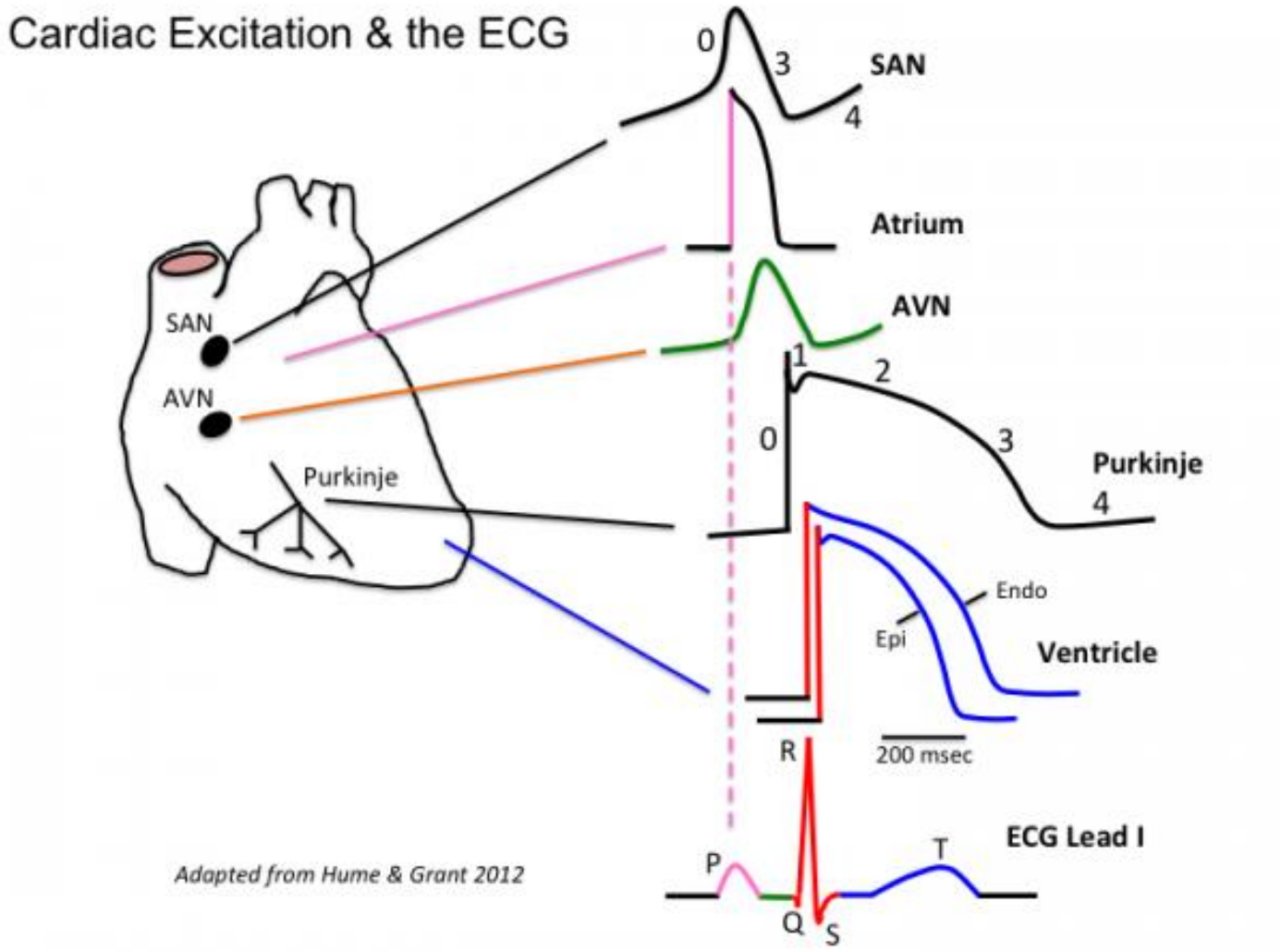
Cardiac action potentials in the heart differ considerably from action potentials found in neural and skeletal muscle cells. One major difference is in the duration of the action potentials.

In a typical nerve, the action potential duration is about 1 ms. In skeletal muscle cells, the action potential duration is approximately 2-5 ms. In contrast, the duration of cardiac action potentials ranges from 200 to 400 ms.

Another difference between cardiac and nerve and muscle action potentials is the role of calcium ions in depolarization.

