IDH 3034 (U38): Biophysics of Neuroscience

Instructor: Dr. Jorge Riera Diaz, PhD
Phone: (305) 348-4948
Email: jrieradi@fiu.edu
Department of Biomedical Engineering
Office: EC 2678
Office Hours: 11:00am-12:00am, Monday
Classroom: Chem & Physics 107
Time: TuTh 2:00PM - 3:15PM
Course ID: 035890/020950
Class Number: 84119/87980 (Regular Academic Session)

Course Description

This course will discuss the biophysics of neuronal computation for biological neuronal networks. It will provide a detailed introduction to: i) the anatomy/physiology of excitable cells, ii) the major brain architectures and principles, and iii) the most relevant mathematical models for neural computation from single neurons to circuits. Therefore, this course will prepare the students to apply the main principles by means of which our brains work and computers recognize patterns, learn/plan actions, and interact with humans.

Course Outcome:

<table>
<thead>
<tr>
<th>No.</th>
<th>Course Learning Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>apply physiological/anatomical principles of excitable cells and their neuronal circuits</td>
</tr>
<tr>
<td>2</td>
<td>represent these principles using mathematical tools</td>
</tr>
<tr>
<td>3</td>
<td>create a dictionary about neuronal computation</td>
</tr>
<tr>
<td>4</td>
<td>make connections between neuronal computation concepts and modern research</td>
</tr>
<tr>
<td>5</td>
<td>comprehend and synthetize a scientific paper about neuroscience topics</td>
</tr>
<tr>
<td>6</td>
<td>present scientific research to other students</td>
</tr>
</tbody>
</table>

Prerequisites

BME Students:
- EEL 3110/3110L (Electrical Circuits & Circuits Lab)
- BME 3403 (Engineering Analysis of Biomedical Systems I)

Honor College Students:
- Permission from Instructor (Interview)

Textbooks (Recommended, not mandatory)

Grading

30% Assignments (4), 1% of the total grade will be deducted for assignments turned in late
35% Midterm Exam
35% Final Exam

**Grading scale:** 95-100 A; 90-94.9 A-; 86-89.9 B+; 82-85.9 B; 79-81.9 B-; 76-78.9 C+; 72-75.9
C; 69-71.9 C-; 67-68.9 D+; 63-66.9 D, 60-62.9 D

<table>
<thead>
<tr>
<th>Grade</th>
<th>Points Per Credit Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>4.00</td>
</tr>
<tr>
<td>A-</td>
<td>3.67</td>
</tr>
<tr>
<td>B+</td>
<td>3.33</td>
</tr>
<tr>
<td>B</td>
<td>3.00</td>
</tr>
<tr>
<td>B-</td>
<td>2.67</td>
</tr>
<tr>
<td>C+</td>
<td>2.33</td>
</tr>
<tr>
<td>C</td>
<td>2.00</td>
</tr>
<tr>
<td>D</td>
<td>1.00</td>
</tr>
<tr>
<td>F</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Attendance

Attendance is mandatory but up to three classes can be missed without incurring penalties. However, a
formal justification note should be provided to the instructor by email.

Religious Holidays

Every effort will be made, where feasible and practical, to accommodate students whose
religious practices coincide with class requirements scheduling. Please make sure to notify your
instructor at the beginning of the semester of which dates you will be absent or any anticipated
problems with completing course work.

Physical, Mental and Sensory Challenges

Every effort will be made, where feasible and practical, to accommodate students who are so challenged.
Should you require accommodations, contact the Disability Resource Center (DRC), if you have not done
so already.
Information for Honor Students

Global Learning Graduation Honors
FIU’s Excellence in Global Learning Graduation Medallion is awarded to students who complete at least four global learning courses, participate in a variety of global co-curricular activities, and complete a capstone consisting of one of the following: a substantial original research project and presentation on a global topic; extensive foreign language study; long-term study abroad; or, a globally-focused internship. The Peace Corps Prep certification is conferred upon students who complete at least four global learning courses, extensive language study, and a global problem-solving project. For more information, visit goglobal.fiu.edu.

- **Global Awareness** - Students will demonstrate knowledge of the interrelated global dynamics (social-cultural, political, economic, etc.) that shape aesthetics, values, and authority in diverse cultural contexts.
- **Global Perspective** - Students will be able to analyze the multiple global forces that shape their understanding of aesthetics, values, and authority — economic, political, sociological, technological, cultural, etc.
- **Global Engagement** - Students will be able to develop solutions to local, global, international, and/or intercultural problems and be able to articulate the causes and contributions to these problems through the paradigm of aesthetics, values and authority.

Honors College Requirements
Registration in this course implies an acceptance of and compliance with the Honors College policies for students and the FIU Code of Academic Integrity.

Honors Citizenship Requirements
Beginning in Fall 2014, Honors College students are required to accumulate at least 20 citizenship points each academic year (Fall and Spring) by attending Honors College activities. Students attending only one semester (Fall or Spring) are required to accumulate 10 citizenship points. See http://honors.fiu.edu/academics/policies/citizenship/.

Student Portfolios
The Honors College will be using a portfolio method to assess students’ learning outcomes. The portfolio allows for maximum flexibility in gauging student learning. Students decide (with instructor consultation) what “artifacts” or assignments to include for consideration in their portfolios to demonstrate successful achievement of each of five key student learning outcomes over the 4-year Honors experience. See http://honors.fiu.edu/students/honors-advising-center/portfolio-for-graduating-seniors/.

