BME 7380 – From Neurons to Behavior in Health and Disease

Course Description

Presents the stretch reflex as an example of a neural circuit and how it mediates movement. Discussion of the neuronal components that form the stretch reflex circuit and how electrical signals are generated and processed in this circuit under normal and pathological conditions. Computer modeling of neuronal elements of the stretch reflex circuit, including simulations and comparison of modeling data to experimental results. Emphasis on active participation. Includes accompanying lab exercises.

Graduate level – 3 credit hours

Course Learning Objectives

Students enrolled in this course will learn:

1. The stretch reflex – example of a neural circuit that mediates movement and its modulation
2. The motoneuron – cell anatomy and synaptic inputs, ion channels that mediate the electrical signal (action potential), action potential generation and propagation, assessment of motoneuron excitability
3. Axons – sensory and motor axons and differences in their electrical and morphological properties, their roles during movement, transmission of action potentials along axons
4. Synapses – the role of the neuromuscular junction and the Ia-motoneuron synapse in the stretch reflex, transmission of the electrical signal along the chemical synapse and neurotransmitter
5. Release, types of synapses and their effects on the membrane potential, integration of synaptic potentials on the motoneuron dendrites
6. The muscle-motoneuron relationship – their type, function, and electrical/contractile properties match
7. The membrane mechanisms underlying the generation and propagation of action potentials – types, function, and membrane distribution
8. Neuromodulatory regulation of motoneuronal properties during movement
9. Clinical and experimental methods of motoneuron excitability assessment

Course Learning Outcomes

As a result of their learning experience, students successfully completing this course can:

1. Develop computer models of the neuronal elements of the stretch reflex circuit.
2. Run simulations to compare modeling data to experimental results.
3. Model pathological changes in motoneuron cellular properties in neurogenerative disease (MS and ALS) and after spinal cord injury (SCI).
4. Develop computer models of spinal motoneurons in the NEURON software environment.
5. Verify model properties versus experimental data.
6. Conduct sensitivity analysis of model properties to test rigor of simulations.
7. Develop motoneuron pool models to simulate spinal network function.

Tentative Weekly Schedule

	Tuesday (Lecture) Thursday (Computer Lab)
Week 1	Course outline; Introduction to the NEURON simulation software and NEURON scripting
Week 2	The spinal cord organization and sensorimotor circuits (The stretch reflex circuit); Introduction to NEURON scripting and programming

Week 3	Muscle fiber and motoneuron types and their properties; Development of a multi-unbranched cable model of a motoneuron (Step 1 – modeling cell anatomy)
Week 4	The resting membrane potential; Development of a multi-unbranched cable model of a motoneuron (Step 2 – modeling the electrical properties)
Week 5	The passive membrane properties; The membrane passive properties Lab
Week 6	Voltage-gated ion channels - action potential generation/ propagation, somatic vs. dendritic channels and the generation of nonlinear
Week 7	Channel kinetics – persistent vs. inactivating ion channels; The voltage-clamp lab
Week 8	Mid-term Exam – Project assignment; Introduction to the neuroscience gateway (NSG)
Week 9	Synaptic integration and amplification in the passive dendrites; Development and running motoneuron pool models on NSG
Week 10	Synaptic integration and amplification in the active dendrites; Synaptic integration & amplification lab – simulating linear/sub-linear/supra-linear EPSPs & IPSPs summation
Week 11	Sensory and motor axons (Health) and demyelination of axons (Disease); Demyelination in Multiple Sclerosis
Week 12	Motoneuron abnormalities in amyotrophic lateral sclerosis (Disease); Modeling ALS changes
Week 13	Motoneuron abnormalities in spinal cord injury (Disease); Modeling Spinal cord injury changes (PICs)
Week 14	Project presentations and code demo – Part #1; Project presentations and code demo – Part #2
Week 15	Finals Week