

GEM<sup>4</sup> Summer School on  
CELL AND MOLECULAR MECHANICS  
IN BIOMEDICINE  
with a focus on infectious diseases

August 7-18, 2006  
MIT, Cambridge, MA

[www.gem4.org](http://www.gem4.org)  
Conference website: [www.gem4.org/summerschool2006](http://www.gem4.org/summerschool2006)



# Summer School organization and instructors

Organized by: GEM<sup>4</sup>

Local organization:

Massachusetts Institute of Technology

with participation from the Division of Biological Engineering, Harvard-MIT Division of Health Sciences and Technology, and the Departments of Chemical Engineering, Mechanical Engineering, Materials Science and Engineering, and Electrical Engineering and Computer Science

Harvard University

with participation from the Harvard Medical School, Harvard School of Public Health and Division of Engineering and Applied Sciences

Overall Organizational support:

GEM4 Secretariat, National University of Singapore  
B.V.R. Chowdari (chowdari@gem4.org)

Technical Program Co-Chairs:

Subra Suresh and Roger D. Kamm, MIT

Technical Organizing Committee:

Gang Bao (Georgia Tech), Roger Kamm (MIT), L. Mahadevan (Harvard), Genevieve Milon (Institut Pasteur), Taher Saif (University of Illinois)

Summer course organizational contact:

Maggie Sullivan (sullmag@mit.edu).  
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## **Summer School Lecturer/Guest Lecturer Legend**

(in alphabetical order of last name)

GB - Gang Bao (Georgia Tech/Emory University)  
JB - Joseph Bonventre (Harvard Medical School)  
AC - Arup Chakroborty (MIT)  
PD - Peter David (Institut Pasteur, Paris)  
PSD - Pat Doyle (MIT)  
JD - Jeffrey Drazen (Harvard Medical School/Editor, NE J. Medicine)  
JF - Jeffrey Fredberg (Harvard School of Public Health)  
AG - Alan Grodzinsky (MIT)  
WH - Wonmuk Hwang (Texas A&M)  
RK - Roger Kamm (MIT)  
ML - Matthew Lang (MIT)  
JL - Ju Li (Ohio State University)  
CTL - Chwee Tech Lim (National University of Singapore)  
LM - L. Mahadevan (Harvard-Engineering)  
PM - Paul Matsudaira (MIT, Biology/Whitehead Institute)  
NM - Narla Mohandas (New York Blood Center)  
TS - Taher Saif (University of Illinois, Urbana-Champaigne)  
GS-S - Geert Schmid-Schonbein (UC San Diego)  
MS - Michael Sheetz (Columbia University)  
PS - Peter So (MIT)  
SS - Subra Suresh (MIT)  
KT - Kevin Tan (National University of Singapore)

### **Laboratory/Case Study Lecturers/Instructors:**

Ming Dao (MD), Scott Manalis (SM), Krystyn Van Vliet (KvV),  
Rhonda O'keefe (RO), Monica Diez Silva (MDS), Mohammad Mofrad  
(MM), Jorge Ferrer (JF1), John Higgins (JH), John Mills (JM), Alisha  
Sieminski (AS)

# CELL AND MOLECULAR MECHANICS IN BIOMEDICINE with a focus on infectious diseases

## Day 1 – Monday, August 7th

**8:30 AM – 12:00 noon (with a 15-minute coffee break)**

**Welcome and Introduction to GEM4**

(SS, RK)\*

*Parallel Tutorial Session #1: Basic mechanics*

Force, stress, strain, material properties, simple deformation  
(tension, torsion, bending, buckling) analysis

(LM)

Connection between mechanics, physiology and biology

(GS-S)

*Parallel Tutorial Session #2: Introduction to physiology*

(JB, JD)

**12:00 noon – 1:30 PM Lunch**

**1:30 PM – 5:00 PM**

*General Tutorial Session #1:*

Introduction to infectious diseases

(JD)

Using tuberculosis and malaria as examples

(GM, PD)

Inflammation

(GS-S)

Biosafety and laboratory preparedness

(RO)

