<u>Title</u>: BIOEN 305 Bioengineering Analysis of Human Physiology II

<u>Instructor</u>: Regnier **Credits:** 4

<u>UW General Catalogue Course Description:</u>

<u>Current</u>: Introduction to the cardiovascular system. Explores the cardiovascular system as an engineering system in which the heart is a pump, and the load and distribution of blood to organs on the heart depend on the demands of the system. Introduces principles of fluid transport.

<u>Instructor's Detailed Course Description:</u>

The purpose of this course is to build a fundamental understanding of the biophysical and engineering principals that are the basis of cellular and systems human physiology. Problem sets will be used to reinforce these principles and provide quantitative analysis skills,for a variety of applications, including experimental data from skeletal muscle mechanical measruements, cardiovascular hemodynamics and renal function. The laboratory component encourages critical thinking, the understanding of scientific methodology, and the application of scientific principles to understanding non-invasive measurements of cardiorespiratory, muscle and renal function. It also includes components of measurement analysis and statistics. Discussion of exercise, disease processes, bodily dysfunction and diagnosis will be incorporated in lectures for examples of systems integration.

<u>Pre-Requisites:</u> Biology, physics, calculus, differential equations, chemistry (biochemistry preferred), Bioe 302, 304.

Textbook: Silverthorn (3rd edition) Human Physiology: An Integrated Approach. Handouts are used to supplement the book and to provide more depth in subject matter.

<u>Learning Objectives:</u> Understand the relationship between structure and function of proteins, cells and systems. Understand the physical properties that determine function and the regulatory processes that modulate function. Labs involve learning about hypothesis generation and testing, experimental design, and data collection and analysis in research and diagnostics. Computational models describe biological systems (*e.g.,* models for motor proteins and cellular mechanical properties of striated muscle that have potential diagnostic use), and how they can be used to raise questions and suggest further experimentation. Education to understand the impact of bioengineering solutions and the benefits of life-long learning are acquired through student presentation of bioengineering research, with introductions on the health benefits. Assessments are made by a question and answer period and by a written summary of the oral presentations.

<u>Topics Covered</u>:

Having successfully completed the course the student should have a good working knowledge of the following upon which to build in the future:

a. Muscle: Structure, regulation, biochemistry and function of smooth and striated muscle.
b. Comparative aspects of muscle function and regulation.
c. Motor control; central and spinal-reflex pathways, voluntary movement, biomechanics.
d. Physiology of the cardio-vascular system: heart as a pump, auto- and reflex regulation of cardiac output, vascular hemo-dynamics.
e. Anatomy and physiology of the respiratory system: gas exchange, blood transport and control of respiration.
f. Metabolism and energetics; mechanisms and control.

g. Anatomy and physiology of the renal system: clearance, reabsorption/secretion, osmoregulation.
h. Integrated control of blood pressure and volume.
i. Fluid, electrolyte and acid-base balance: integration of respiratory and renal regulation of acid-base balance.
j. Plasticity and adaptation of cells, organs and systems with exercise and disease.

Class Schedule: Lectures (3 hrs/week) and Lab (one 3-hr session/week)

Computer Use: Requires use of on-line access for lecture notes and course assignments. Laboratories include use of computer software linked to hardware for acquisition of biological process data (*e.g.,* EMG, ECG, blood pressure, thoracic pressure, etc.). Measurement and statistical analysis of data are done with provided software. A modeling component utilizes Matlab programming.

Laboratory Projects: Laboratory exercises reinforce and extend critical concepts provided in lectures. They also provide measurement and analysis tools for diagnostics of normal physiological function and clinically relevant pathological conditions. Labs subjects may include such topics as: EMG, ECG, blood pressure, respiratory capacity, renal function and their integrative capacities.

Course Outcomes and Assessment: Bioe 305 includes interactive lectures, weekly laboratories, problem sets and group presentations of research papers. As such, several ABET outcome criteria are incorporated into the course structure. These are listed below, along with their assessment mechanisms.

ABET OUTCOMES

(b) Design and conduct experiments; analyze and interpret data. Laboratory exercises include learning how to determine the best protocols to obtain data that can be compared between subjects, control/baseline measurements. The concept of rationale and hypothesis testing are used for each lab. Students learn methods for standardizing data collection, how to compare data between individuals or phenotypic categories in graphical or tabular form. Statistical analyses are employed to determine if significant differences occur with time, trial or between individuals/groups. Examples of ‘normal’ and pathological conditions are provided in some labs to aid in discussion of results and use of techniques/protocols for diagnostics. Lab reports are used to asses how well students learn these concepts.

