CENTRALE NANTES

ENGINEERING PROGRAMME

2024-2025

Year 2 / Year 3

Specialisation option

Digital Sciences for Life Sciences and Healthcare

OD BIOSTIC

PROGRAMME SUPERVISOR

Sophie LIMOU

Autumn Semester

Course unit	ECTS Credits	Track	Course code	Title
UE 73	12	Core course	BIOCEL INFAVA SIMCHI STAPRE	Cellular Biology Advanced Computer Sciences Computational Surgery Statistics and machine learning
UE 74	13	Core course	BIOMOL IMMUNO MOQUAN PHYSIO PROENC1	Molecular biology and genetics Immunology Systems Biology: Probablistic Modeling and Quantitative Analysis of Biological Networks Physiology Tutorel project 1

Spring Semester

Course unit	ECTS Credits	Track	Course code	Title
UE 83	14	Core course	BIOGEN CONFER MODIAN PROENC2 SYSBAD	BioInformatics and Genomics Conferences Systems Biology: Discrete Modeling and Qualitative Analysis of Biological Networks Tutorel project 2 Computer systems and Databases

Cellular Biology [BIOCEL]

LEAD PROFESSOR(S): Aurélien SERANDOUR

Requirements

No prerequisites

Objectives

Understanding the fundamental mechanisms in an eukaryotic cell

Course contents

Cell adhesion and extracellular matrix
Apoptosis
Cancer
Cell cycle
Cytoskeleton
Degradation of biomolecules
Genetic expression
Plasma membrane and membrane transport
Protein routing
Cellular signalling

Course material

Cell Biology 3rd Edition, Thomas D. Pollard , Elsevier

Assessment

Individual assessment: EVI 1 (coefficient 0.6)
EVI 2 (coefficient 0.3)
EVI 3 (coefficient 0.1)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	20 hrs	6 hrs	4 hrs	0 hrs	2 hrs

Advanced Computer Sciences [INFAVA]

LEAD PROFESSOR(S): Olivier ROUX

Requirements

Objectives

Object oriented programming / Programming in JAVA / Data structures.
Multi-core architecture / Methodology for parallelization / OpenMP / MPI.

Course contents

1. Introduction
2. Object Oriented Langages: Classes, objects, inheritance, polymorphism, etc.
3. Introduction to programming in JAVA
4. Data Structures (linear structures, trees, hash functions, etc)
5. Multi-core architecture and methodology for parallelization
6. OpenMP/ MPI
7. Enforcement

Course material

Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	14 hrs	0 hrs	16 hrs	0 hrs	2 hrs

Computational Surgery [SIMCHI]

LEAD PROFESSOR(S): Domenico BORZACCHIELLO

Requirements

Objectives

Computational surgery is a new discipline that focuses on the use of medical imaging, robotics and simulation. In this field, simulation techniques are of capital importance in order to have a faithful patient-specific model. This course covers the fundamentals in biophysics with application to surgical simulation. An introduction to numerical methods for efficient implementation and simulation of these models is also presented. Advanced topics include: 3D modeling based medical imaging techniques, computational anatomy and parametric modeling.

Course contents

-Introduction to Computational Surgery
-Mesh Generation from Medical Images
-Bone Mechanics
-The finite element method for biomechanics
-Fundamentals of Computational Anatomy

Course material

Slides and Course Notes
A selection of scientific articles provided by the teacher
Notebooks in Jupyter-Python and R

Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	22 hrs	8 hrs	0 hrs	0 hrs	2 hrs

Statistics and machine learning [STAPRE]

LEAD PROFESSOR(S): Mathieu RIBATET

Requirements

Objectives

Introduction to the principles of artificial intelligence and Machine Learning and statistical and in-depth study of statistics

Course contents

Machine learning:
+ Introduction to statistics
+ Clustering
+ Principal component analysis
+ Logistic regression

Survival analysis:
+ Framework and definition
+ Non parametric estimation
+ Comparison of survival curves
+ Cox proportional hazard model

Course material

Assessment

Individual assessment: EVI 1 (coefficient 0.5)
EVI 2 (coefficient 0.5)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	25 hrs	5 hrs	0 hrs	0 hrs	2 hrs

Molecular biology and genetics [BIOMOL]

LEAD PROFESSOR(S): Aurélien SERANDOUR / Sophie LIMOU

Requirements

Objectives

Introduction to major molecular biology concepts
Presentation of recent biotechnological challenges and opportunities

Course contents

The introduction to Molecular Biology will cover gametogenesis and the basis of sexual reproduction, the basis of heritability and diversity, embryonic development and cell differentiation.
Genetic analyses in biomedical research and clinical settings (linkage, next-generation sequencing, and genome-wide association analyses).
Biotechnological advances in genomics and functional genomics (gene expression regulation, gene editing, single-cell technologies).
Lab classes will include exploration of bioinformatic databases, R statistics, and analytical reading of scientific papers.

