## BME 382 - Engineering Models in Physiology II

3 Credits, 5 Contact hours
Instructor: William C. Hunter, Ph.D.
Course Coordinator: William C. Hunter, Ph.D.

**Textbook(s)/Materials Required:**
***Modeling and Simulation in Medicine and the Life Sciences*** (2nd Edition), by F.C. Hoppensteadt and C.S.Peskin, Springer (2002) ISBN: 0-387-95072-9

**Description:**
Engineers in all fields use computational models of complex systems to help them design applications that will interact with those systems. Biomedical engineers must therefore be able to build and apply models of complex cellular and physiological functions. This requires them to translate their fundamental understanding of how a physiological system works into an engineering model that often evolves dynamically based on a differential equation. Physiological complexity is based on hierarchical structure, where subsystems interact to produce overall function, so biomedical engineers must know how to build and interpret models that mimic biological subsystem organization. Many physiological systems operate based on principles of negative feedback control, so biomedical engineers need to understand those principles and be able to model feedback-controlled systems. Finally, parameters in physiological control systems can often be difficult to determine *a priori*, so biomedical engineers need to know approaches to estimate parameters.

**Prerequisites:**
Math 222 (Differential Equations), BME 105-106 (Intro to Human Physiology),
Physics 111-121 (Physics I: mechanics and Physics II: electricity and magnetism)

**This is a required core course for the Biomedical Engineering Program**.

**Course Learning Outcomes (CLO):**

6. Build on a basic understanding of physiology (from pre-requisites) to develop a more in-depth level of understanding that will enable engineering analysis of selected physiological systems: (1) cardiovascular system, (2) pulmonary gas transport system, (3) neuro-muscular spinal reflex system, (4) cellular volume control system, and (5) action potential generating system in excitable cells.
7. Be able to translate the understanding of physiological function into an engineering model based on block-diagram analysis of a dynamic system whose function is based on a differential equation.
8. Develop skill in applying a high-level engineering tool for block diagram modeling (SIMULINK).
9. Be able to apply engineering models of physiological systems to answer questions relevant to the design of biomedical engineering devices or processes.
10. Be able to break down a complex physiological system into the function of its component subsystems, and then build an engineering model based on subsystems.

11. Be able to apply basic principles of steady-state and dynamic negative feedback control to physiological systems.
12. Be able to recognize the difference between the roles of variables and parameters in a model.
13. Be able to use dimensionless values or principles of dimensional analysis to determine how parameters must vary with the scale of the individual being modeled.
14. Be able to use inverse modeling to determine unknown parameters from known observations of model output variables.

**Student Outcomes:**

**Student outcome A –** Apply foundations of math, science, and engineering.
**Related CLO - 1, 2, 6,7**

**Student outcome B –** Ability to design and conduct experiments and analyze data.
**Related CLO – 4, 8, 9**

**Student outcome E –** Ability to identify, formulate, and solve engineering problems.
**Related CLO – 2, 5, 6**

**Student outcome K –** Ability to use the techniques, skills, and modern engineering tools needed for engineering practice.
**Related CLO – 3**

**Student outcome L –** Ability to apply biological/physiological insight for BME application
**Related CLO – 2, 4, 9**

**Student outcome M-1 –** Ability to model biological and physiological systems
**Related CLO – 1, 2**

**Course Topics:** Students build ten engineering block-diagram models of specific physiologic functions. Initial models focus on building successively more complex models of the cardiovascular system, so that students gradually gain experience with the hierarchical nature of physiologic systems. The last 4 models diverge into other important physiological functions to provide some scope of diverse modeling in the course. For each model, one assignment focuses on understanding how the model & physiological system work; the second assignment focuses on using the model in a novel engineering application. The 10 models are:

1-arterial pressure pulsations
2-pressure-volume loops of the left ventricle interacting with valves and the arteries
3-Guyton's steady-state model of the circulation – the importance of venous function
4-Baroreceptor control of mean arterial pressure via the autonomic nervous system
5-Two halves of the circulation: pulmonary + systemic; right + left halves of the heart
6-Fetal circulation and changes in the circulation at birth
7-Transport of oxygen and carbon dioxide by alveoli and red blood cells
8-Spinal neuromuscular reflex control of elbow angle
9-Control of cell volume and resting potential by the sodium-potassium pump
10-State-variable model of the Hodgkin-Huxley model of neural action potentials