A Crash Course in Computational Neuroscience for Undergraduate Students

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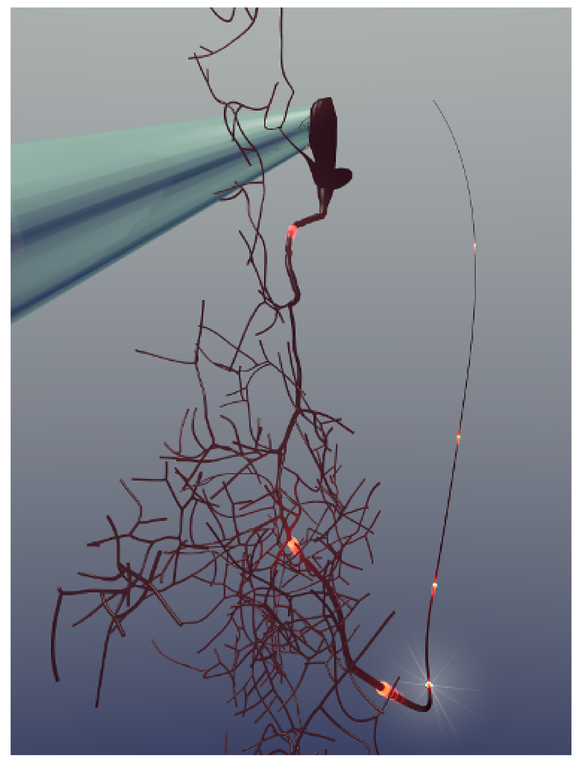
ABSTRACT

Computational neuroscience is an advanced topic that is usually chosen to be taught and studied at a post-graduate level. This choice is justified because understanding the topic requires knowledge of advanced concepts in multiple disciplines such as biology, physics, mathematics, and computer science. However, it is desirable for students to be involved in research earlier, specifically at the undergraduate level. An open educational resource (OER) for an introductory course can provide the necessary background in fundamental topics with simplified diagrams. In this digital poster presentation, we will present our course materials that explain the fundamentals of computational neuroscience that will allow us to simulate computer models of neurons that include realistic morphologies, active Hodgkin-Huxley type ion channels, and synaptic components.

