This course is an INTRODUCTION to biopolymers and biological physics. The course will emphasize physical ideas involved in experimental and theoretical understanding of biological and synthetic macromolecules and materials. The following outline is an "ideal" plan. Because of time constraints, some of the topics will be only mentioned, while others will be developed to some depth. The order of the topics is subject to change.

The major topics are:

**Introduction to polymers**

We will discuss terminology, architecture, and physical states of polymers to provide background and an overview of the topic.

**Ideal Single Chain Conformations**

Polymers are flexible molecules. We will mainly discuss the ideal chain, its end-to-end distance and entropic elasticity (as measured in single molecule stretching experiments). In addition to ideal chains, we will discuss the mechanical properties of rubbery materials (elasticity entropy).

**The worm like chain (semi-flexible polymers)**

Biopolymers form networks (i.e. cytoskeleton) with relatively stiff rods. We will explore the worm-like chain model to describe the physics of such beams, their persistence length, and the energy it takes to bend DNA in tight loops or to pack it into a virus.

**Real Single Chain Conformations**

In addition to ideal chains, we will discuss the conformation of real chain in poor and good solvent. We will introduce the Flory blob theory.

**Polymer dynamics and diffusion**

Diffusion is a major transport process in biological systems, especially at the scale of the cell. We will cover the fundamentals of diffusion and polymer diffusion modes.

**Biopolymers**

Brief background on the structure of biopolymers, their stability, and essential concepts, such as the central dogma. We will especially focus on DNA and proteins.

**Properties of polymer aqueous solutions**

We start by considering the hydrodynamics of water, viscosity, the special case of ‘life at low Reynolds numbers’, its implication for swimming of bacteria for example. We will discuss the free energy of binary mixing, osmotic pressure and the consequences of molecular crowding.

**Biopolymers: states, equilibria, and forces**

Many biopolymers are molecular-sized machines performing specific functions. Here we explore the thermodynamics that govern biopolymers with distinct functional states.

**Biopolymer as polyelectrolytes**

We will explore the presence of charges on polymers in a salty solution and develop models to describe charge interactions and screening.

**Lab visit**: we will go into a lab at least 1 time to show applications of the course (electrophoresis of DNA, observation of diffusion under the microscope, ….).
Special Topic
If time permits, we will cover:
• biological membrane mechanics: the physical boundary of cells is a lipid bilayer with many interesting mechanical aspects.
• gene networks in biological systems: in the past two decades, understanding the logic of the flow of information in biological systems has become a discipline on its own.
• We will discuss the dynamics of molecular motors, rectified Brownian motion, and force generation by actin polymerization.

PRE-REQUISITES:
To feel comfortable in class, students will be expected to have taken standard college level introductory physics; standard introductory level thermal/molecular physics (or a corresponding chemistry course); standard college level calculus, including vector calculus. Students should be prepared to deal with elementary concepts from probabilities and statistics.

Students will be expected to have reached the level of maturity typically achieved by the senior year of physics, chemistry, or other majors. Please don't hesitate to see the instructor if you feel uncertain about your meeting these requirements.

TEXTBOOK(s):
There is no book that can serve as a single text for the class. "Biological Physics" by Philip Nelson (W.H. Freeman and Company, Updated First Edition, 2008) is overall appropriate in level for a senior undergraduate course, and does cover a significant fraction of material, but not all of it. This book will serve as official textbook for the course. Physical Biology of the Cell (by Phillips, Kondev, and Theriot, Garland Science; 2nd edition, 2012) is another very nice book, appropriate in level and has significant overlap with our course. A useful introduction including probabilities and statistical mechanics is the book by Dill and Bromberg "Molecular Driving Forces" (Garland Science, 2003). Grosberg and Khokhlov on “Giant Molecules” is a nice introduction to the topic of polymers and biopolymers. A more advanced treatment is given by Pierre-Gilles de Gennes’s book “Scaling Concepts in Polymer Physics”. In addition, there are graduate-level books (beyond the scope of this course), such as the book from Rubinstein (Polymer Physics), Doi and Edwards (The Theory of Polymer Dynamics), Grosberg and Khoklov (Statistical Physics of Macromolecules).