**Evening mixer and social**

## Day 2 – Tuesday, August 8th

**8:30 AM – 12:00 noon (with a 15-minute coffee break)**

*Parallel Tutorial Session #3: Continuum and statistical mechanics*

(AG, LM, GS-S)

Brief introduction to the foundations of continuum and statistical mechanics; elastic  
and viscoelastic response; hydrodynamics

*Parallel Tutorial Session #4: Introduction to cell biology*

(PM, MS, NM, KT)

Basic cellular structure and functions; cell nucleus, membranes (including membrane  
microdomains); cytoskeleton, subcellular organelles; cell adhesion, cell-cell interaction, cell  
locomotion; cell metabolism, signal sensing and processing, cell cycle, etc.

**12:00 noon – 1:30 PM Lunch**

**1:30 PM – 5:00 PM (two sessions, each lasting 1.5 hours, repeated for two groups)**

*Parallel Tutorial Session #5: Introduction to the Immune System*

(PD, GM)

*Parallel Tutorial Session #6: Cell biology lab*

(AS, MD, RO)

Video show of cell structures, cell adhesion, cell growth and cell motion; laboratory  
demonstrations of cell culture; basics of light microscopy

## Day 3 – Wednesday, August 9th

**8:30 AM – 12:00 noon (with a 15-minute coffee break)**

*Parallel Tutorial Session #7: Molecular mechanics*

(WH, LM, JL)

Basic laws of thermodynamics, energy, entropy, ensembles; molecular dynamics, diffusion,  
persistence length, etc.

*Parallel Tutorial Session #8: Introduction to molecular biology*

(MS, PM)

Basics of molecular genetics; DNA, RNA and protein structure and function; protein  
synthesis and secretion; lipids; signaling pathways; motor molecules;

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\* Bold entries denote Session Chairs.

etc.

**12:00 noon – 1:30 PM Lunch**

**1:30 PM – 5:00 PM**

*General Tutorial Session #2: Importance of mechanics in human disease*  
Review of all lecture material to this point. Open questions and discussion

(LM, PM, MS, GM, PD, WH, JL)

**Day 4 – Thursday, August 10th**

**8:30 AM – 12:00 noon (with a 15-minute coffee break)**

*General Tutorial Session #3: Experimental methods*

Mechanical response of single cells and populations of cells – micropipette aspiration, mechanical plate stretcher, optical stretcher, optical tweezers, AFM, magnetic tweezers, laminar shear flow methods, two-photon microscopy, substrate stretching experiments, MEMS-based tools, molecular force probes, cell adhesion and attachment, effect of loading rate

Pushing and pulling on molecules

In vivo mechanical assays of tissues, cells and molecules

(RK, MS, ML, PS, TS, CTL)

**12:00 noon – 1:30 PM Lunch**

**1:30 PM – 5:00 PM (two sessions, each lasting 3.5 hours, offered both Thursday and Friday)**

*Demonstration laboratory on mechanical measurement:*

Demonstration of simple mechanical testing of biological specimens; Atomic Force Microscope testing of cells; mechanical force probe; high force optical trapping; micropipette aspiration; magnetic tweezers; 2-photon microscopy and other imaging methods.

*Hands-on laboratory.* Experiments with multiple AFM and optical trap systems.

(KvV, CTL, TS, RO, PS)

(ML, Scott Manalis)

**Day 5 – Friday, August 11th**

**8:30 AM – 12:00 noon (with a 15-minute coffee break)**

*General Tutorial Session #5: Space, time and energy landscapes mechanobiology*

Length and time-scales in biology and force ranges encountered for tissues, cells and molecules

Molecules of interest: DNA, RNA, proteins, peptides, lipids

Molecular forces: charges, dipole, van der Waals, hydrogen bonding

kT as ruler of molecular forces

Thermal forces and Brownian motion

Reaction kinetics - rate processes, binding affinity, binding energy

(RK, JL, WH, MS, PSD)

**12:00 noon – 1:30 PM Lunch**

**1:30 PM – 5:00 PM**

*Demonstration laboratory on mechanical measurement:*

Demonstration of simple mechanical testing of biological specimens; Atomic Force Microscope testing of cells; mechanical force probe; high force optical trapping; micropipette aspiration; magnetic tweezers; 2-photon microscopy and other imaging methods.

