ME 339 - Cell Mechanics

Tue/Thu 3:15-4:30pm, 380-380d

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Cells are the fundamental building blocks of life. The understanding of their characteristic biological features, their motility, their biochemistry and their interaction with the environment is crucial when cells are to be applied, modified or engineered in health care and modern medical therapies. This class focuses on the mechanical aspects of the cell which can be two fold: On the one hand, cell biology and biochemistry influence the mechanical properties of the cell. On the other hand the mechanical environment, load, pressure, stress, or strain can influence the cell's shape and integrity, and eventually its biology and biochemistry. In the first part of this class, we will discuss how cell properties can be measured experimentally and how they can be characterized in the form of equations. Concepts of energy and entropy will be elaborated for different structural units of the cell: biopolymers, i.e., microtubules, actin, and intermediate filaments and biomembranes, i.e., the lipid bi-layer that forms the cell membrane. Computational simulation tools will be introduced to explain and understand cell behavior in silico. In the second part, we address aspects of mechanotransduction which are part of active research in cell mechanics. We discuss different aspects of how cells sense loads and how signals are transmitted within the cell and through the extracellular matrix.

	Grading	
Homework	30 %	three homework assignments, 10% each
Midterm	30 %	open notes, with calculators, no books
Final Project	40 %	oral part graded by the class, written part by instructor

Tue 9/23 **Introduction I - Cell biology**
Overview of the cell
Biochemistry
Biopolymers
Biomembranes

Thu 9/25 **Introduction II - Cytoskeletal biology**
Cytoskeletal composition and structure
Role of cell mechanics in regulating cell structure and function
Directed stem cell lineage specification

Tue 09/30 **Introduction III - Structural mechanics**
Equilibrium - stress
Kinematics - strain

Material behavior – stress strain relation
In plane and out of plane deformation
Energy and entropy

Thu 10/02 **Biopolymers I – Energy**
Structural mechanics of biopolymers
Tension, bending, and buckling

Tue 10/07 **Biopolymers II – Entropy**
Introduction to statistical mechanics

Thu 10/09 **Biopolymers III – Entropy**
Random walk
Gaussian chain model
Entropic spring model

Tue 10/14 **Biopolymers IV - Entropy**
Freely jointed chain model
Worm like chain model

Thu 10/16 **Cytoskeletal mechanics I**
Filopodia
Fiber bundle model

Tue 10/21 **Cytoskeletal mechanics II**
Red blood cells
Chain network models

Thu 10/23 **Cytoskeletal mechanics III**
Actin, myosin, and intermediate filaments
Tensegrity models

Tue 10/28 **Biomembranes I**
Pipette aspiration
Liquid drop model
Laplace's law

Thu 10/30 **Biomembranes II**
Lipid bilayers
Soap bubbles
Cell membranes
Laplace's equation

Tue 11/04	**Biomembranes III** Mechanics of biomembranes Tension, shear, and bending
Thu 11/06	**Mechanotransduction I** Physical signaling Cellular transduction Intracellular signaling Transcription factors Ion channels
Tue 11/11	**Mechanotransduction II** Electrical signaling Electrophysiology Nerve cells Huxley Hodgkin model
Thu 11/13	Midterm
Tue 11/18	**Mechanotransduction III** Electromechanical signaling Excitation contraction Skeletal muscle cells and cardiac muscle cells Filament sliding theory FitzHugh Nagumo model
Thu 11/20	**Mechanotransduction IV** Generation and measurement of cell force Focal adhesion Cells on wrinkled thin sheets Traction force microscopy Cells on beds of microneedles
Tue 11/25	no class
Thu 11/27	no class
Tue 12/02	**Final projects I** Oral presentations evaluated by the class
Thu 12/04	**Final projects II** Oral presentations evaluated by the class
Fri 12/12	**Final projects due** Written projects due