FACULTY of SCIENCE
Department of Physics and Astronomy

Course: SC/BPHS 2090 3.0 (crosslisted to SC/BIOL 2090 3.0) – **Current Topics in Biophysics**
Course Webpage: http://www.yorku.ca/bphs
Term: Fall Term 2014/2015

Prerequisite / Co-requisite: SC/PHYS 1010 6.00 or SC/PHYS 1410 6.00 or SC/PHYS 1420 6.00; SC/BIOL 1000 3.00 and SC/BIOL 1001 3.00 or SC/BIOL 1410 6.00.

Course Instructors:

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Time and Location

Lectures	TR	11:30 AM–1:00 PM	Stong College 218

Course Description

An introduction to biophysics highlighting major themes in pure and applied biophysical research. Included is coverage of fundamental concepts in fluid mechanics. The course will present students with an overview of the role of physics in biological research. Three lecture hours. One term. Three credits.

Expanded Course Description. This course will introduce students to biological physics. The current topics format gives the course directors latitude to choose topics that illuminate both biology and physics, and to bring in guest lecturers from many disciplines that require a biophysics background. Sample Topics: life and cycle, biomechanics, biological pumps, nanomoters, molecular spectroscopy, laser biophysics, nuclear physics and nuclear magnetic resonance. Guest lectures may include bio-imaging, high energy particle beam applications in biology, nuclear magnetic spectroscopy etc. For Biophysics majors: Concepts surveyed in this course will be further expanded in the third and fourth year biophysics courses. For Biology and other majors: Students are expected to be comfortable with introductory calculus.

Organization of the Course. The course involves formal lectures by the lecturers and guest lecturers. The lectures are central to the course. Lectures serve to enrich, clarify, and illustrate crucial current issues biophysics, with a primary focus on the application of physical approaches to biological problems. The material is reinforced by take-home assignments, gists of guest lectures and term tests.

Course Learning Objectives. Please note that a detailed syllabus of lecture material and past assignments and tests on the course website (www.yorku.ca/bphs) provide a highly detailed and practical presentation of the Learning Objectives.

Brief statement of the purpose:

The objectives of the course are to give students the opportunity to integrate the knowledge they gained in first year biology and physics courses into an interdisciplinary exploration of biological problems amenable to physics-based analysis, and to expose students to modern topics in biophysics. Specifically:

- Students are presented with case studies of current biological problems and the physical approaches used to solve them. These case studies are used as the foundation for assignments and test questions that require students to apply what they have learned to solve open-ended problems.
- Students learn pertinent aspects of foundational physics knowledge, and then apply that knowledge to relevant biological problems. Students are then given an in depth opportunity to solve work problems using fundamental physics-based knowledge in assignments and tests.
- Finally, students are introduced to current topics through guest lectures, and given the opportunity to synthesize what they learned into informative summary gists.

These three approaches intermesh in a framework of knowledge that encourages students to apply and integrate their understanding to novel biological problems using interdisciplinary problem solving.

Brief list of specific learning objectives of the course

The specific objectives of the course are that students will be able to:

- Critically examine the diversity of major organismal groups with reference to their usefulness as models for biophysical research.
- Understand key physical approaches that can be used to understand the how the form and function of diverse biological organisms are limited by physical constraints.
- Obtain detailed knowledge of the diversity of foundational physics that is relevant to biological processes.
- Develop their independent ability to apply their knowledge of biophysics to new biological problems and goals.

Course Text / Readings

Lew, R.R. and S. Jerzak (2014) Course Notes for Current Topics in Biophysics

(Detailed handouts and pdf files will be available on the Moodle website to provide the students with basic knowledge that is then expanded on in lecture.)

Evaluation

- Two term tests (30% total) and a final exam (40%)
  The term tests will be held on the 9th of October and 18th of November)
- Assignments (20%)
- Guest lecture gists (10%)

In the event of an absence from a term test, please provide a letter stating that you were absent, and acknowledging that the weight of the missed term test (15%) will be added to the weight of the final exam.

"Final course grades may be adjusted to conform to Program or Faculty grades distribution profiles."