*Hands-on laboratory.* Experiments with multiple AFM and optical trap systems.

(Instructors same as for Day 4 afternoon)

**Reception and dinner**

**August 12th-13th**

Review problems, and simple homework assignment during weekend

Trainees prepare posters to illustrate their own related work, pose research questions

**Day 6 – Monday, August 14th**

**8:30 AM – 12:00 noon (with a 15-minute coffee break)**

*Session on Connective Tissue Mechanics*

Elastic and viscoelastic response of connective tissues  
Review of basic mechanics  
Poroelectricity; Darcy's Law; Hydraulic Permeability  
Tissue Mechanics and Case Studies in Human Health:  
Arthritis and joint regeneration  
Atherosclerosis  
Tendon, ligament, cartilage, bone

(AG, GB, JF, RK)

**12:00 noon – 1:30 PM Lunch**

**1:30 PM – 5:00 PM**

General discussion of the dynamics of infectious diseases  
Beyond single organism, discuss infection mechanisms and  
epidemiology/population dynamics

(PD, KT, GM)

**Day 7 – Tuesday, August 15th**

**8:30 AM – 12:00 noon (with a 15-minute coffee break)**

*Session on Cell Biomechanics*

Cell membrane mechanics  
Cytoskeleton structure and mechanics – actin, keratin, tubulins and  
properties of filament networks  
Time-dependent response of cell deformation; cytoskeletal dynamics  
Cell adhesion and aggregation - Receptor-ligand interactions; focal adhesions  
Measurements of cell adhesion forces and kinetics  
Cell motility

(JF, RK, SS)

**12:00 noon – 2:00 PM Lunch and poster set up**

**2:00 PM – 4:00 PM**

*Case studies on inflammation and mechanotransduction*

Mechanotransduction  
Malaria  
Asthma  
T-cells and immunology  
Prion disease

(PD)  
(RK)  
(PD, GM, SS)  
(JF)  
(AC)

**4:00 PM – 7:00 PM** (Food and drink will be provided)

*Poster session:* Each trainee presents a poster and instructors/other trainees will  
discuss

**Day 8 – Wednesday, August 16th**

**8:30 AM – 12:00 noon (with a 15-minute coffee break)**

*General Session on Molecular Biomechanics*

Polymer chains, statistics of random walks, persistence length, Boltzmann distribution,  
freely jointed chain, worm-like chain model  
Protein conformational dynamics, the role of force in protein-protein interactions  
Motility at the macromolecular level  
Polymerization forces  
Motor molecules and protein nanomachines

(GB, WH, JL)

**12:00 noon – 1:30 PM Lunch**

**1:30 PM – 5:00 PM**

*Applications and Case Studies*

Case studies on molecular biomechanics and its linkage to infectious diseases  
Molecular biomechanics issues in viral replication and viral packaging  
Molecular pathways in infectious diseases  
Molecular aspects in therapeutics and vaccine design

(GM, PD, PM, SS)

## **Day 9 – Thursday, August 17th**

**8:30 AM – 12:00 noon (with a 15-minute coffee break)**

*Session on Computational Biomechanics*

(SS, MD, WH, JL, MM)

Continuum computational simulations of cells

Continuum computational simulations of cell motility

Molecular level simulations of proteins and subcellular structures

Computations of protein folding and unfolding

Multi-scale simulation and modeling in mechanobiology

**12:00 noon – 1:30 PM Lunch**

**1:30 PM – 5:00 PM**

**Computational case studies**

(JL, WH, RK, SS, MM)

Cell mechanics,

Molecular mechanics

Tissue mechanics

## **Day 10 – Friday, August 18th**

**8:30 AM – 12:00 noon (with a 15-minute coffee break)**

**Summary session**

(All)

8:30 – 11:00 Trainee presentation – 15 min per group

11:00 – 12:00 noon Summary and discussion

**12:00 noon – 2:00 PM Lunch**

**2:00 PM Summer school adjourns**