COURSE OUTLINE

(1) GENERAL

SCHOOL			
ACADEMIC UNIT	**Interdisciplinary Graduate Programme in the BRAIN and MIND sciences**		
LEVEL OF STUDIES	7		
COURSE CODE	**B&M-103**	**SEMESTER**	**Spring**
COURSE TITLE	Introduction to Computational Neuroscience		

INDEPENDENT TEACHING ACTIVITIES *if credits are awarded for separate components of the course, e.g. lectures, laboratory exercises, etc. If the credits are awarded for the whole of the course, give the weekly teaching hours and the total credits*	**WEEKLY TEACHING HOURS**	**CREDITS**
lectures	6	6
Add rows if necessary. The organisation of teaching and the teaching methods used are described in detail at (d).		

COURSE TYPE *general background, special background, specialised general knowledge, skills development*	General Background
PREREQUISITE COURSES:	N/A
LANGUAGE OF INSTRUCTION and EXAMINATIONS:	English
IS THE COURSE OFFERED TO ERASMUS STUDENTS	YES
COURSE WEBSITE (URL)	

(2) LEARNING OUTCOMES

Learning outcomes

The course learning outcomes, specific knowledge, skills and competences of an appropriate level, which the students will acquire with the successful completion of the course are described.

Consult Appendix A

- *Description of the level of learning outcomes for each qualifications cycle, according to the Qualifications Framework of the European Higher Education Area*
- *Descriptors for Levels 6, 7 & 8 of the European Qualifications Framework for Lifelong Learning and Appendix B*
- *Guidelines for writing Learning Outcomes*

Understanding the relationship between the brain, learning, memory, and behavior is one of the greatest challenges in neuroscience. The aim of this course is to introduce students to the fundamental principles of computational neuroscience, a scientific field that has seen significant growth in recent years. This area serves as a bridge between the neurophysiology and anatomy of the central nervous system from the perspective of experimental sciences and the modeling methods, machine learning, and data analysis from the perspective of mathematics and computer science.

The goal of the computational neuroscience course is to introduce students to the study of complex neural circuits that drive cognitive activity: perception, planned action, and thought. Understanding how these networks produce the cognitive functions of the brain is one of the ultimate challenges of neuroscience.

Specifically, after successfully completing the course, students will gain specialized knowledge in:

- The basic concepts of scientific programming, linear algebra, differential equations, probabilities, and statistics.

- The different types of Machine Learning (supervised, unsupervised, reinforcement learning) and how they are used for analyzing experimental data.
- Modeling simple, phenomenological, as well as complex biophysical neural models and integrating them into neural networks.
- The mathematical methods for training a neural network.
- Synaptic plasticity and how it is utilized in neural networks to understand and explain phenomena during learning and memory formation.

After successfully completing the course, students will be able to:

- Demonstrate a comprehensive understanding of the knowledge that constitutes the subject matter of the unit.
- Understand the basic theories, concepts, and principles governing computational neuroscience.
- Reproduce the knowledge they have acquired and convey it clearly and unambiguously to both specialized and general audiences.

General Competences

Taking into consideration the general competences that the degree-holder must acquire (as these appear in the Diploma Supplement and appear below), at which of the following does the course aim?

Search for, analysis and synthesis of data and information, with the use of the necessary technology	*Project planning and management*
Adapting to new situations	*Respect for difference and multiculturalism*
Decision-making	*Respect for the natural environment*
Working independently	*Showing social, professional and ethical responsibility and sensitivity to gender issues*
Team work	*Criticism and self-criticism*
Working in an international environment	*Production of free, creative and inductive thinking*
Working in an interdisciplinary environment	*……*
Production of new research ideas	*Others…*
	…….

- Search for, analysis and synthesis of data and information, with the use of the necessary technology
- Working independently
- Teamwork.
- Working in an interdisciplinary environment.
- Production of new research ideas
- Criticism and self-criticism
- Production of free, creative and inductive thinking
- Applying knowledge in practice.

(3) SYLLABUS

- An overview and introduction to the course
- Basic principles of scientific programming with Python (+Tutorial)
- Basic Mathematics (+Tutorial)
    - Basic principles of linear algebra
    - Differential equations
    - Probability and Statistics
    - Examples of using Python to solve relevant problems
- Principal Component Analysis (PCA)
- Spike Statistics and Information Theory
- Introduction to Artificial Neural Networks
    - Perceptron, Rate-based models
    - Feedforward and Recurrent neural nets
- Supervised and Unsupervised learning
    - Gradient-descent
    - Hebbian-like rule(s)

- Introduction to reinforcement learning
  - Model-based
  - Model-free.
- Spiking neuronal models
  - Biophysical neurons
  - Integrate-and-Fire neurons

(4) TEACHING and LEARNING METHODS - EVALUATION

DELIVERY *Face-to-face, Distance learning, etc.*	Face-to-face
USE OF INFORMATION AND COMMUNICATIONS TECHNOLOGY *Use of ICT in teaching, laboratory education, communication with students*	Use of slides/videos from the computer for teaching. Use of an online platform for posting lectures and exercises. Communication through the course website and email.
TEACHING METHODS *The manner and methods of teaching are described in detail.* *Lectures, seminars, laboratory practice, fieldwork, study and analysis of bibliography, tutorials, placements, clinical practice, art workshop, interactive teaching, educational visits, project, essay writing, artistic creativity, etc.* *The student's study hours for each learning activity are given as well as the hours of non-directed study according to the principles of the ECTS*	see table below
STUDENT PERFORMANCE EVALUATION *Description of the evaluation procedure* *Language of evaluation, methods of evaluation, summative or conclusive, multiple choice questionnaires, short-answer questions, open-ended questions, problem solving, written work, essay/report, oral examination, public presentation, laboratory work, clinical examination of patient, art interpretation, other* *Specifically-defined evaluation criteria are given, and if and where they are accessible to students.*	Evaluation Language: English Assessment Methods: Multiple-choice questionnaires, short- and long-answer questions Written exam (oral examination available in special cases) Evaluation criteria are outlined in the study guide and communicated to students at the beginning of the course.

Activity	***Semester workload***
Lectures	30
Tutorials	10
Study and analysis of bibliography	110
Course total	***150***

(5) ATTACHED BIBLIOGRAPHY

Textbooks:

- Arbib, Michael A., ed. The handbook of brain theory and neural networks. MIT press, 2003.
- Ermentrout, Bard, and David H. Terman. Mathematical foundations of neuroscience. Vol. 35. New York: springer, 2010.
- Izhikevich, Eugene M. Dynamical systems in neuroscience. MIT press, 2007.
- Sutton, Richard S., and Andrew G. Barto. Reinforcement learning: An introduction. MIT press, 2018.
- Sterratt, David, et al. Principles of computational modelling in neuroscience. Cambridge university press, 2023.
- Gerstner, Wulfram, et al. Neuronal dynamics: From single neurons to networks and models of cognition. Cambridge University Press, 2014.
- Dayan, Peter, and Abbott, Laurence F. Theoretical neuroscience: computational and mathematical modeling of neural systems. MIT press, 2005.

Online resources:

Neuromatch Academy Precourse https://precourse.neuromatch.io/

- Python Workshops 1 & 2 (WOD1, WOD2)
- Linear Algebra (WOD3)
- Calculus (WOD4)
- Statistics (WOD5)