UNIVERSITÀ DEGLI STUDI DI PALERMO

DEPARTMENT	Ingegneria
ACADEMIC YEAR	2021/2022
MASTER'S DEGREE (MSC)	BIOMEDICAL ENGINEERING
INTEGRATED COURSE	BIOMECHANICS OF BIOLOGICAL TISSUES - INTEGRATED COURSE
CODE	20272
MODULES	Yes
NUMBER OF MODULES	2
SCIENTIFIC SECTOR(S)	ICAR/01, ICAR/08
HEAD PROFESSOR(S)	ZINGALES MASSIMILIANO — Professore Ordinario — Univ. di PALERMO
OTHER PROFESSOR(S)	NAPOLI ENRICO — Professore Ordinario — Univ. di PALERMO ZINGALES MASSIMILIANO — Professore Ordinario — Univ. di PALERMO
CREDITS	12
PROPAEDEUTICAL SUBJECTS	
MUTUALIZATION	
YEAR	2
TERM (SEMESTER)	1° semester
ATTENDANCE	Not mandatory
EVALUATION	Out of 30
TEACHER OFFICE HOURS	**NAPOLI ENRICO** Thursday 12:00 13:30 Ufficio Enrico Napoli - Secondo piano Friday 12:00 13:30 Ufficio Enrico Napoli - Secondo piano **ZINGALES MASSIMILIANO** Tuesday 14:00 15:00 Dipartimento di Ingegneria Civile, Ambientale, Aerospaziale, dei Materiali-Sezione strutture- Viale delle Scienze, Edificio n.8, secondo piano.

DOCENTE: Prof. MASSIMILIANO ZINGALES

PREREQUISITES	The student has basic knowledge of calculus, linear algebra and he has some competences in solid and fluid mechanics
LEARNING OUTCOMES	Knowledge and understanding ability • The student at the completion of the course will have deeper knowledge and understating of tissue mechanics. In particular non-linear elasticity, hereditariness and poromechanics represents the basic knowledge acquired during the course in conjunction with the presence of the emetic tissue that flow inside the vessel. • Capacity to apply knowledge and understanding The student will be able to set the governing equations of tissue mechanics focusing on the specific feature to model. A specific care is to be placed in terms of the experimental evaluation of tissue parameters. Making judgments • The student will be motivated to critical thinking and self-evaluation about: - The limits applicability of the structural models commonly used to describe biological materials and structures; - Levels of accuracy and correlated degree of difficulty related to modeling biomaterials and structures. Communication skills • The student will acquire the ability to communicate and express issues about the topics of the course. He will be able to communicate about the mechanical charecterization of the specific tissue considered as well as about the most appropriate test to determine the mechanical behavior of the material. Learning skills • The student will learn the basics of the theory soil and fluid mechanics. This knowledge will contribute to the formation of wide background about the behavior of biological tissues as well as about the presence of multiphysics problems in the computational models of the tissues. These skills will provide the student with autonomy and capacity of decision about the specific tissue modeling that he may use in the computational simulation of the tissues as well as of the endoprosthesys interactions with the biological tissues.
ASSESSMENT METHODS	The assessment is achieved through a final colloquium , to certify that the main targets of the course have been gained by the student. The colloquium is a discussion to ascertain the student's knowledge of theoretical and applied topics discussed in lessons and exercise lectures. The exam score is awarded by a vote expressed in 30 over 30 To finalize the exam, that is considered positive with a score of 18/30, the student must demonstrate a basic achievement of the goals. Objectives that are considered basic as the student acquires fundamental knowledge of the topics described in the program, is able to operate with minimal links between them, shows that they have acquired a limited degree of autonomy; His language is enough to communicate with the examiners. To get a score of 30/30 and laude, the student must demonstrate an optimal knowledge of the goals. The achieved goals are optimum when examining has gained a full knowledge of the topics of the program, demonstrating how to apply acquired knowledge , also in different / new / advanced contexts, he also expresses vocabulary competence within the specific reference language and is able to elaborate and express independent judgements The final grade is achieved with the following skills: 30- 30 cum laude: Excellent knowledge of the topics, excellent communication skills excellent analytical skills i; 26-29: Very good knowledge of the topics, Very good communication skills, very good analytical skills. 20-25: Good knowledge of main topics, Good communication skills, Acceptable analytical skills 12-19: Sufficient knowledge of some topics, acceptable communication skill, not acceptable analytical skills 0-11: not acceptable knowledge of course topics, not acceptable communication skills, not acceptable analytical skills. The exam is not sufficient as the student does not provide acceptable knowledge of the main topics of the course. The kind of test and the evaluation are the same for any student attending and non-attending the course.
TEACHING METHODS	The course program is developed during lecture hours. The lectures are accompanied by some applications, in order to guide students to solve specific problems of continuum mechanics based on

	the basic knowledge that has been acquired in classrooms.