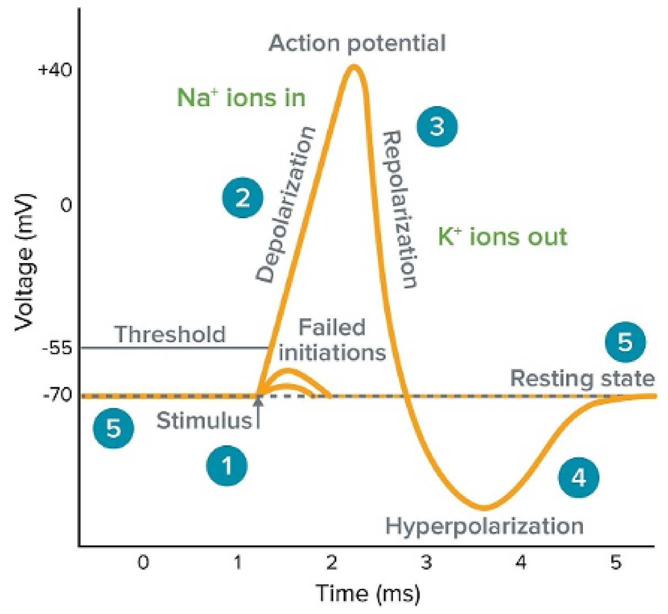
GOAL

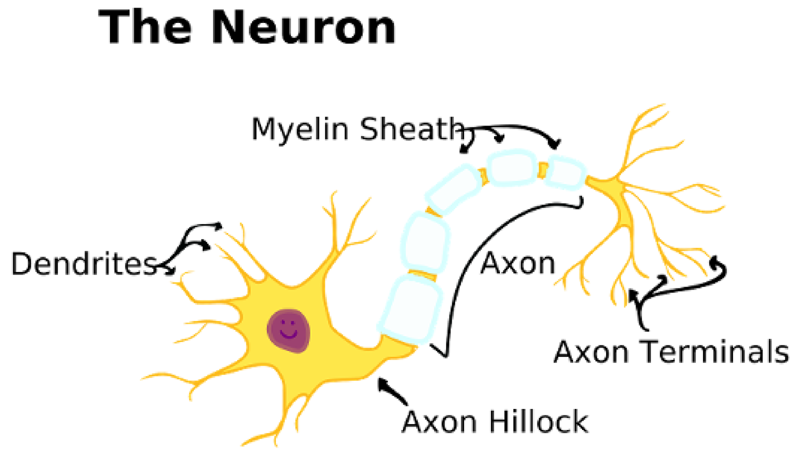
The goal of our computational seizure models in *Drosophila* is to accurately model a specific motor neuron named the anterior corner cell (aCC). The aCC motor neuron was chosen because it has been well-studied and can be easily accessed electrophysiologically. An accurate computational model consists of proper dendritic arborization, location of synaptic inputs, passive electrical properties, and placement of sodium, potassium, and leak channels.



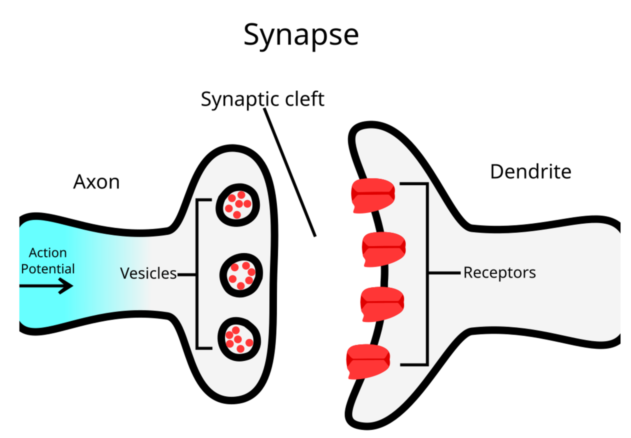
ACTION POTENTIAL

An action potential is the rapid rise and fall of voltage which causes depolarization inside of a neuron. It originates at the axon hillock, travels down the axon, and ends at the axon terminal. An action potential works in three phases: depolarization, repolarization, and hyperpolarization.

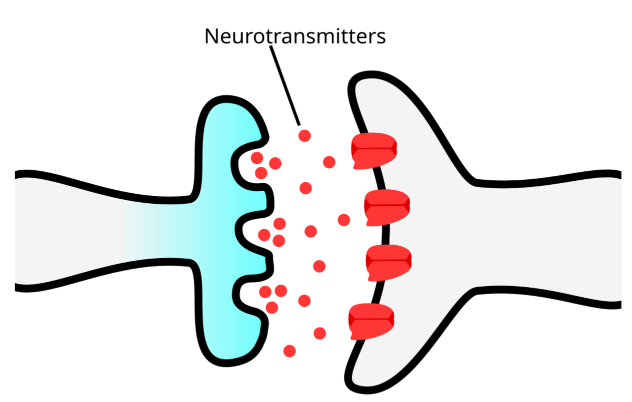




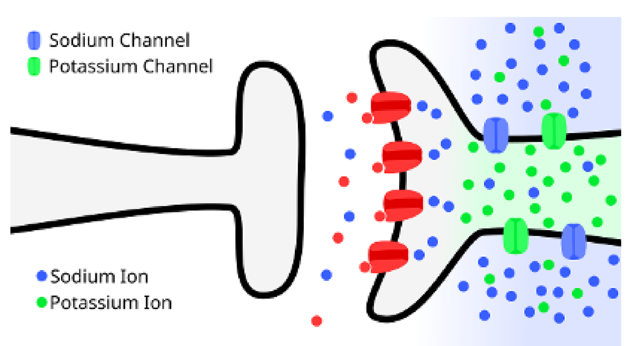
SYNAPTIC TRANSMISSION



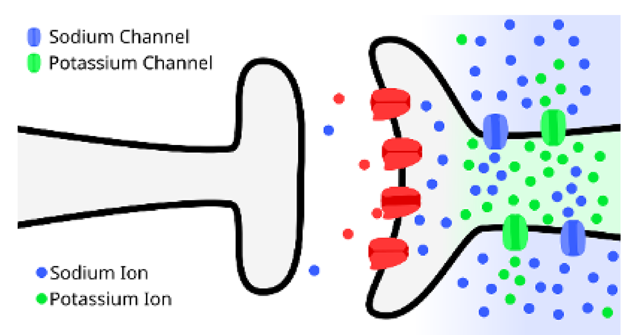
Step 0: Action potential travels down pre-synaptic neuron.