HOMEWORK:
A VERY IMPORTANT part of the course will be problem solving of homework assignments. Homework solutions will be provided, they will be considered as a hand-out material and students will be expected to study them carefully, like a text. Additional reading from current journals will be assigned during the semester.

GRADING AND RELATED MATTERS:
In general, there will be a new homework set every two weeks (8 HW this semester, tentative dates: 26-Jan, 09-Feb, 23-Feb, 08-Mar, 22-Mar, 04-Apr, 18-Apr, 03-May). Score and percentage will be computed for every homework assignment. Homework will be due one or two weeks after they are handed out. Every homework will have the exact due date printed on the assignment sheet. No late homework will be accepted.

There will be three mid-term tests and a final exam. The tentative dates for the mid-terms are: 18-Feb, 24-Mar and 21-Apr. Mid-term test will be given in regular class time. The final exam will be held on Tuesday May 10, 0830-1130 (room TBA later). Final overall percentage will be based on the average of all HW (50% of course grade) and the better three of four tests – three mid-terms and final (the other 50% of the course grade). Final letter grades will be determined based on the percentage and the curve.

This class has two levels: 4911 and 5081. The content of HW and midterms will be slightly different as well as the grading scale to take the difference between the two levels into consideration.

FINAL SCORE CALCULATION:
50% = average of all HW
50% = better three of four tests (three midterms and the final)
Mandatory Statement about academic integrity

The University expects the highest standards of honesty and integrity in the academic performance of its students. Any act of scholastic dishonesty is regarded as a serious offense, which may result in expulsion. Scholastic dishonesty is defined as plagiarizing; cheating on assignments or examinations; engaging in unauthorized collaboration on academic work; taking, acquiring, or using test materials without faculty permission; submitting false or incomplete records of academic achievement; acting alone or in cooperation with another to falsify records or to obtain dishonestly grades, honors, awards, or professional endorsement; altering, forging, or misusing a University academic record; or fabricating or falsifying data, research procedures, or data analysis. Aiding and abetting an act of scholastic dishonesty is also considered a serious offense with the same possible consequences. Students may not make commercial use of their notes of lectures or University-provided materials without the express written consent of the instructor. (See the Senate policy at: http://policy.umn.edu/education#Education

Academic dishonesty in any portion of the academic work for a course shall be grounds for awarding a grade of F or N for the entire course. See http://regents.umn.edu/policies/index

Below is a list of links for University and Departmental policies and resources. You are responsible for knowing the policies.

- **Student conduct code**

- **Scholastic Dishonesty**
  See student conduct code. Also for an FAQ on what actions could constitute scholastic dishonesty:
  http://oscai.umn.edu/avoid-violations/avoiding-scholastic-dishonesty
  http://oscai.umn.edu/address-misconduct/promoting-academic-integrity

- **Disability Accommodations**
  https://diversity.umn.edu/disability/

- **Use of Personal Electronic Devices in the Classroom**
  http://policy.umn.edu/education/studentresp

- **Makeup Work for Legitimate Absences**
  http://policy.umn.edu/education/makeupwork

- **Appropriate Student Use of Class Notes and Course Materials**
  Taking notes is a means of recording information but more importantly of personally absorbing and integrating the educational experience. However, broadly disseminating class notes beyond the classroom community or accepting compensation for taking and distributing classroom notes undermines instructor interests in their intellectual work product while not substantially furthering instructor and student interests in effective learning. Such actions violate shared norms and standards of the academic community. For additional information, please see:
  http://policy.umn.edu/education/studentresp

- **Grading and Transcripts**
  http://policy.umn.edu/education/gradingtranscripts

- **Sexual Harassment**
  http://regents.umn.edu/sites/default/files/policies/SexHarassment.pdf

- **Equity, Diversity, Equal Opportunity, and Affirmative Action**
  http://regents.umn.edu/sites/regents.umn.edu/files/policies/Equity_Diversity_EO_AA.pdf

- **Mental Health and Stress Management**
  http://www.mentalhealth.umn.edu