Grading: The grading scheme for the course conforms to the 9-point grading system used in undergraduate programs at York (e.g., A+ = 9, A = 8, B+ - 7, C+ = 5, etc.). Assignments and tests* will bear either a letter grade designation or a corresponding number grade (e.g. A+ = 90 to 100, A = 80 to 90, B+ = 75 to 79, etc.). For a full description of York grading system see the York University Undergraduate Calendar - http://calendars.registrar.yorku.ca/2013-2014/index.php. Students may take a limited number of courses for degree credit on an ungraded (pass/fail) basis. For full information on this option see Alternative Grading Option in the *(Faculty of Science and Engineering)* section of the Undergraduate Calendar.
Assignment Submission: Proper academic performance depends on students doing their work not only well, but on time. Accordingly, assignments for this course must be received on the due date specified for the assignment.
Lateness Penalty: Assignments received later than the due date will be penalized (usually 10% for the first day, 20% for the second, 40% for the third, ad infinitum).
Missed Tests: Students with a documented reason for missing a course test, such as illness, compassionate grounds, etc., which is confirmed by supporting documentation (e.g., doctor's letter) will have the weight of the missed term test transferred to the final exam.

IMPORTANT COURSE INFORMATION FOR STUDENTS

All students are expected to familiarize themselves with the following information, available on the Senate Committee on Academic Standards, Curriculum & Pedagogy webpage (see Reports, Initiatives, Documents) - http://www.yorku.ca/secretariat/senate/committees/ascp/index-ascp.html

- Senate Policy on Academic Honesty and the Academic Integrity Website
- Ethics Review Process for research involving human participants
- Course requirement accommodation for students with disabilities, including physical, medical, systemic, learning and psychiatric disabilities
- Student Conduct Standards
- Religious Observance Accommodation

18 August 2014

Lew Lectures

Lecture I. GROWTH AND FORM

A. Allometry[1]

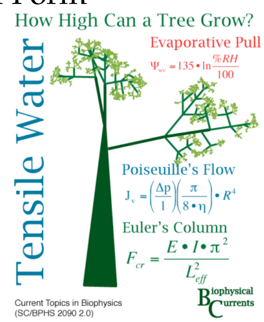
1. growth and life cycle
2. dimensional analysis

The relations between organismal size, life cycle and physiological function (metabolism, etc.) will be introduced to form a general overview of the physical envelope of organismal life.

B. Biomechanical Constraints on Growth and Form[2]

1. the height of a jump
2. the height of a tree

The relations of force and motion will be explored in the context of 'defying' gravity (to explain why fleas and humans are able to jump to the same height). The height of a tree relates to growing high to optimize light collecting for photosynthesis, the strength of materials and how they limit height, and the need to supply water to the topmost regions of the tree, all constrained by physical limits.



Lecture II. DIFFUSION, ADVECTION AND BIOLOGICAL PUMPS: The Evolution of Multi-Cellularity

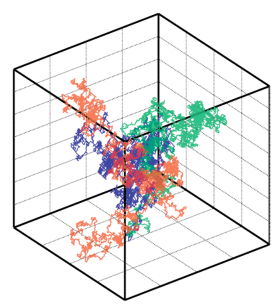
A. Diffusion: Thermodynamics and molecular explanations from Einstein[3]

1. Einstein's explanation of Brownian motion
   - a. thermodynamics
   - b. molecular theory

Einstein's explanation, a derivation from a two-dimensional random walk, was the starting point for a physical explanation of the flux of neutral solutes, in solution (Fick's equations).

2. Time dependence of diffusion

The constraints on biological organisms as a consequence of the slowness of diffusion over long distances will be presented.



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[1] **REQUIRED READINGS**

Alexander, R. McNeill (1971) Size and Shape. Edward Arnold (Publishers) Limited. Chapters 1 and 2;

West, Geoffrey B. and James H. Brown (2004) Life's universal scaling laws. Physics Today (September) pp. 36–42.

[2] **REQUIRED READINGS**

Thompson, D'Arcy Wentworth (1961) On Growth and Form (ed. By John Tyler Bonner). Cambridge University Press. Pp. 26–28;

McMahon, Thomas (1973) Size and shape in biology. Science 179:1201–1204;

Tyree, Melvin T. (2003) Tree hydraulics. Nature 423:923.

[3] **REQUIRED READINGS**

Einstein, Albert (1907). Investigations on the Theory of the Brownian Movement. Edited by R. Furth. Translated by A.D. Cowper. Published by Dover Publications. Chapter V (The elementary theory of the Brownian motion).

B. Advection and the Peclet Number

1. Laminar flow at low Reynolds number
2. Nutrient supply by diffusion or advection.

As multicellular organisms evolved, their size increased. This creates a challenge: How to supply nutrients at sizes where diffurion is too slow. Advective flow can work, the Peclet number compares the relative contributions of advection and diffusion.