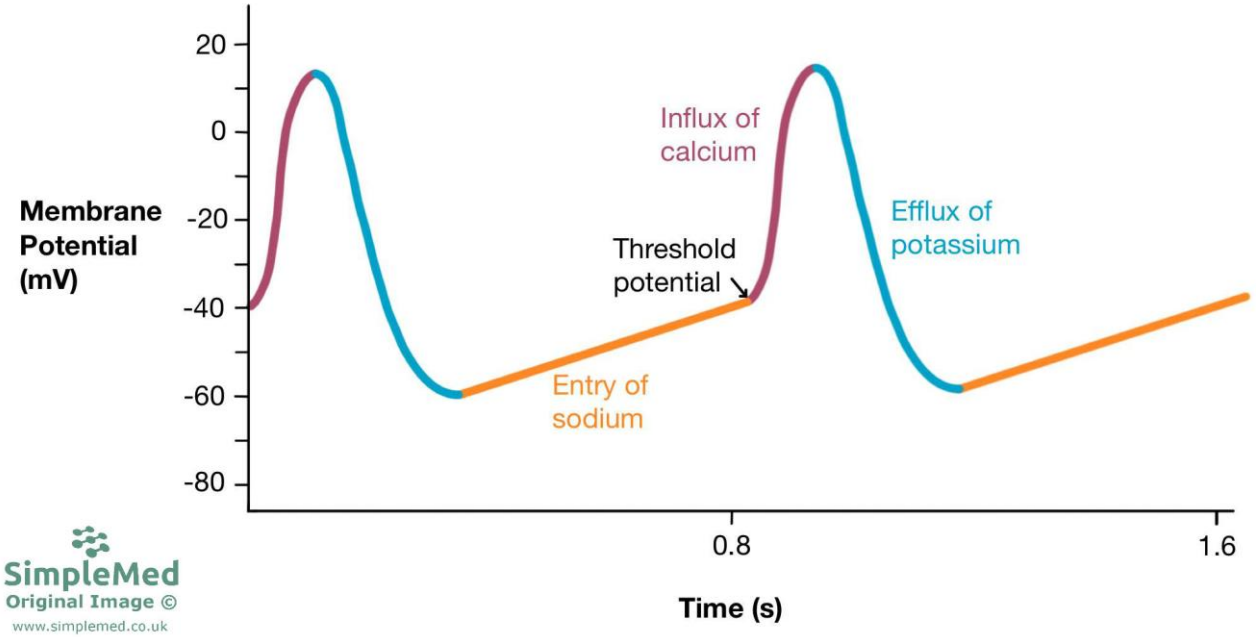


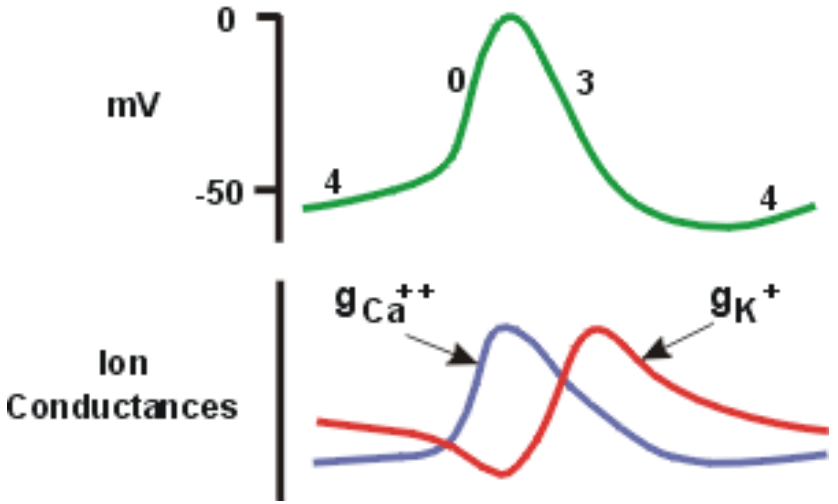
Action potentials in the heart



- Depolarization starts in the SA node, travels through the atrial internodal fibers, then through the AV node and subsequent Purkinje fibers, and finally out through the working cells in the ventricles.
- There are variability in the shape of the action potential at each location. Those action potentials can be fast and long, or slow and brief.
  - Fast/long action potentials are produced in working cells and Purkinje fibers.
  - Slow/brief action potentials are produced in the SA & AV nodes.

Sinoatrial Node Action Potentials





Summary

- The reason of resting membrane potential
- Ionic mechanisms of action potentials
- Membrane and action potential difference between neuronal, skeletal and heart muscle

Thank you very much for your patience