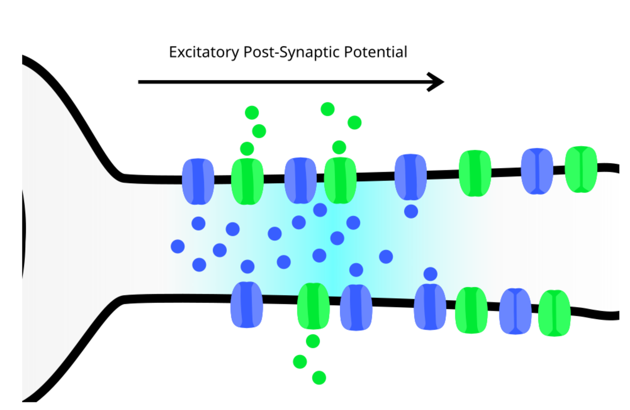
Step 1: Action potential reaches the synapse causing vesicles to fuse with cell membrane, releasing neurotransmitter.



Step 2: Neurotransmitters bind with receptor sites of post-synaptic neuron, allowing sodium into cell



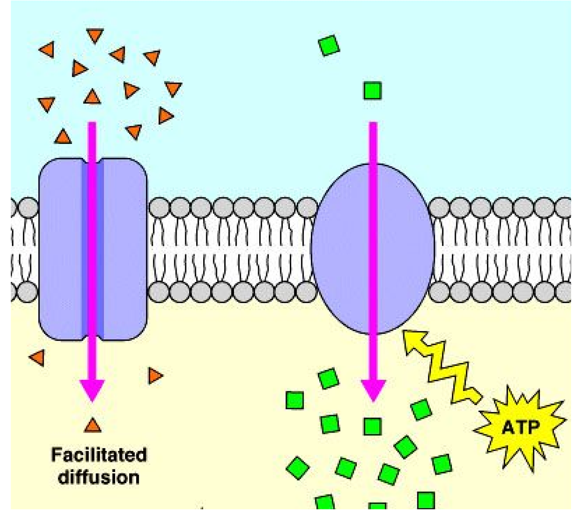
Step 3: Potassium channels begin to release potassium while allowing more sodium into the cell.



Step 4: Chain reaction continues, known as an excitatory post-synaptic potential, down to the soma where an action potential will occur in the axon hillock.

MEMBRANE CONDUCTANCE

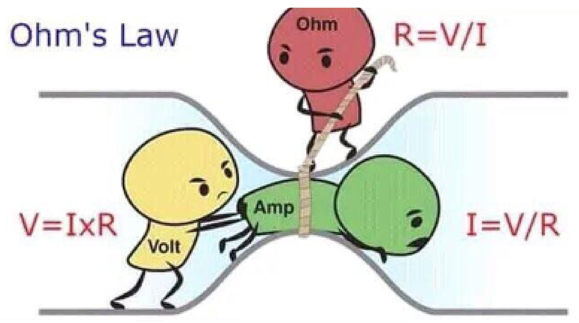
Membrane conductance is the ease of which ions can flow into or out of the cell. This is directly related to the membrane's permeability, which is determined by the active and passive transport.

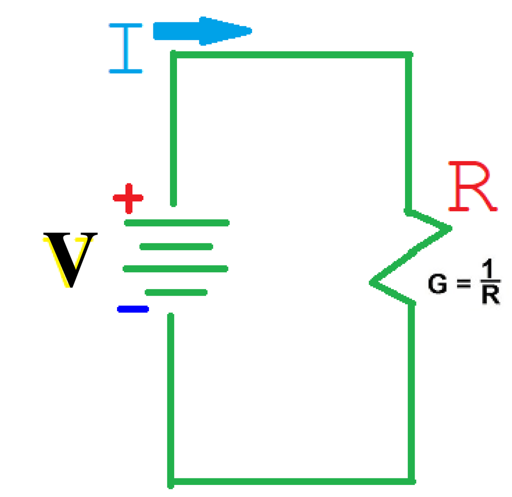


OHM'S LAW

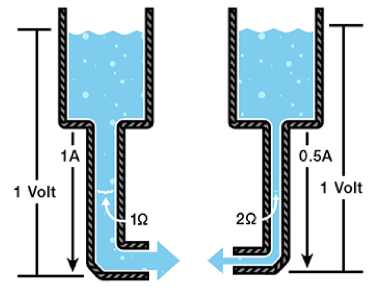
Ohm's law explains the relationship Voltage and Resistance have with Current. The relation goes as follows:

- If voltage increases, then current increases.
- If resistance increases, then current decreases.

