Bioengineering 6003 Cellular Electrophysiology and Biophysics
Fall Semester, 2010
Syllabus

Rob MacLeod, Steve Poelzing, John Bridge,
Alonso Moreno, Frank Sachse, Michael Sanguinetti, Mark Warren, and John White

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Description

The goal of this class is to provide an intermediate level overview of electrophysiology and biophysics at the level of the membrane and cell to students with special interest in cardiology and neurosciences. We will develop the structural and functional characteristics at each scale with emphasis on integration across the scales. We will try to emphasize common elements of structure, function, and control that arise across the cardiovascular and nervous systems and also across species and also identify differentiating features. The approach will be a combination of qualitative explanations, quantitative analysis,laboratory experience, and mathematical simulation. The class format will include didactic lectures, group discussion of primary literature, quantitative problem solving exercises, writing assignments, and laboratory exercise. The prerequisite for the course are Bioengineering 6000, 6010, 6430, or equivalent or permission of the instructor and knowledge of university undergraduate level calculus and physics. Homework assignments will require the use of MATLAB and familiarity with internet based transfer of computer files. All course materials will be available through a web site www.sci.utah.edu/~macleod/bioen/be6003 and the class will communicate by means of an electronic mailing list (see the web page for instructions).

Class time and venue

Class times: Monday and Wednesday, 10:45-12:15 am, labs schedule separately
Classroom: CVRTI Library/Meeting room
Credits: 3 credit-hours

Instructors

Name	Phone	Email	Office	Hours
Rob MacLeod (RM)	5-7596	macleod@sci.utah.edu	CVRTI/WEB	by appt.
Steve Poelzing (SP)	5-1862	poelzing@cvrti.utah.edu	CVRTI	by appt.
John Bridge (JB)	7-5845	bridge@cvrti.utah.edu	CVRTI	by appt.
Alonso Moreno (AM)	7-5845	moreno@cvrti.utah.edu	CVRTI	by appt.
Frank Sachse (FS)	7-9514	fs@cvrti.utah.edu	CVRTI	by appt.
Michael Sanguinetti (MS)	1-3058	sanguinetti@cvrti.utah.edu	CVRTI	by appt.
John White (JW)	7-8347	john.white@utah.edu	BPRB	by appt.
Mark Warren (MW)	1-8183	warren@cvrti.utah.edu	CVRTI	by appt.

(See also `www.cvrti.utah.edu/personnel.html` for more information)

Text and resource materials

There is no required text for the class and topics will be covered with handouts or journal articles. However, the following resources provide good sources of background material:

- **Ion Channels of Excitable Membranes** by Bertil Hille.
- **The Physiology of Excitable Cells** by David Aidley.
- **Heart Physiology** by Lionel Opie.

Grading

The grade for the course will be based on some combination of homework assignments, and laboratory exercises.

Lectures and Reading Material

Date	Instructor	Topic	Reading
Week #1, Aug. 23–25	RM	Intro and Math/Physics Background	Hille Ch. 1
Week #2, Aug. 30–Sept. 1	JW	Biophysics Background	Handout
September 6	**Labor Day**	**Holiday**	
Week #3, Sept. 13–15	JB	Whole cell cardiac	
Week #4, Sept. 20–22	JB	EC Coupling	
Week #5, Sept. 27–29	MS	Ion channel structure	
Week #6, Oct. 4–6	MS	Ion channels types	
Oct 11–15	**Fall Break**		
Week #7, Oct. 18–20	FS	Modeling of channels	
Week #8, Oct. 25–27	MS	**Ion channel lab**	
Week #9, Nov 1–3	JW	Whole cell neuron	
Week #10, Nov. 8–10	JW	Neural synapse	
Week #11, Nov. 15–17	RM	Whole cell modeling	
Week #12, Nov. 22–24	SP & MW	**Optical methods lab**	
Nov 25–26	**Thanksgiving**		
Week #13, Nov. 29–Dec. 1	AM	Cell to cell communications	
Week #14, Dec. 6–8	RM & FS	**Simulation lab**	

List of topics

Lectures (one week for each item)

1. Introduction and basic math, physics, and chemistry
    - Overview of course perspective and goals
    - Ohm's law, diffusion, electric fields, potentials, and charge
    - I-V curves, rectification, basics of voltage clamp
    - ODEs, stochastic processes
2. Background of membrane biophysics
    - Basic structure and composition of membrane
    - Donnan equilibrium, GHK
    - Ion transport system overview
3. Whole cell behavior: cardiac
    - Integration: from channels to whole cell
    - Whole cell behavior: currents, gating, kinetics, control
    - Measurement approaches
    - Automaticity and pacemakers
4. Excitation-contraction coupling (cardiac and neuro)
    - Cardiac EC coupling, structure and function
    - NMJ
5. Ion channel structure and gating function
    - Common elements organized to make specific function
    - Protein structure, pore formation, charge field
    - Control of channel function, voltage activation, ligand activation, signaling, gating kinetics
    - Ion selectivity
6. Ion channel types and characterization
    - Channel types, structure, function
    - Same channels in different cell types
    - Molecular biology in ion channels
    - Sample channelopathies
7. Modeling and simulation of channels
    - Stochastic processes
    - State transition mechanics and modeling
    - Examples of disease modeling

8. Whole cell behavior: neuron
    - Integration
    - Propagation, saltatory conduction,
9. Neuron synapse, synaptic plasticity
    - Structure of the synapse
    - Electrochemical transduction
    - Postsynaptic integration and information processing
10. Modeling and simulation of whole cell EP
    - Review of HH formalism; modern extensions
    - Mathematical formulation, numerical implementation, examples of software
    - Strengths and limitations of simulation
11. Cardiac cell-to-cell communication
    - Gap junction structure, function

Labs

1. Ion channel lab (MS)
    - Voltage clamp techniques
    - Heterologous expression of channels in Xenopus oocytes
    - Biophysical properties of wild-type and mutant K+ channels
2. Optical methods lab (SP, MW)
    - Chemical and physical basis of optical methods
    - Instrumentation for optical measurement
3. Simulation lab (FS, RM, JW)
    - Computational approaches to simulation
    - Whole cell simulation, role of currents and ion channels

Instructor absences

Rob MacLeod

- August 27–September 11
- September 25–October 2
- October 6–13

John Bridge

- August 27–September 1
- October 6–October 20

Alonso Moreno

- October 4–15

Frank Sachse

- August 30–September 5
- November 1–30
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Michael Sanguinetti

- August 27–September 10
- September 21–23
- September 30–October 1
- October 19–21

John White

- August 23-27
- September 20–24
- October 4–8
- November 11–26

Mark Warren

- TBA