Honors Education in the ARTS (HEARTS)
The HEARTS program is designed to give Honors College students opportunities to “explore and appreciate different artistic and cultural traditions and modes of artistic expression. HEARTS will also serve as a clearinghouse (and curatorial framework) for our students to experience the arts on campus and in the community by providing them with information about cultural activities and access to performances with free or discounted tickets. See http://honors.fiu.edu/hearts/.
Honors College Academic Misconduct Statement
In The Honors College, the term “honor” refers both to academic accomplishment and character. Students in Honors should therefore adhere to and be held to the highest standards of personal academic accountability. Academic dishonesty in any form, including plagiarism, is antithetical to the very definition of being an Honors student at FIU. Consequently, an Honors College student found responsible for academic misconduct will be dismissed from the College.

Procedures and Penalties
An Honors faculty member may bring charges of academic misconduct against an Honors student if the faculty member suspects plagiarism or other forms of academic misconduct. The faculty member will decide whether to pursue informal resolution, file formal resolution charges, or take no further action, and will follow the procedures outlined in the Honors College website (http://honors.fiu.edu/academics/policies/), and the Academic Misconduct Procedures, available at http://integrity.fiu.edu/misconducts.html.

Please refer to the following documents for additional information:
- FIU Honors College Student Handbook – http://honors.fiu.edu/students/policies/
- FIU Honors College Plagiarism Policy – http://integrity.fiu.edu/misconducts.html

Courses designated as Global Learning courses (IDH 3034-3035) must list specific Global Learning outcomes. Assignments must be able to assess the students’ ability to demonstrate these outcomes. Questions on Global Learning should be addressed to Jose Rodriguez, rodriguej@fiu.edu.
Tentative schedule (subject to change to better address goals)

L1: Introduction
- Short History of Neural Computation
- Major Applications in Modern Times
- Open Discussion

Part I - Neurons I
L2: Electrical Circuits
- Capacitors and Resistors
- Kirchhoff Laws
- Norton-Thévenin Theorem
L3: Membrane Equations
- Resting Membrane Potential (**Nernst Equation, Laboratory**)
- Thermodynamics Approaches
- Electrical Equivalent Circuits
L4: The Hodgkin-Huxley Membrane Model
- Voltage- and Ligand- Gated Ion Channels
- Borg-Graham’s Generalizations
- The Action Potential
L5: Information Propagation – Axons
- The Cable Equation
- Myelinated Fibers: Impulse Conduction
- Ranvier Nodes: Structure and Function
- Conduction Velocity
L6: Recapitulation of Part I

Part II - Neurons II
L7: Information Transmission - Synapses
- Types of Synapses
- Synaptic Vesicles: Neurotransmitters
- Post-synaptic Potentials: Excitatory and Inhibitory
L8: Passive Synaptic Trees
- Anatomical Features: Branches and Bifurcations
- Synaptic Efficacy/Strength
- Long-Term Potentiation/Depression
L9: Synaptic Interactions
- Excitation vs. Inhibition Balance (**up and down states**)
- Absolute vs. Relative Depression
- Shunting and Hyperpolarizing Inhibitions
L10: Roles for Non-Excitable Cells
- Support and Modulation by Glia Cells
- Neurotransmission Recycling by Astrocytes
- Cellular Metabolism and Active Transport
L11: Recapitulation of Part II

Midterm Exam (Concept Evaluation L1-L11 + Solve a Problem)
Part III- Neuronal Circuits I
L12: Large-Scale Circuits in the CNS
- Sleep-Awake Thalamocortical Loop
- Circuitry for Space Memory
- Body Movement Control Loop & Reflex-Arc Circuit
L13: Electrical Activity at the Mesoscopic Scale
- Local Field Potentials & Current Source Density (CSD) Analysis
- Line Source Model
- Single/Multi – Unit Activity: Spike Sorting and Classification
L14: Semi-Realistic Models of Neuronal Excitability
- FitzHugh-Nagumo Model
- Morris-Lecar Model
- Integrate-and-Fire Model: Leaky and Exponential Versions
- Hindmarsh-Rose Model
L15: Multi-Compartmental Models of Neuronal Excitability
- Dimensionless Distance/Time Variables
- Linearization of Ionic Current Kinetics
- The Equivalent Cylinder Theorem
- Branches/Dendritic Attenuation:
  - The Cumulative Electrotonic Length
  - The 3/2 Power Law
  - The Termination Condition
L16: Recapitulation of Part III

Part IV- Neuronal Circuits II
L17: Neural Oscillations
- Feed-Back Loops
- Synchronization and Neuro-modulation
- Oscillatory Activity: Phase-Locked Vs. Spectral Perturbations
L18: Small-Scale Circuits in the CNS
- Different Types of Neurons
- Microcircuits in the Neocortex, Hippocampus and Cerebellum
- Major Working Principles of the Thalamus, Basal Ganglia and Spinal Cord
L19: Neuronal Ensemble Models and Oscillators
- Wilson–Cowan model
- Kuramoto model
- Mean field theory (Ermentrout-Kopell canonical model)
- “Synfire Chain” (Abeles)
L20: Quantitative & Qualitative Analysis
- Spectral Analysis
- Granger Causality Measures
- Nonlinear Oscillators: Bifurcation Analysis
L21: Recapitulation of Part IV

Final Exam (Concept Evaluation L12-L21 + Solve a Problem)