BE/APh161: Physical Biology of the Cell
Course Syllabus
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1. Perspective, Vision, Preliminaries

Here we introduce some of the broad philosophical themes that animate our subject and this course.

SARS-CoV-2 and the pandemic. Science and life in a global pandemic.

Barbara McClintock and a feeling for the organism.

Schrödinger's "What is Life?" at 75. The physical basis of the living organism.

Order of magnitude thinking and street-fighting mathematics.

Tom Hanks, Wilson and what we can figure out by pure thought alone.

Survey of what it means to be the physics of a subject.

Topics we want to do physics to in the study of the living world.

2. A Feeling for the Organism.

What limits the rate of bacterial cell division? Linking modern proteomics and order of magnitude thinking to get a feeling for the processes controlling the rate of cell division.

Scaling, dimensionless ratios and non-dimensionalization.

Buckingham Pi theorem. Discovering Fick's law and diffusion time by dimensional analysis.

Scaling of organelles with cell size. The nucleolus as a case study.

Natural variables as one of the principal goals of models in science. Data collapse as a reflection of natural variables.

3. From Data to Insight: Thinking Big About Data.

The great probability distributions, the stories they tell, how to use them.

The unexpected reach of coin flips in probabilistic thinking and the way we see the world. Case study in molecular partitioning during cell division.

The Poisson distribution. Prussian horses to bombs over London to mRNA in yeast.

How cells keep their size constant from one generation to the next.

4. The Dynamical Cell.

Diffusion as biology's dynamical null model. Diffusion as viewed using coin flips, Langevin equations, chemical master equations, the diffusion equation. Fluorescence-recovery after photobleaching (FRAP). Reaction-diffusion and positional information. Turing patterns.

The dynamics of chemical transformation. Rate equations. Michaelis-Menten kinetics. Compartmentalization of the reactions of carbon fixation. Dynamics of sRNA regulation in bacteria. Cytoskeletal length control.

Dynamical systems as a paradigm for time evolution in biology and beyond. mRNA production. Two-state models of transcription.

5. Life as Defiance.

What is equilibrium? What is equilibrium thinking and what place does it have in biology?

What is life? Life as a series of defiances of the tendency towards equilibrium.

Case study in beating diffusion - membrane potentials to molecular motors.

Case study in adaptation. Beating Langmuir and Michaelis-Menten.

Case study in fidelity of polymerization. Beating Langmuir and Michaelis-Menten.

6. Theory of Living Matter.

The place of field theory in science. The place of field theory in biology.

Continuum theory protocol.

The theory of linear elasticity. Gut folding as a case study.

The theory of hydrodynamics. Cytoplasmic streaming as a case study.

The theory of viscoelasticity. Cell junction dynamics as a case study.

Active matter. Dynamics of actomyosin in embryos. Dynamics of tissues.