NS102 Learning Objectives (Spring 2019)

Module 2: "Can We Ever Comprehend the Workings of Brain?"

BRN 1: How complex is the brain? How can we understand how it works?

By the end of this week, you should be able to:

Describe the properties of cells that constitute brain (neurons and glial cells), and discuss how ions can diffuse across cell membrane

1. Describe the structure and parts of the brain, features and functions of neurons (nerve cells) that distinguish them from other types of cells
2. Compare the scales involved in our brain (number of networks, neurons, response time, etc.) with the numbers we are more familiar with (internet, computing power, etc.) to highlight the complexity of our brain
3. Describe concept of flux due to macroscopic diffusion and relate it to the concept of concentration gradients
4. Apply the Fick's law ($J = -D\, dC/dx$) to calculate the flux of ions diffusing across neuronal membrane in 1 dimension with a given concentration function

BRN 2: All cells maintain a potential difference to sense the world

Explain the origin of resting membrane potential by relating the concepts of potential energy due to electric charges of ions and their concentrations

5. Calculate change in the "chemical" potential energy (= Gibbs free energy) due to diffusion for given concentrations and relate that to the spontaneity of diffusion
6. Calculate electric potential energy of a system of charges in a constant electric field and the work done by the field
7. Relate the ionic concentration differences and electric charge distributions to the establishment of resting membrane potential of a neuron, and calculate the electrochemical-equilibrium potential using Nernst equation

BRN 3: Information is communicated in neurons through electricity: Action potential

Using the concepts of diffusion and membrane potential, describe how electrical signal is generated within a neuron (stimulation and action potential), and how it can be modeled with an electric circuit.

1. Describe the mechanism of electric signal (action potential) formation in a small patch of neuron membrane by relating it to the electric field, potential across the neuron membrane, and ion diffusion
2. Compare and contrast the components of neuron membrane and a simple RC circuit model of the membrane patch
3. Relate the concepts of resistance to modeling of the cell membrane by describing how ion channels can regulate ion current

BRN 4: Neuron axon can be mathematically modeled by simple circuits

Discuss the parameters in the neuron circuit model and relate them to the signal generation and transmission in actual neuron

1. Relate the concepts of capacitance to modeling of the cell membrane by describing how capacitance of the membrane affect the formation of an action potential
2. Model an action potential using the concept of resistors and capacitors and relate the time constant in the RC circuit to the action potential model
3. Describe how the action potential travels along the neuron axon using the concepts of the space (length) constant in the circuit membrane model
4. Given the time constant and space constant, estimate the signal transmission speed within a given neuron using the RC circuit model

BRN 5: Neurons communicate fast, efficiently and continuously to keep us functioning

Based on the circuit model, discuss the factors affecting the speed of neuron signals, and relate the single neuron circuit to neuron communication

1. Evaluate and discuss the factors affecting the speed of the signal transmission
2. Compare and contrast "myelinated" and "un-myelinated" axons, using the concepts of time constant and space constant
3. Apply the concepts of passive transport mechanisms to explain how a neuron communicates with another neuron through synaptic transmission
4. Relate electric and chemical potential energy concepts to active membrane transport mechanisms (Na/K pump)

BRN 6: How can we measure brain activity and interpret the data?

Discuss various ways of measuring brain anatomy and activities, and data interpretations and limitations

1. Compare and contrast various brain activity measurement techniques and their use, and create an appropriate hypothesis that can be tested by one of the techniques
2. Discuss how same data can be interpreted differently based on the threshold values applied, and illustrate how it could give rise to false scientific claims
3. Evaluate an experiment designed to probe a certain brain function, based on the scientific method and considering the challenges in data analysis

BRN 7: How does brain function and how does our mind work? Inner workings of brain and cognitive science

1. Apply the concepts of passive transport mechanisms to explain how a neuron communicates with another neuron through synaptic transmission
2. Relate single neuron circuit model to the web of neural circuit to explain how animals function
3. Summarize how neurons in different parts of the brain communicate and make long-lasting connections
4. Discuss why we are yet away from understanding very-complicated workings of our brains