UNIVERSITÀ DI PISA

# BIOELECTRIC PHENOMENA

## ALESSANDRO TOGNETTI

| | |
|---|---|
| Anno accademico | 2023/24 |
| CdS | BIOMEDICAL ENGINEERING |
| Codice | 480II |
| CFU | 12 |

| Moduli | Settore/i | Tipo | Ore | Docente/i |
|---|---|---|---|---|
| FENOMENI BIOELETTRICI I | ING-INF/06 | LEZIONI | 60 | ALESSANDRO TOGNETTI |
| FENOMENI BIOELETTRICI II | ING-INF/06 | LEZIONI | 60 | ALESSANDRO TOGNETTI |

### Learning outcomes

*Knowledge*
Quantitative approach to Bioelectricity. Accurate study of membrane phenomena in excitable tissues, mechanisms of generation / propagation of action potentials. Finally, diagnostic and therapeutic techniques based on the use and analysis of bioelectrical signals are modeled in relation to the electrophysiology of excitable tissues.

*Assessment criteria of knowledge*
The knowledge will be assessed through the oral exam, in which the student will have to demonstrate an in-depth familiarity with the main concepts of the course and capacity to analyze both theoretical and applicative problems.

*Skills*
The student will be able to formulate accurate dissertations on the bioelectrical phenomena through simplified mathematical models and the solution of analytical equation and, if needed, through numerical codes available in Matlab.

*Assessment criteria of skills*
During lectures and the final exam, the student is asked to solve exercises and to answer questions that exploit the acquired skills.

*Behaviors*
The student will be able to model the main bioelectrical sources, to solve the direct (elecrical potential generated by the bioelecric source) and inverse (to infer the bioelectric source from the mesured bioelectric signals) problems with application to monitoring (ECG, EMG) and stimulation (FES, pacing, defibrillation) cases.

*Assessment criteria of behaviors*
The behaviors will be verified in the oral discussion during the exam.

### Prerequisites
Basic knowledge of mathematics, chemistry, calculus, physics (in particular thermodynamics and electrostatics)

### Syllabus
**BIOELECTRIC PHENOMENA 1**
Introduction to bioelectric phenomena: electrically excitable tissues, direct problem, inverse problem.
Vector analysis (gradient, divergence, Laplacian, and their application); Laplace and Poisson equations.
Elementary bioelectric sources and associated potentials (monopole and dipole of current).
Modeling of the neuron's action potential (resting membrane cell model, Hodgkin and Huxley model).
Propagation of the action potential.
Electrical stimulation of nervous tissue (FES - Functional Electrical Stimulation).
Phenomenological models of the action potential (Simplifications of the Hodgkin and Huxley model, dynamic systems).
**BIOELECTRIC PHENOMENA 2**
Introduction to bioelectric phenomena associated with cardiac activity.
Model of ECG generation based on current source density and dipole density.

Cardiac bidomain and boundary conditions (coupled, uncoupled, and isolated bidomain with monodomain reduction).
Vector leads method and Einthoven's triangle.
Applications: Principles of ECG diagnosis and cardiac pacing.
Modeling of the cardiac action potential using biophysical and phenomenological models.
Propagation of the cardiac action potential and calculation of extracellular potentials (pseudo-ECG).
Introduction to modeling the electrical activity of the muscle.
Fuglevand model (models of: single fiber, motor unit using the method of isopotential layers, whole muscle), Twitch force model.

## Bibliography

Book: Barr, Roger C; Plonsey, Robert, Bioelectricity: a quantitative approach, Springer 2007
At the end of each lesson the teacher shares the contents projected on the blackboard via pdf files (available on Teams).
Matlab files associated to practical exercises are avaiulable on Teams.

## Non-attending students info

There are no variation for the non-attending students.

## Assessment methods

The exam is made of two tests, the first one (in itinere on the first part of the course) and the last on (on the second part of the course). The final mark is the average values of the two tests. A pre-oral questionnaire will be administered in which the student will have to solve some theoretical / practical problems.
**Optional project work** only for the **second part of the exam** (the project work substitutes the pre-oral questionnaire)
The exam aims at:

1. assessing the comprehension and the presentation skills in relation to the course contents
2. verifing, through specific calculation, the capacity to analyze quantitative contents and to verify the correctness of results.
3. evaluating the capacity of solving problems that needs the integration of different program sections

*Updated: 01/08/2023 17:52*