Revised: 29 May 2008

Lecture I. GROWTH AND FORM

A. Allometry[1] (*ca* 1 lecture hour)

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 (*ca* 2-3 lecture hours)[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. MOLECULAR MOTION

A. Brownian Motion[3] (*ca* 1 lecture hour)

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.

B. Membrane Partitioning (ca 1 lecture hour)

1. Osmotic flux and membrane permeation
2. Collanders' data on The permeability of Nitella cells to non-electroytes.

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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).

3. Osmotic pressure and permeability

Olive oil partitioning and membrane permeability reveal the properties of the plasma membrane, but also offer insight into osmotic gradients and the flow of water across membranes. Osmotic pressure measurements of permeability recall the thermodynamic underpinnings of Einstein's explanation of Brownian motion.

Lecture III. MOLECULAR MOTORS

A. Cellular Movement[4] (*ca* 0.5 lecture hours)

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] (*ca* 1.5 lecture hours)

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.

Addendum Lecture

Lecture IV. ELECTRICAL LIFE

A. Ions in Aqueous Solutions[6]

1. Charge density and solvation energies

The concepts of ion selectivity rely heavily on an understanding of the remarkable energetics and steric nature of ionic hydration.

B. Cellular Resistance and Capacitance

1. Cellular batteries
2. Propagation of electrical signals

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)
• On Size and Life by Thomas McMahon and John T. Bonner
• Life's Devices. The physical world of animals and plants by Steven Vogel
• Random Walks in Biology by Howard C. Berg
• Theory of the Brownian Motion by Albert Einstein

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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.
[6] Source: Ionic Channels of Excitable Membrane by Bertil Hille