Soft Matter and Biological Physics

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Experimental and Theoretical Physics
Part III
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Preface

How to use this handout:

Where derivations are written out extensively here, they will probably not be reproduced in class, and vice versa. You will be expected to have understood all of these, and to be able to reproduce these results and variations that use the same methods. Derivations obtained in the examples sheets are also part of the course, and worked out solutions will be made available towards the end of the course.

Dos:

- Use the handout to follow progress through the course material. The structure of the handout is almost the same as the lectures.
- Integrate the lecture overheads and the handout material yourself. There is examinable material that only appears in one place.
- Follow suggestions and think about the questions in the notes. These are distributed through the text to help you determine if you are understanding the material.

Don'ts:

- Expect to study only from these notes. You will need the other main references. Most of all you will need to understand how to use the material and methods presented, rather than memorising information.
- Expect these notes to be error free. They will contain a higher density of errors than a typical book! e-mail us if you think something is wrong or unclear, and the notes will improve.
- Expect these notes to be even in the level of presentation. Some paragraphs are minimal, and some section labels are only place holders for material that will be covered in class. Instead, use these notes to guide you through the books and primary literature.

Contents

Disclaimer

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The topics of soft matter and biological are not like quantum mechanics or thermal and statistical physics. In most respects the latter are complete and done. In our opinion, it is unlikely that both will fundamentally change in the next decades, if ever. The situation is completely different for soft matter and biological physics, which are topics which only in the last two decades became a focus of physics departments around the world. This makes the field exciting to work in but also poses problems for students and for us; there is no single standard textbook that covers all of soft matter and biological physics. Thus we decided to provide some notes in the present form, not to replace a textbook but to help accessing the material of the course.

These are notes for the Part III 'soft and biological physics' course and they are and probably always will remain preliminary. They are neither fully complete, nor fully correct and will be constantly updated. It is very important that you look at other material as well to fully understand the topics covered in the course. Notes like these can almost never replace a proper textbook (until they become one). This even more so in an advanced course covering 'hot' topics discussed at the moment in the scientific community. This makes it often necessary to read (very often recent) journal articles. We know that this can be a challenge but you are expected to be able to do this when you start to work on your Part III projects - so this is another, perhaps more painful but also more useful, exercise than you realize during the course.

Please send corrections to Ulrich Keyser (ufk20 (at) cam.ac.uk) or Ray Goldstein (reg53 (at) damtp.cam.ac.uk).

Introduction

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2.1 Recommended books

Books best suited for introductory reading for the course:

(1) Biological Physics, P. Nelson, W. H. Freeman (2007)

(2) Mathematical Biology I. and II., J. D. Murray, Springer (2007, 2008)

(3) Molecular Driving Forces, K. Dill and S. Bromberg, Garland Science (2009)

And we recommend the following books for advanced and complementary reading

(1) Soft Condensed Matter Physics in Molecular and Cell Biology, D. Andelman and W. Poon, Taylor and Francis (2006)

(2) Van der Waals Forces, A. Parsegian, CUP (2005)

(3) Intermolecular and Surface Force, J. N. Israelachvili, Academic Press (1992)

(4) The Theory of Polymer Dynamics, M. Doi and S. Edwards, OUP (1986)

(5) Theory of the Stability of Lyophobic Colloids, E. Verwey and J. Overbeek, Elsevier (1948)

Other interesting books are,

(1) What is life? (Schrödinger)

(2) Stochastic Processes

(3) Mathematical Biology (Murray)

(4) Molecular Biology of the Cell, Alberts, et al.

(5) Lectures on the Physiology of Plants, J. Sachs

(6) for diffusion, random walks, nice introduction: H. C. Berg ”Random Walks in Biology”

2.2 Overview of Course

2.2.1 Microscopic Physics

- Inter-molecular attraction (Van der Waals, Lennard Jones potentials, fluctuating dipoles, etc.)
- Charged Particles in Solution (Debye-Huckel theory)

- Membranes of a cell (deformed, charged sheets of positive ions)
- Bending energy of membranes

2.2.2 Fluctuations and Fluctuation Induced Forces

- Dynamics of polymer chains and DNA (entropic springs)
- Brownian Motion (stochastic differential equations)

2.2.3 Elasticity

- Curve dynamics, elasticity, bending energies, curve shortening, elasticity in higher dimensions (membranes, etc.)

2.2.4 Chemical Kinetics and Pattern Formation

- Simple kinetic models (Michaelis Mentin, etc.)
- Reaction/diffusion equations, slaving, multiple time scales
- Interface dynamics
- Pattern formation in the Fitz-Hugh Nagumo model

2.2.5 Bioconvection

- Gyrotaxis
- bio-convection/diffusion equations
- Instabilities

2.2.6 Electrokinetic phenomena

- Electrophoresis
- Electroosmosis
- Single molecule sensing
- Coupled Poisson-Boltzmann Navier-Stokes equation

2.2.7 Techniques

- Optical tweezers (calibration)
- Atomic force microscopy
- Single particle tracking
- Resistive-pulse sensing