621.126 Seminar on Optimization and Control in Physiological Systems
(for Mathematicians and Life Scientists, 2st.)

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Course purpose

This course will examine some important concepts and systems in human physiology both from the perspective of the physiologist and the mathematician. As an end result of this seminar it is hoped that both the physiologist's and the mathematician's perspective will complement each other and advance joint knowledge.

A number of physiological systems in the human body act to stabilize critical quantities or state variables such as systemic blood pressure. In general, the mechanism involves a negative feedback loop which depends on a sensory system which provides information to a controller which acts to maintain a stable level of this quantity. Furthermore, many physiologists believe that physiological control systems often act to optimize the efficiency and to minimize variations in the system in an effort to conserve energy or to minimize deviations from steady state values of critical quantities. For these reasons optimal control theory can be used to study physiological systems.

The inspiration for the course stems from a joint Physiology and Mathematics working seminar within the Cardiovascular respiratory Control Group of the Special Research Center for Optimization and Control at the University of Graz (Spezialforschungsbereich F-003) sponsored by the Austrian Science Fund).

This working group is preparing an international workshop on "Cardiovascular and Respiratory Control Modeling" which will be held from June 14-16, 2001 in Graz. The web page for this workshop can be found from the KFUG Mathematics web page or at:

http://bedvgm.kfunigraz.ac.at:8001/jerry/conference.html

Course organization

- The course will meet on Tuesdays from 16.00 to 17:30 in the Seminarraum 11.34 of the Department of Mathematics.

- Twelve lecture topics will alternate between a physiological topic and a mathematical topic

- Handouts on presented topics and examples will be made available during the course. Please, provide your e-mail address.

- For students wishing credit for this course, homework will be periodically assigned. Please, see us after the first meeting if you are planning to take this course for credit.

Schedule

March 6	Introductory meeting
March 13	Physiological lecture (Schneditz)
March 20	Mathematical lecture
March 27	Physiological lecture (Kenner)
April 03	Mathematical lecture
April 24	Physiological lecture (Pilgram)
May 08	Mathematical lecture
May 15	Physiological lecture (Auerbach)
May 22	Mathematical lecture
May 29	Physiological lecture (Moser)
June 5	Mathematical lecture
June 12	Physiological lecture (Scheditz)
June 14 to 16	Workshop
June 19	Mathematical lecture

Physiological Topics

Metabolic control (Schneditz)

A major fraction of food is used to generate the energy to carry out our current activities utilizing enzymes to break down and to synthesize major fuel substrates such as carbohydrates and fats. The fate of glucose, one of the most important fuel substrates, is controlled by the hormone insulin. Failure of glucose and insulin control frequently occurs with western lifestyle leading to diabetes mellitus and subsequent multiple tissue damage. Analysis of actions and physiologic control mechanisms required to substitute for lost function will be provided in this lecture.

Basic problems in biological systems (Kenner)

Energy-production and -storage

Information-storage and –transmission

The genome

- Genotype and phenotype

An attempt to define ”life”

The minimum size of a living system

Scaling

The meanings of the term ”receptor”

Description of the term ”enzyme”

Mathematical description of enzymatic reactions

Some specific properties of living systems

- Spontaneous activity
  - noise

- Reactions to input (stimuli)
  - Threshold
  - ”all or none”
  - stimulus-response relation
  - adaptation
  - asymmetry
    - unidirectional rate sensitivity
- Nonlinearity of living systems
  - The question of linearization
  - Simple and complex models (viewpoint of a physiologist)
- Description of cells and cell-functions, cell systems - examples

Blood pressure and volume control (Pilgram)

Blood pressure is one of the most important driving forces to transport nutrients and metabolites across the body and to the cells which are bathed in the extracellular fluid. The control of blood pressure and extracellular fluid volume is related. This lecture will provide an introduction to short term, mid term, and long term control of blood pressure and volume homeostasis and discuss the classic Guyton/Coleman model.

Dimensional analysis in biological transport (Auerbach)

Matter, heat, energy and momentum are constantly transported through the body, each in their own peculiar way. Their motion serves the most varied purposes: thought, emotion, tonus and mobility, heating, growth, metabolism, transparency, reproduction, to mention but a few. So many variable quantities are involved, and investigating how various quantities scale (vary by being multiplied with a factor) with one another - based on a simple analysis of the dimensions involved - helps in both understanding and modeling these processes.

Autonomic control (Moser)

Respiratory and exercise control (Schneditz)

Exercise requires a large flow of oxygen from the atmosphere to the mitochondria in the working muscle by a multi-step process. The transfer via the lung and the cardiovascular system has distinct physical barriers each of them posing a limitation to optimum oxygen transfer under certain circumstances. The basics of oxygen transport and metabolism and the control of oxygen uptake and its limitations at exercise will be analyzed.

Mathematical Topics

Review of ordinary differential equations

Elements of dynamical Systems

Elements of control theory (I)

Elements of control theory (II) and applications of control

Systems involving delay

Bifurcation and chaos