CELLULAR AND TISSULAR MECHANOBIOLOGY

Learning outcomes

After successful completion of the course, students are able to understand the mechanics of different cellular processes ranging from cell division to cell differentiation and death and to propose mechanical models for a number of applications related to human physiology and disease, from cells to tissues.

Contents

1. General presentation of cells: history of cell concept in biology, functional biology, roles of the cell (exchanges, genetics, "ordered" organ constitution), cell composition, main types of cellular structures...

2-3. Cellular biomechanics, experimental aspects: means of imaging and observation (confocal microscopy, AFM microscopy), mechanical test means (indentation, tensile tests, rotational magnetocymetry, microplate testing). Interest in the characterization of cell adhesion.

4-5. Cellular biomechanics, modelling aspects: viscoelasticity, active behaviour, mechanotransduction. Models of cellular structure: membrane models, tensegrity models...

6-7. Growth and remodeling in soft tissues: Important experimental and clinical observations, including tensional homeostasis, pathologies (aneurysms, tortuosity, etc.), and observations from comparative biology and animal models;

8. Micromechanical and molecular foundations of mechanobiology (mechanotransduction, signaling, etc.)

9-11. Major mathematical approaches to model growth and remodeling in soft tissues, including the kinematic growth theory, constrained mixture models, hybrid approaches, open system thermodynamics, and computational implementations;

12-13. Numerical implementation of growth and remodelling, application to the growth of aneurysms in arteries, tutorials in FEBio

14-15. Thermodynamics of the cell. Exchange of ionic and organic species. Laws of diffusion (Fick's law) and thermodynamics. Diffusion through the cell wall, membrane exchanges. Influence of osmotic pressure. Action of physiological saline.

Teaching methods

Direct teaching and tutorials to introduce and practice theoretical aspects

Reading and commenting scientific papers

Introduction to using a finite-element software dedicated to mechanobiology of soft-tissues

Examination modalities

Creation of a software application

Mode of examination

written

Previous knowledge

Mathematics: linear algebra, matrices

Continuum solid mechanics: stress, strains, linear elasticity, equilibrium equations

Basics of fluid mechanics: navier-stokes equations

Basic background in biology