Course material

Assessment

Collective assessment: EVC 1 (coefficient 0.2)

Individual assessment: EVI 1 (coefficient 0.8)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	25 hrs	5 hrs	0 hrs	0 hrs	2 hrs

Immunology [IMMUNO]

LEAD PROFESSOR(S): Aurélien SERANDOUR / Sophie LIMOU

Requirements

Objectives

The objective of this course is to give students basic training in biology focusing on the main cellular and molecular components of the immune response (innate and acquired), the implementation of this response in the fight against infectious agents and their use for vaccines or therapeutic purposes.

At the end of the Immunology course, the student:
1-Will postion the main cellular and molecular actors of the immune system during an innate and adaptive immune response.
2-Define and memorize the structure and function of the different lymphoid organs.
3-Will associate with each actor its main function.
4-Discuss the basics of the main successes and failures of immunology (vaccination, AIDS).
5-Explain the basics of the main analytical techniques using antibodies (flow cytometry, ELISA in particular).

Course contents

Overview of the immune system
Innate Immunity
Adaptive immunity
Major histocompatibility complex
Primary and secondary lymphoid organs
Activation of T lymphocytes
Directory of B lymphocytes
Transplantation
Acquired Immune Deficiencies (AIDS)
Autoimmune diseases
Anti-tumor immune response
Vaccination

Program of practical work (1 day):
Production and observation of a blood smear, application to the diagnosis of hemopathies in humans.
Analysis of the phenotype of lymphocytes circulating in human blood by multiparametric flow cytometry.

Course material

Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	18 hrs	8 hrs	4 hrs	0 hrs	2 hrs

Systems Biology: Probablistic Modeling and Quantitative Analysis of Biological Networks [MOQUAN]

LEAD PROFESSOR(S): Sophie LIMOU

Requirements

Objectives

Introduction to the modeling of biological systems

Course contents

Introduction to the modeling of biological systems / Principal laws and modeling based on differential equations / Approximation of dynamics based on probabilistic models (PBN and DBN) and asymptotic analysis of models: application to regulatory models / Approximation of dynamics at quasi-stationary equilibrium and stress-based analysis: application to metabolic models.

Course material

Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	21 hrs	9 hrs	0 hrs	0 hrs	2 hrs

Physiology [PHYSIO]

LEAD PROFESSOR(S): Aurélien SERANDOUR / Sophie LIMOU

Requirements

Objectives

This is an introductory course to medicine designed to introduce the essential notions in human physiology.

Course contents

Brain function and main neurological diseases. Causes, underlying mechanism, diagnostic methods, treatments and outlook.

Cardiovascular physiology.

Functional anatomy in animals, muscle and bone physiology.

Kidney and lung physiology

Numerical modeling methods in physiology. Modeling of bone remodeling. Modeling of muscle contraction. Numerical methods for the simulation of physiological systems.

Course material

Assessment

Collective assessment: EVC 1 (coefficient 0.3)

Individual assessment: EVI 1 (coefficient 0.7)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	24 hrs	6 hrs	0 hrs	0 hrs	2 hrs

Tutorel project 1 [PROENC1]

LEAD PROFESSOR(S): Aurélien SERANDOUR / Sophie LIMOU

Requirements

Objectives

Research Project from September to March

Course contents

Supervision carried out by researchers and teacher-researchers from Nantes on their research theme at the mathematical / informatics / physics / biology interface

1 intermediate oral
1 report to write
1 final oral

Course material

Assessment

Collective assessment: EVC 1 (coefficient 1)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	1	0 hrs	0 hrs	0 hrs	32 hrs	0 hrs

BioInformatics and Genomics [BIOGEN]

LEAD PROFESSOR(S): Sophie LIMOU

Requirements

Objectives

Overview of major challenges in bioinformatics
Discovery of two big data approaches
Applications with a project