(d) Work in Teams. Laboratory exercises and write-ups are done in teams of 4-5 students. Coordinated effort is required to collect data from individual group members under controlled conditions, measure and analyze data and to develop lab reports.

(g) Communicate effectively. Written communication is via lab reports, with an emphasis on idea (hypothesis) development, clear and efficient presentation of results and discussion of the data in terms of physiological systems under homeostatic/non-homeostatic and pathological conditions. Oral communication practice is obtained by group presentations of a research paper.

(i) Recognition of need for and ability to engage in life-long learning. This concept is taught in lectures and reinforced by group presentations of research papers. Students are reminded that many details and mechanisms of physiological function are not known or not well-understood, and are the subject of current research. Assessment comes from group paper presentations where students should point out what is currently known, what remains unclear and how does the research presented advance our understanding.

(j) Knowledge of contemporary issues. Lectures are based on development and use approaches and/or devices to improve physiological function of patients with pathological conditions. Questions addressed may include limits of use, whether these approaches should be made available to individuals without pathological conditions, and whether Bioengineering research should focus on advanced (often expensive) or simple, effective means to improve health in economically challenged areas. Topics vary each year and are evaluated in the form a written report, usually related to ethical issues.

(l) An understanding of Biology and Physiology. Students enter the course having taken at least two quarters of biology and upon the completion of Bioen 304. In Bioen 305 they learn physiology in an integrative manner, with several examples of function from the molecular to systems level. Examples include understanding striated muscle function from individual protein interactions to the biomechanics of limb movement, cardiac electromechanical physiology from the level of ion channels to heart pump function and the Frank-Starling law of the heart, etc. There is also emphasis on showing how individual systems are interdependent. Exams are used to assess how well students learn these concepts and material.

(m) Capacity to apply advanced mathematics, science, and engineering in solving problems at the interface between living and non-living systems. Students learn concepts described below in (e) in terms of physical, chemical and mathematical descriptions that apply to non-living and living materials. Examples include material properties, flow dynamics, pressure-volume relationships and mechanics. This material is assessed in exams and problem sets.

Additional specific outcomes and their assessment mechanisms considered **of HIGH relevance** by the department for Bioen. 305 are:

(a) Apply knowledge of mathematics, science and engineering. There are 3 large problem sets during the course. For example, one problem set includes the development of a computational mass-action kinetic model (e.g., actin-myosin interaction during muscle contraction). This example uses of ordinary differential equations and Matlab programming. This problem set also involves solving forces and torques for a biomechanical joint movement problem. Examples of other problem sets include questions on hemodynamics, tissue and organ compliance, renal fluid filtering and flow, and metabolic energetics.

(n) Ability to make measurements on and interpret data from living systems, addressing problems associated with interactions between living and non-living material and systems. Labs require collection of data from individual and groups of students. Problems associated with instrumentation for data collection, data acquisition and analysis software, etc. are an integral part of lab writeups in explaining ‘good’ vs. ‘bad’ data, how data collection could be improved, and how to revise protocols to improve measurements.

Those specific outcomes and their assessment mechanisms considered of **MEDIUM relevance** by the department for Bioen. 305 are:

(e) Identify, formulate and solve engineering problems. Problem sets involve multiple engineering principles; such as: chemo-mechanical transduction and kinetics of protein-protein interaction (motor proteins), ligand-substrate interactions, pressure-volume relationships, biological filter functions, determination of flow patterns with variable resistance and viscosity and cellular/systems level +/- feedback.

(g) Communicate effectively. Written communication is via lab reports, with an emphasis on idea (hypothesis) development, clear and efficient presentation of results and discussion of the data in terms of physiological systems under homeostatic/non-homeostatic and pathological conditions. Oral communication practice is obtained by group presentations of a research paper.

k) Computer/analytical equipment. Laboratories and one problem set involve the use of computers and analytical equipment. Collection of EMG, ECG, blood pressure, thoracic pressure and lung volumes involve hardware with computer software interfaces for acquisition, measurement and analysis of data. Additional software, such as Excel and Matlab are also used. One problem set involves use of a Matlab program for computational modeling of muscle contraction.

Relationship of Course to Departmental Objectives: A goal of the junior core is to teach students how to use quantitative and analytical techniques to investigate health-related issues. Bioen 305 is fundamentally a course to teach physiological principles that all bioengineering students should have, but from an engineering, chemical and mathematical perspective. The department believes that this will prepare students to be able to communicate between different fields in science, engineering and medicine and will also best prepare them for post-graduate education.