Lew Lectures

Lecture I. Growth and Form

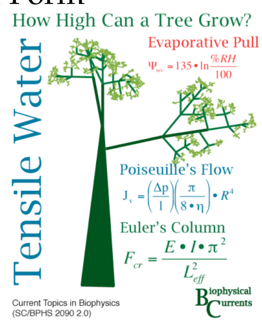
A. Allometry[1]

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

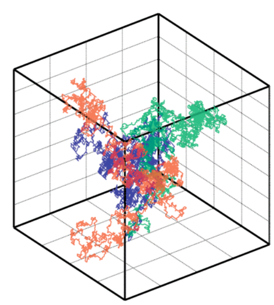


The relations of force and motion will be explored in the context of 'defying' gravity (to explain why fleas and humans are able to jump to the same height). The height of a tree relates to growing high to optimize light collecting for photosynthesis, the strength of materials and how they limit height,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

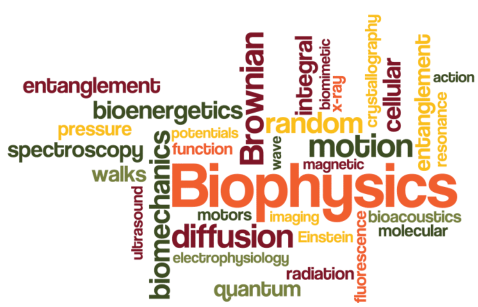
1. Reynold's number: Laminar and turbulent flow
2. Viscosity and drag

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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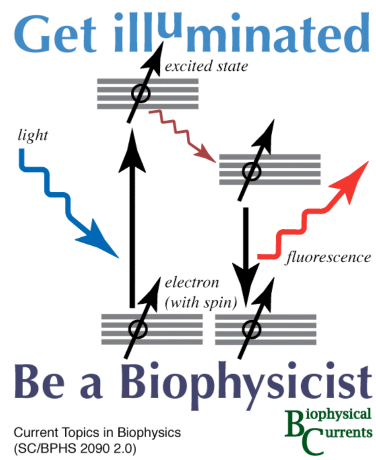
[4] **REQUIRED READINGS**
Purcell, EM (1977) Life at low Reynolds number. American Journal of Physics 45:3–11.

[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

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