42441
Cardiovascular Biomechanics
MW 09:00AM to 10:20PM Doherty Hall 1117

Instructor: Kerem Pekkan

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office hours:	FR 9:15a-10:30a

Text Used:

Thubrikar MJ, *Vascular Mechanics and Pathology*, 2007, Springer-Verlag

In addition each module has its own reading material which is compiled from multiple sources (including one current selected journal paper per lecture). These will be assigned from the blackboard course website.

Other related text books
Humphrey JD. *Cardiovascular Solid Mechanics: Cells, Tissues, and Organs*, 2002, Springer-Verlag
K B. Chandran, A P. Yoganathan, *Biofluid Mechanics: The Human Circulation*, 2006, CRC Press
Holzapfel GA. *Nonlinear Solid Mechanics: A Continuum Approach for Engineering*, 2001 Wiley
Mofrad RKM, Kamm R. *Cytoskeletal Mechanics: Models and Measurements*, 2006, Cambridge

Prerequisites: Basic knowledge on engineering fluid, solid mechanics and introductory matlab programming is desirable. Please notify the instructor and he will supply supplementary reading on these areas.

Objectives:
The purpose of this course is to introduce students to cardiovascular mechanics. Complementing cardiovascular biology, this research field focuses on quantitative understanding of the mechanical phenomena that governs the cardiovascular system. Upon completing this course, the students should:

- understand the governing physics of solid and fluid mechanics as applied to the cardiovascular system
- be familiar with the current state of the art computational modeling tools, experimental *in vitro, in vivo* and multi-scale methodologies
- learn to conduct biomedical research on a clinical problem and apply engineering fundamentals to contribute its solution
- learn the fundamentals of interdisciplinary (clinician/engineer) work (collaboration/research)

The course covers normal cardiovascular system, diseases, and devices. A biomechanical engineering approach will be followed throughout the course; more applications from Cardiovascular Mechanics but fundamentals of Soft-Tissue Solid Mechanics, hemodynamics and cellular mechanics will be also reviewed.

Spring 2009: (tentative)

Lecture 1:	Why we study cardiovascular mechanics? Review of cardiovascular physiology – I (How the heart is built? - a developmental approach)
Lecture 2:	Review of cardiovascular physiology – II (Valves & Vessels) Introduction to Myocardial Mechanics - 1
Lecture 3:	Hands on lab study and demonstration; dissecting a porcine heart.
Lecture 4:	Introduction to Solid mechanics (incl. composite and multi-scale materials)
Lecture 5:	Basic concepts and Governing equations of fluid flow & Flow visualization techniques
Lecture 6:	Effects of fluid flow on biology (Assignment of literature review projects) Hydrostatics and steady flow models
Lecture 7:	A lumped parameter model of the cardiovascular system - 1
Lecture 8:	Developing the lumped parameter model of the cardiovascular system - 2
Lecture 9:	Arterial wall mechanics of wave reflections boundary conditions (embryonic heart example)
Lecture 10:	Quantitative heart function and energetic parameters (PV loops)
Lecture 11:	Review of cardiovascular physiology – IV (Modeling the coronary system) Extra curriculum: Art of medical illustration
Lecture 12:	Medical Image Modalities and 3D temporal surface data acquisition
Lecture 13:	Developing the lumped parameter model of the cardiovascular system - 3 (Distributing long projects on Lumped parameter code)
Lecture 14:	Cardiovascular Biology - 1
Lecture 15:	Cardiovascular Biology – 2
Lecture 13:	Modeling of cellular components (Myocytes, endothelium)
Lecture 14:	Unsteady flow and non-uniform geometries, compliant tubes, peristalting pumping
Lecture 15:	Intro to cardiovascular soft tissue mechanics - 1
Lecture 16:	Intro to cardiovascular soft tissue mechanics – 2 (Take-home exam)
Semester break	
Lecture 17:	Myocardial Mechanics – 2
Lecture 18:	**Invited guest lecture TBD, Dr. Doni Wulandala**
Lecture 19:	Diseases 1 (Atherosclerosis)
Lecture 20:	Diseases 2 (AAA)
Lecture 21:	Diseases 3 (congenital heart defects)
Lecture 22:	Heart Valve Mechanics (aortic valves)
Lecture 23:	Hands on lab study and demonstration; visualizing developing hearts in the chick embryo. Heart Valve Mechanics (AV valves)
Lecture 24:	Venous vascular mechanics
Lecture 25:	Devices 1 (Heart valves)

Lecture 26:	**Invited Lecture TBD (Growth models)**
Lecture 27:	Devices 2 (Stents, other devices, patient specific surgical planning.)
Lecture 28:	Control and cardiopulmonary interactions – 1
Lecture 29:	Control and cardiopulmonary interactions - 2
Lecture 30:	Comparative cardiovascular biomechanics and allometric relations
Lecture 31:	15 min literature research presentations and discussion. (Take-home exam)

Guest Lecturers: TBD

Grading:

Mid-term Exam: 20%
Final Exam: 20%
Weekly Homeworks: 20%
Long Lumped-Parameter modeling projects (2-3): 25%
Class presentations (including journal article reviews): 15%
Participation to the invited lecture discussion: 5%

Note: Graduate and undergraduate students will be graded separately.

Peer-reviewed journals of interest:

Journal of Biomechanics
Annals of Biomedical Engineering
ASME Journal of Biomechanical Engineering
ASAIO Journal
Artificial Organs, Tissue Engineering
Circulation
Circulation Research
IEEE Transactions, Annals of Thoracic Surgery, JTCVS

Annual conferences: (CD's available for check-out from Kerem Pekkan's office)

American Heart Association Scientific Sessions
ASME Summer Bioengineering Meeting
Biomedical Engineering Society (BMES) Meeting
EMBS Meeting
ASAIO Meetings
European Society of Bioengineering (ESB) Meeting

Movie: "Something the Lord Made" (DVD is available for check-out from Kerem Pekkan's office)

Web sites:

http://www.pubmed.org
http://www.hsls.pitt.edu/about/libraries/falk/
http://www.medicalarchives.jhmi.edu/tausbio.htm
http://math.nyu.edu/faculty/peskin/ModSimPrograms/ch1/ (Lumped parameter code)

Note: If you wish to request an accommodation due to a documented disability, please inform Dr. Kerem Pekkan and contact: Disability Resources, 102 Whitfield Hall 412.268.2013, lpowell@andrew.cmu.edu, as soon as possible. For ongoing documented classroom accommodations one week's notice is required. Accommodations for finals require three weeks' notice