Interdisciplinary Training in Mechanobiology from nm to cm
Coursework and discussion group options: 2018

Coursework taken by trainees to satisfy requirements of the PhD programs will provide depth in either basic biological science or applied physics/engineering. The proposed MBnc training program adds breadth across disciplines and length scales (Figure 6). The following framework will apply to all trainees:

- **Core courses in the trainee’s curriculum** (ME, BME, Physics, or DBBS program)
- **One basic “cross-disciplinary” course**: MEMS 5566 Engineering Mechanobiology. Trainees with suitable background may petition to substitute a fundamental course in mechanics or biology, whichever is NOT the focus of the trainee’s core curriculum.
- **One second “cross-disciplinary” course** (may be taken pass/fail)
- **Journal clubs and discussion groups**
  - One core journal club / discussion group: 1 unit per semester for at least 3 semesters
  - One secondary journal club / discussion group: 1 unit per semester for at least 1 semester
- **Electives**

The first “cross-disciplinary” course for all trainees will be the new course developed by the CEMB MEMS 5566 Engineering Mechanobiology. For **engineering/physics students**, alternative or second courses could be BME 530A Molecular Cell Biology for Engineers or BIO 5357 Chemistry and Physics of Biological Molecules. Core curriculum courses for engineering/physics trainees would be MEMS 5501 Continuum Mechanics, BME 559 Intermediate Biomechanics, MEMS 5510 Finite Element Analysis. For **biology or DBBS students**, alternative or second cross-disciplinary courses could be BME 240 Biomechanics, Physics 411 Mechanics, PHY 563 Biophysics or BME 559 Intermediate Biomechanics. If the trainee has taken such a cross-disciplinary course as an undergraduate, the second course would not be required. For instance, often an incoming biophysics or bioengineering student will have taken a mechanics course like PHY 411 Mechanics or BME 240 Biomechanics and a molecular biology course like BIO 5088 Molecular Cell Biology.

Many elective courses that cover aspects of mechanics in biology are available at WU, reflecting the large and diverse group of faculty with interests in this area. Courses include offerings from other members of the CEMB consortium (U. Penn, e.g.). A partial list of courses and brief descriptions is below (blue font = new):

**BME 240: Biomechanics** - Principles of static equilibrium and solid mechanics applied to the human anatomy and a variety of biological problems (Shao)

**BME 559: Intermediate Biomechanics** - The theories of nonlinear elasticity, viscoelasticity, and poroelasticity are applied to a large range of biological tissues including bone, articular cartilage, blood vessels, the heart, skeletal muscle, and red blood cells (Shao)

**BME 530A: Molecular cell biology for engineers** - This course covers the biology of cells of higher organisms: protein
structure and function; cellular membranes and organelles; cell growth and oncogenic transformation; cellular transport, receptors and cell signaling; the cytoskeleton, the extracellular matrix, and cell movement

**BME 557: Cellular and Subcellular Biomechanics** - An advanced course intended to cover the applications of mechanics to biological problems at cellular and subcellular levels (Shao)

**BME 563 / MEMS 5630: Orthopaedic Biomechanics Bone** - Basic and advanced solid mechanics applied to the musculoskeletal system, with a primary focus on bone and joint mechanics.

**BME 564 / MEMS 5564: Orthopaedic Biomechanics Cartilage/Tendon** - The biomechanics of orthopaedic soft tissues such as cartilage, tendon, ligament, meniscus. (Lake)

**BME 565 Biosolid Mechanics**: Introduction to the mechanical behaviors of biological tissues of musculoskeletal, cardiac and vascular systems. (Setton)

**BME 568 / MEMS 5562: Cardiovascular Mechanics** - Basic cardiovascular anatomy and physiology, flow in heart chambers, valves, and coronary arteries, peristaltic flow in the embryonic heart, steady and unsteady flow in tubes, wave propagation in blood vessels, flow in collapsible tubes, and microcirculation (Wagenseil)

**MEMS 5501: Continuum mechanics** - A broad survey of the general principles governing the mechanics of continuous media (Pathak)

**MEMS 5510: Finite Element Analysis** - Theory and application of the finite element method. (MEMS faculty)

**MEMS 5560: Interfaces and Attachments in Natural and Engineered Structures** - This course bridges the physiologic, surgical, and engineering approaches to connecting dissimilar materials. (Genin)

**MEMS 5561 Mechanics of Cell Motility**: A detailed review of biomechanical inputs that drive cell motility in diverse extracellular matrices (ECMs). (Pathak)

**MEMS 5565 Mechanobiology of Cells and Matrices**: Cytoskeletal force-generation machinery, mechanical roles of cell-cell and cell-matrix adhesions, and regulation of matrix deformations are discussed. (Pathak)

**MEMS 5566 Engineering Mechanobiology**: Mechanical force is involved in all biological systems, during morphogenesis, cell migration, polarization, proliferation, and single molecule behavior. This course provides a foundation to understand these factors. Prerequisites: undergraduate calculus and physics (Genin)

**MEMS 5606: Soft Nanomaterials** – This course intends to introduce the fundamental aspects of nanotechnology pertained to soft matter. Topics include responsive polymers structures (films, capsules), polymer nanocomposites, biomolecules as nanomaterials and soft lithography. (Singamaneni)

**PHY 411: Mechanics** – Motions of a particle and systems of particles; oscillations; gravitational and central forces. (Physics faculty)

**PHY 509: Nonlinear Dynamics** - The theoretical foundations of nonlinear dynamics, and its applications to phenomena in diverse fields including physics, biology, and chemistry. (Carlsson)

**PHY 563: Topics in Theoretical Biophysics** - Application of physical theory to a broad range of biological problems. (Carlsson)

**BIO 5068: Fundamentals of Molecular Cell Biology** - Research and experimental strategies to dissect molecular mechanisms that underlie cell structure and function, including protein biochemistry
BIO 5357: Chemistry and Physics of Biological Molecules - This course covers three major types of biomolecular structure: proteins, nucleic acids and membranes. Basic structural chemistry is presented, as well as biophysical techniques used to probe each type of structure.

BIO 5312: Macromolecular Interactions - This course will cover equilibria, kinetics and mechanisms of macromolecular interactions from a quantitative perspective. (Lohman, Galburt, Greenberg)

BIO 4071: Developmental Biology - Analysis of a selected set of key processes in development, such as pattern formation, cell-cell signaling, morphogenesis. (Kornfeld)