Volvox is used as a case study of the utility of advective flow for a relatively simple multi-cellular form.

C. Biological pump mechanisms causing advective flow

The remarkable diversity of advective pumps in biological organisms is outlined.

D. Xylem feeding insects

Cicadas and spittle bugs are used as an example of a relatively simple valve-less chamber pump.

Lecture III. MOLECULAR MOTORS (time permitting)

A. Cellular Movement[4]

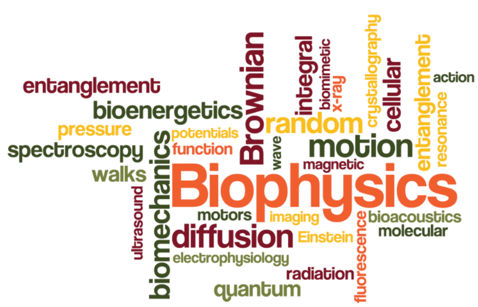
1. Reynold's number: Laminar and turbulent flow
2. Viscosity and drag

Small sizes, low velocities and viscosity create a very different physical 'universe' for small versus large organisms.

B. Bacterial Motility[5]

1. Rotatory engines
2. Chemiosmotics (energetics)

Vectorial movement of hydronium ions passing through the stator/rotor causes rotatory motion of the flagella and thus bacterial motility.



Bibliography (Some books that offer a variety of insights into aspects of the lecture topics)

• On Growth and Form (Canto) by D'Arcy W. Thompson (edited by John T. Bonner)

This book is considered a classic exploration of the relations between growth and form and the physical limits that constrain growth and form.

• On Size and Life by Thomas McMahon and John T. Bonner

As a Scientific American publication, the level of presentation is relatively easy. It is an excellent introduction to the diversity of aspects of size and biological form, with emphasis on dimensional analysis.

• Random Walks in Biology by Howard C. Berg

A physicist's perspective on random walks and biological phenomena, biased towards the small (bacterial motility and the like).

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[4] **REQUIRED READINGS**

Purcell, EM (1977) Life at low Reynolds number. American Journal of Physics 45:3–11.

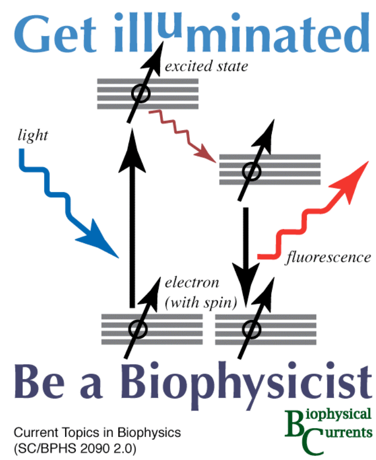
[5] **REQUIRED READINGS**

Berg, HC (2000) Motile behavior of bacteria. Physics Today (January) pp. 2–7.

Jerzak Lectures

ABSORPTION AND LUMINESCENCE MOLECULAR SPECTROSCOPY

- Electromagnetic waves and photons
- Atomic and molecular orbitals
- Energy diagrams
- Absorption and emission of radiation
- Fluorescence and phosphorescence in biology
  Fluorescence microscopy
- Energy transfer and charge transfer in biology
- Photothermal and photodynamic cancer therapy
- Photosynthesis
- The eye
- Laser tweezers in biology



NUCLEAR PHYSICS AND BIOLOGY AND MEDICINE

- Nuclear binding energy
- Types of radioactive decays
- Rate of radioactive decay
- Effects of nuclear radiation on living organisms
- Biological dose equivalent and effects of radiation on living organisms
- Radioisotopes in biology and medicine

NUCLEAR MAGNETIC RESONANCE SPECTROSCOPY / MAGNETIC RESONANCE IMAGING

- Spin angular momentum and magnetic dipole moment in magnetic field
- NMR spectrometer
- Chemical shift
- Spin–spin splitting
- Spin–lattice relaxation time and spin-spin relaxation time
- MRI in medicine
- Brain imaging (fMRI)

NANOBIOPHYSICS

- Nanoparticles in biology and medicine
- Magnetic hyperthermia cancer therapy
- Plasmonic photothermal therapy
- Nanoparticles in image enhancement
- Nanoparticles in drug delivery

Revised 14 August 2014