MODULE
NUMERICAL BIO-FLUID-DYNAMICS

Prof. ENRICO NAPOLI

SUGGESTED BIBLIOGRAPHY	
Biofluid Mechanics: The Human Circulation, Second Edition (Inglese), 2012, di Krishnan B. Chandran, Stanley E. Rittgers, Ajit P. Yoganathan. CRC Groups, Taylor and Francis. ISBN-10 : 1439845166 Fluid Mechanics (Sixth Edition). Chapter 16 - Introduction to Biofluid Mechanics, Portonovo S.Ayyaswamy. Academic Press. Fifth Edition, 2012. ISBN: 978-0-12-382100-3 Dispense a cura del docente.	
AMBIT	20909-Attivit Formative Affini o Integrative
INDIVIDUAL STUDY (Hrs)	96
COURSE ACTIVITY (Hrs)	54
EDUCATIONAL OBJECTIVES OF THE MODULE	
The course aims to provide students with advanced skills in the field of Mechanics of biofluids, with particular reference to numerical methods useful for the analysis of the most relevant phenomena affecting the cardiovascular system. In particular, the course intends to provide the skills necessary for the numerical modeling of blood flows in the cerebral arteries and in the four cardiac chambers and of the fluid-structure interactions within the arterial system.	

SYLLABUS

Hrs	Frontal teaching
8	Fundamentals of Fluid Mechanics of Incompressible Flows
4	Cardiovascular Physiology
4	Rheology of Blood and Vascular Mechanics
4	Cardiac valves and interactions with blood flow
12	Numerical methods for blood flows in the circulatory system
4	Fluid-structure interactions

Hrs	Practice
6	Numerical simulation of the blood flow in cerebral aneurysm
6	Numerical simulation of the blood flow in an arterial bifurcation
6	Numerical simulation of the fluid-structure interaction in the arterial system

MODULE **TISSUE BIOMECHANICS** *Prof. MASSIMILIANO ZINGALES*
SUGGESTED BIBLIOGRAPHY
Cowin, S C., Doty, S B., "Tissue Mechanics", Springer, 2001, ISBN 978-0-387-36825-2 Holzapfel G.A. Ogden R., "Mechanics of Biological Tissues", Springer, 2006, ISBN 978-3-540-25194-1 Y.C. Fung "Biomechanics:II", 1991, ISBN 978-0-387-97947-2 Martin B. R., Burr D. B., Sharkey N. A., Fyhrie D. P., "Skeletal Tissue Mechanics",2015, ISBN 978-1-4939-3001-2

AMBIT	20909-Attivit Formative Affini o Integrative
INDIVIDUAL STUDY (Hrs)	96
COURSE ACTIVITY (Hrs)	54

EDUCATIONAL OBJECTIVES OF THE MODULE
The course aim to provide the main formulations to study biological tissues in terms of their mechanical behavior. In more detail the fundamentals of linear and non-linear theory of elasticity, viscoelasticity, poroelasticity will be provided with applications to skeletal system as well as to cardiovascular circulation.

SYLLABUS

Hrs	Frontal teaching
5	Fundamentals of solid mechanics: Material and spatial configurations, strain measures, polar decomposition, left-right Cauchy green tensor, principal strain and stretch, Green-Lagrange strain measure. The linearized strain theory.
3	Fundamental of solid mechanics: Cauchy stress tensor, Principal stress, Nanson Formula, First Piola-Kirchhoff tensor, Second Piola-Kirchhoff tensor. Principle of virtual power.
3	The linear elasticity of biological tissue: The mechanical behavior of compact bone, isotropy, transverse isotropy, ortotropy, anisotropy.
10	Non-linear elasticity of biological tissues: Free energy, Internal energy, isotropy, transverse isotropy, the mechanics of tendons , ligaments, arterial vessels, cardiac valves.
11	Linear hereditariness of Materials, Boltzmann-Volterra integrals, Loss and Storage moduli, Rheological Models, Differintegral operators, The multiaxial constitutive equations of linear hereditariness. Mechanics of cancellous bones.
10	Non-linear material hereditariness, Nutting relations, Creep and Relaxations of materials, Quasi-linear hereditariness, The mechanics of blood vessels, tendons and ligaments.
10	Diffusion in biological systems, Fick relation, Theory of Poroelasticity, Principle of efficace stress, constitutive equations of poroelasticity, Navier governing equations.
2	Anomalous diffusion, Fick' relations, Fractional-order poromechanics, Mittag-Leffler functions, Parameter estimations in an 1D diffusion problem for meniscal tissue