Course contents

Overview of major challenges in bioinformatics: main databases in the biomedical field, sequence alignment, phylogeny and evolution basics, protein structures
Discovery of two big data approaches: genome-wide association studies, single-cell transcriptomics
Applications with a project

Course material

Assessment

Collective assessment: EVC 1 (coefficient 0.4)
EVC 2 (coefficient 0.1)

Individual assessment: EVI 1 (coefficient 0.5)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	25 hrs	5 hrs	0 hrs	0 hrs	2 hrs

Conferences [CONFER]

LEAD PROFESSOR(S): Olivier ROUX / Sophie LIMOU

Requirements

Objectives

Presentation of many different application fields in biomedical engineering from academia and private companies actors

Course contents

Course material

Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	30 hrs	0 hrs	0 hrs	0 hrs	2 hrs

Systems Biology: Discrete Modeling and Qualitative Analysis of Biological Networks [MODIAN]

LEAD PROFESSOR(S): Morgan MAGNIN

Requirements

Basic knowledge of computer science: modeling principles and implementation issues

Objectives

Knowledge:

- Boolean networks
Interaction graphs and associated properties
Analysis of the dynamics via the calculation of the transition graph
Formal verification of dynamic properties through model-checking (LTL / CTL)

- Petri nets:
Discrete properties (invariants)
Time extensions
Formal verification of dynamic properties thanks to parametric timed model-checking (TCTL and parametric extension)
Control of hybrid models

Skills:
- Given a specific problem, choose which of the different discrete and hybrid formalisms is the most suitable for analyzing a system biology problem?
- Validate a model / family of models with respect to a set of expected properties (logical reasoning, formal verification)
- Enrich a model with respect to issues of interest (for example, integrating a time dimension into the model when the temporal component plays a crucial role in the evolution of a system)
- Confront a model with biological data

Course contents

1. Boolean networks, their dynamics and influence graph
2. Temporal logic and model verification
3. Cell mutations and reprogramming
4. Other discrete models for modeling biological networks: Petri nets and automata
5. Model-checking of timed models

Course material

Kauffman, S. (1969). Homeostasis and differentiation in random genetic control networks. Nature, 224(5215), 177-178.

Thieffry, D., & Thomas, R. (1997, December). Qualitative analysis of gene networks. In Pacific Symposium on Biocomputing (Vol. 3, pp. 77-88).

Folschette, M., Paulevé, L., Magnin, M., & Roux, O. (2015). Sufficient conditions for reachability in automata networks with priorities. Theoretical Computer Science, 608, 66-83.

R. Alur, C. Courcoubetis, N. Halbwachs, T. A. Henzinger, P.-H. Ho, X. Nicollin, A. Olivero, J. Sifakis, and S. Yovine. The algorithmic analysis of hybrid systems. THEORETICAL COMPUTER SCIENCE, 138:3–34, 1995.

Louis-Marie Traonouez, Didier Lime, and Olivier (H.) Roux. Parametric model-checking of stopwatch petri nets. Journal of Universal Computer Science, 15(17):3273–3304, December 2009.

Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	18 hrs	2 hrs	10 hrs	0 hrs	2 hrs

Tutorel project 2 [PROENC2]

LEAD PROFESSOR(S): Aurélien SERANDOUR / Sophie LIMOU

Requirements

Objectives

Research Project from September to March

Course contents

Supervision carried out by researchers and teacher-researchers from Nantes on their research theme at the mathematical / informatics / physics / biology interface

1 intermediate oral
1 report to write
1 final oral

Course material

Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	2	0 hrs	0 hrs	0 hrs	48 hrs	0 hrs

Computer systems and Databases [SYSBAD]

LEAD PROFESSOR(S): Jean-Yves MARTIN

Requirements

Objectives

The purpose of this course is to understand operating systems and database mechanisms.

For databases part, we study modélisation technics, conception tools, management tolls and the way to interact with databases.

For Operating System part, we study main basics for Operating Systems, Command language tools, and the way to use them.

Course contents

This course is divided in two parts.

For the Database part:
- Data modeling, Conceptual Data Model, Entity-Association Model
- Relationnal Model
- Phisical Data Model
- SQL
- Introduction to noSQL and BigData

For the Operating System part:
- Introduction to Operating Systems
- Command Language
- Data security
- Introduction to Batchs and Scheduling

Practical work aims at writing Shell script for the first part, and building and managing a database for the second part.

Course material

Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	14 hrs	8 hrs	8 hrs	0 hrs	2 hrs