CELLULAR BIOELECTRICITY
ELEC ENG 3BB3

(Winter 2014)

CALENDAR:

Generation and transmission of bioelectricity in excitable cells; ionic transport in cellular membranes; propagation of electricity within and between cells; cardiac and neural physiology; measurement of extracellular fields; electrical stimulation of excitable cells.

Three lectures + one tutorial; second term.

Prerequisite: Registration in Level III Electrical and Biomedical Engineering.

COURSE OBJECTIVES:

To develop both a qualitative and a quantitative understanding of the generation and transmission of bioelectricity in and between excitable cells. This will involve circuit analysis and modelling of potentials and currents across the cellular membrane, action potentials, propagation of potentials along the cellular membrane, electrical stimulation of excitable tissue, extracellular fields, neural electrophysiology, cardiac electrophysiology, the neuromuscular junction, skeletal muscle, and functional electrical stimulation.

COURSE LOADING:

- Lectures: 3 1-hour lectures per week
- Tutorials: 1 1-hour tutorial per week
- Reports, homework assignments: 2 hrs per week
- Study time: 2 hours per week
- **Total hours per week: 8**

CEAB WEIGHTING:

ES = 90%, ED = 10%

WEBSITE:
http://www.ece.mcmaster.ca/faculty/debruin/debruin/EE%203BB3/index.htm

TEXTBOOK:

- R. Plonsey and R. C. Barr, "Bioelectricity: A Quantitative Approach," 3rd Edition, Springer, 2007.

DETAILED COURSE CONTENT:

Introduction to Bioelectricity and Excitable Cells (2 hours)

Bioelectric Potentials and Currents (4 hours)

- Ionic composition of excitable cells
- Nernst-Planck equation
- Membrane structure
- Nernst potential
- Parallel-conductance model

Membrane Channels (2 hours)

- Channel structure
- Biophysical methods for measuring channel properties
- Macroscopic channel kinetics
- Channel statistics
- Introduction to the Hodgkin-Huxley membrane model

Action Potentials (5 hours)

- Observing action potentials
- Nonlinear membrane behavior
- Origin of action potential, resting and peak voltages
- Voltage and space clamp
- Hodgkin-Huxley equations
- Simulation of membrane action potential
- Action potential characteristics
- Active transport
- Calcium channels and "other" membrane models

Impulse Propagation (3 hours)

- Core-conductor model
- Cable equations
- Local circuit currents during propagation
- Mathematics of propagating action potentials
- Propagation velocity constraint for uniform fiber
- Propagation in myelinated nerve fibers

Electrical Stimulation of Excitable Tissue (3 hours)

- Linear (subthreshold) response of a single spherical cells
- Linear (subthreshold) response of a cylindrical fiber

Extracellular Fields (3 hours)

- Basic formulation
- Lumped fiber source models

Cardiac Electrophysiology (2 hours)

- Electrical nature of intercellular communication
- Source models
- ECG measurement and analysis

The Neuromuscular Junction (0.5 hour)

- Structure of the neuromuscular junction
- Evidence for the quantal nature of transmitter release
- Poisson statistics for transmitter release
- The effect of Ca^{2+} and Mg^{2+} on transmitter release
- Post-junctional response to transmitter

Skeletal Muscle (1.5 hour)

- Muscle structure
- Muscle contraction
- Structure of the myofibril
- Sliding filament theory
- Excitation-contraction
- EMG measurement and analysis

Neural Electrophysiology (4 hours)

- Structure of the nervous system
- Sensory transducers and neurons
- Neural synapses, excitation and inhibition
- Neural coding and computation
- EEG measurement and analysis
- Brain-computer interfaces

Functional Electrical Stimulation (6 hours)

- Electrodes and electrode-tissue behavior
- Nerve excitation
- Recruitment
- Clinical applications

(Total Course = 36 hours)

COURSE POLICIES:

The instructor reserves the right to choose the format (i.e., written or oral) of any deferred midterm or final exam in this course.

Please note that announcements concerning any type of graded material may be in any format (e.g., announcements may be made only in class, via the course e-mailing list, or on the course web site). Students are responsible for completing the graded material regardless of whether they received the announcement or not.

CALCULATOR REQUIREMENT FOR TESTS AND EXAMINATIONS:

McMaster Standard Calculator (Casio *fx*991) only

FACULTY AND UNIVERSITY POLICY REMINDERS:

"The Faculty of Engineering is concerned with ensuring an environment that is free of all adverse discrimination. If there is a problem, that cannot be resolved by discussion among the persons concerned, individuals are reminded they should contact the Departmental Chair, the Sexual Harassment Officer or the Human Rights Consultant, as soon as possible."

"Academic dishonesty consists of misrepresentation by deception or by other fraudulent means and can result in serious consequences, e.g. the grade of zero on an assignment, loss of credit with a notation on the transcript (notation reads: 'Grade of F assigned for academic dishonesty'), and/or suspension or expulsion from the university.

It is your responsibility to understand what constitutes academic dishonesty. For information on the various kinds of academic dishonesty please refer to the Academic Integrity Policy, specifically Appendix 3, located at:

http://www.mcmaster.ca/policy/Students-AcademicStudies/AcademicIntegrity.pdf

The following illustrates only three forms of academic dishonesty:

1. Plagiarism, e.g. the submission of work that is not one's own or for which other credit has been obtained.
2. Improper collaboration in group work.
3. Copying or using unauthorized aids in tests and examinations."

Latest Update January 6, 2014, by Dr. Hubert de Bruin