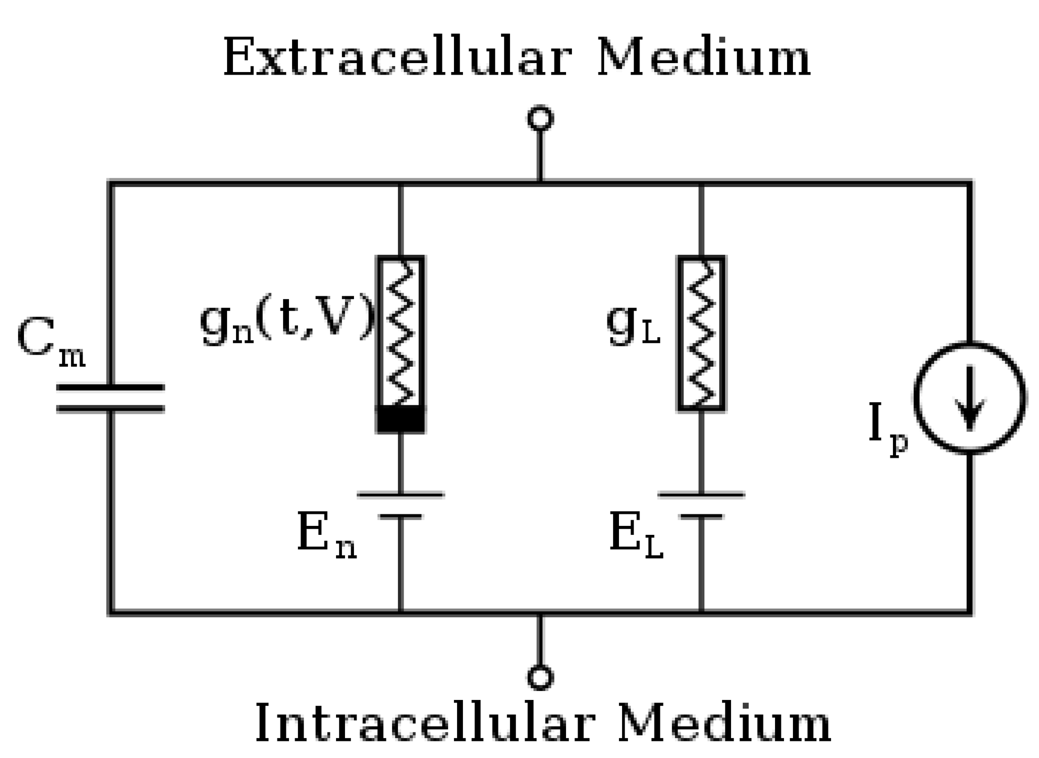




This same principle can be used to explain the passive flow of water through a current.



HODGKIN-HUXLEY MODEL



The Hodgkin-Huxley model can be represented as the equivalent electrical circuit that is meant to represent a cell membrane. This **video** visualizes how ion channels in the cell membrane all work in together during an action potential.

REFERENCES

- http://neuroscience.pitt.edu/
- https://www.khanacademy.org/test-prep/mcat/organ-systems/neuron-membrane-potentials/a/neuron-action-potentials-the-creation-of-a-brain-signal
- https://teaching.ncl.ac.uk/bms/wiki/index.php/Synaptic_transmission
- https://www.tutor2u.net/psychology/topics/synaptic-transmission#:~:text=Synaptic%20transmission%20is%20the%20process, impulse%20known%20as%20action%20potential.&tex=When%20the%20electrical%20impulse%20(action,release%20their%20contents %20of%20neurotransmitters.
- https://www.khanacademy.org/science/biology/human-biology/neuron-nervous-system/a/the-membrane-potential
- https://www.ncbi.nlm.nih.gov/books/NBK441875/figure/article-26142.image.f1/
- https://www.universetoday.com/82339/conduct