**DESCRIPTION/Syllabi of Curricula/Module**

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| **Short Name of the University/Country code Date (Month / Year)** | **HIT**  **Jan 2019** |
| **TITLE OF THE MODULE** | **Code** |
| Introduction to Neural Implants |  |

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| **Teacher(s)** | **Department** |
| **Coordinating:** Ronen Sosnik, PhD  **Others:** | Electrical and Electronics Engineering |

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| **Study cycle**  **(BA/MA)** | **Level of the module**  **(Semester number)** | **Type of the module**  **(compulsary/elective)** |
| Bachelor/Masters | 7th/8th semester (fourth year) for Bachleor, or any semester for Masters | Elective |

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| **Form of delivery**  **(theory/lab/exercises)** | **Duration**  **(weeks/months)** | **Language(s)** |
| Lectures, Seminary | 15 weeks | English |

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| **Prerequisites** | |
| **Prerequisites:**  Knowledge: Basic knowledge of physics (electromagnetic fields), chemistry, biology, digital signal processing (DSP), linear electronic circuits (operational amplifiers, analog filters)  Skills: none  Competences: none | **Co-requisites (if necessary):**  none |

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| **ECTS  (Credits of the module)** | **Total student workload hours** | | **Contact hours** | | **Individual work hours** |
| 6 | 90 | | 30 | | 60 |
| **Aim of the module (course unit): competences foreseen by the study programme** | | | | | |
| Students should be able to:  - Understand the different models and mechanisms underlying the formation of a resting and action potential  - Analyze the characteristics of different muscle fibers types and the various electric stimulation protocols that are used to reduce muscle fatigue  - Formulate the advantage and disadvantages of each of the common recording configurations in the PNS and the tissue response to electrode stimulation  - Differentiate different electrode materials with regards to their electrochemical properties and use in various neuro implants | | | | | |
| **Learning outcomes of module (course unit)** | | **Teaching/learning methods**  **(theory, lab, exercises)** | | **Assessment methods**  **(written exam, oral exam, reports)** | |
| **Knowledge:**  Familiarize the student with the fundamentals of Neurobiology, in general, and neural models, in general, and serves as a key for understanding the basics in neural implants. In addition, several aspects of neural recording and stimulation techniques will be discussed | | Work with the lecture notes as well as on the available fundamental subject literature | | Knowledge test | |
| **Skills:**  Ability to choose appropriate electrode material and recording / stimulation configuration and protocol with regards to the type of signal recorded, the tissue invasiveness, required spatial and temporal resolution and safety regulations | | Lectures, project, consultation | | Active attendance on lectures, individual/group project and presentation | |
| **Competences:**  Study the subject literature, exchange knowledge, working in group | | Lectures, project, consultation | | Individual/group project and presentation | |

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| **Themes** | **Contact work hours** | | | | | | | **Time and tasks for individual work** | |
| Lectures | Consultations | Seminars | Practiacl work | Laboratory work | Placements | **Total contact work** | **Individual work** | **Tasks** |
| 1. The Neuron – Structure and Function of the Cell Membrane | 4 |  |  |  |  |  | 4 | 8 | Understanding membrane resting and active potential – the Hodgkin-Huxley model. Get acquainted with models of dynamic ion concentration equilibrium in neurons - Nernst equation, Donnan equilibrium and Goldman-Hodgkin-Katz equation. Activation, inactivation and deactivation of sodium and potassium ionic channels. The absolute and relative refractory period |
| 2. Neural Recording and Stimulation - Introduction to Basic Electrophysiology | 4 |  |  |  |  |  | 4 | 8 | Study passive models of cell and axon membrane. Understand the model of signal suppression throughout the axon – the standard cable theory and the tole of the Node of Ranvier as a voltage source. Understand the dependency of current threshold and charge threshold on cell geometry, cell distance from the stimulating electrode and the stimulation protocol |
| 3. The Muscle – Anatomy, Physiology and Electromechanical Coupling | 4 |  |  |  |  |  | 4 | 4 | Study different muscle types (red, white) and their characteristics (anatomy, force, fatigue, metabolism). Study muscle innervations characteristics (amplitude, frequency and stimulation time) and their uses. Study adaptivity and transformation of muscle fibers for patients with Myocardial infarction |
| 4. Recording Configurations in the Peripheral Nervous System | 4 |  |  |  |  |  | 4 | 8 | Study recording extracellular potential in homogeneous medium – dependence of recorded amplitude and bandwidth on fiber diameter and recording distance. Study monopolar, bipolar and tripolar recording – advantages, disadvantages and applications. Compare the performance of different electrodes and ways to increase signal-to-noise ratio (SNR). Understand technical considerations for choosing a cuff electrode |
| 5. Recording and Stimulating Electrodes – Reactions, Mechanisms and Materials | 4 |  |  |  |  |  | 4 | 8 | Study Helmholtz double layer, capacitive mechanism and Faraday mechanism. Stusy reversible and irreversible Faraday reactions and linear and cyclic voltammetry. Study reversible charge injection limit, maximal charge storage capacity and maximal charge injection capacity. Stusy polarizable and non-polarizable ideal/real electrode. Study electrode materials (Silicon, noble metals, Iridium Oxide, Tungsten) – advantages, disadvantages and implications. Study electrical analysis of the potentiostat circuit |
| 6. Tissue Response to Electrode Stimulation: Effectivity and Safety | 4 |  |  |  |  |  | 4 | 4 | The therapeutic window – lower threshold, chronic upper threshold and acute upper threshold. Acute damage to neurons and axons – causes and cellular mechanism. Non-acute damage (desensitization) to neurons and axons – causes and cellular mechanism. Means for decreasing the risk of acute and / or desensitization |
| 7. Seminars on each of the six themes (1 to 6) |  |  | 6 |  |  |  | 6 | 20 | Study advanced topics in:   * muscle innervation and transformation * Use of novel biomaterials and electrodes for functional electrical stimulation (FES) * Development of new recording and stimulation systems |
| **Total** | 24 |  | 6 |  |  |  | 30 | 60 |  |

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| **Assessment strategy** | **Weight in %** | **Deadlines** | **Assessment criteria** |
| Individual or group final project referred during seminars | 20 | 3th - 14th week | Project |
| Final exam | 80 |  | Test |

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| **Author** | **Year of issue** | **Title** | **No of periodical or volume** | **Place of printing. Printing house or internet link** |
| **Compulsory literature** | | | | |
| Kenneth WH, Gurpreet SD | 2015 | Neuroprosthetics: Theory and Practice |  | University of Utah, USA |
| Eric R. Kandel (Editor), James H. Schwartz (Editor), Thomas M. Jessell (Editor), Steven A. Siegelbaum (Editor), A. J. Hudspeth (Editor | 2019 | Principles of Neural Science, fifth edition |  | <https://www.amazon.com/Principles-Neural-Science-Fifth-Kandel/dp/0071390111> |
| **Additional literature** | | | | |
| Warren E Finn, Peter G LoPresti | 2002 | Handbook of Neuroprosthetic Methods |  | Oklahoma State University, Tulsa, Oklahoma, USA |