MASTER BIOINFORMATICS
In Silico Drug Design – Bioactive Molecules MSc
Université Paris Cité – Degli studi di Milano
(double diploma franco-italien)
2024-2025

SEMESTER 1 - Université Paris Cité (30 ECTS)

UE 1 Methodology (10 ECTS)
Coordinator : A. Badel

EC 100 Unix and R Introduction : without credits - Upgrade
Coordinator: G. MOROY

Title: Unix and R Introduction
Teaching coordinator: G. Moroy, L. Regad

Knowledge objectives: Acquire the basics of using the Unix operating system and R software.

Targeted skills: To be familiar with Unix and R to be autonomous during the practical sessions of computer science, bioinformatics, and statistics.

Program: Fundamentals of the Unix operating system and R software.

EC 101 Mathematics I – Force field method/Physical chemistry (3 ECTS)
Coordinator : S. Pasquali

Title : Mathématiques I
Teaching coordinator: S. Pasquali
Teachers : S. Pasquali

Knowledge objectives: The purpose of this module is to provide basic mathematical and algorithmic principles for drug design and also an introduction to force field an energy functions.

Targeted skills: Understand the mathematical principles of commonly used numerical methods. Ability to analyse a modelling problem, and correctly use the appropriate methods.

Program:

- - Study of functions: limits, derivatives, graphs.
- - Linear algebra: vectors and matrices, operators in space (rotations, dilatations), inversion of matrices, eigenvalues and determinants, solutions to linear differential equations.
- - Optimisation: multidimensional functions, Hessian matrices
- - Introduction to energy functions (docking-scoring)

EC 102 Python Programming 1 (3 ECTS)
Coordinators : P. FUCHS & P. POULAIN

Title: Python programming 1
Teaching coordinators: P. Fuchs & P. Poulain
Teachers: P. Fuchs & P. Poulain

Knowledge objectives: Train biologists in Python programming. Python is the most used programming language today in bioinformatics, especially for data analysis.

Targeted skills: Know the main concepts related to Python programming. Be able to write simple analysis scripts.
To evaluate the relevance of a result returned by a program.

Program:

- - Programming concept
- - Introduction to the Python language
- - Main data types (integers, real numbers, lists, character strings, dictionaries, tuples)
- - Loops, comparisons, tests
- - Modules
- - Input/output management with files
- - Functions

or

EC 102 Python Programming 2 (3 ECTS)
Coordinators : P. FUCHS & P. POULAIN

Title: Python programming 2
Teaching coordinators: P. Fuchs & P. Poulain
Teachers: P. Fuchs & P. Poulain

Knowledge objectives: Train bioinformaticians in Python programming. Acquire autonomy in the development of a Python program. Python is the most used programming language today in bioinformatics, especially for data analysis. It is in great demand in laboratories, but also in private companies.

Targeted skills: Understand the main concepts related to Python programming.
Be able to write programs (i) for analysing large amounts of data, (ii) producing data (e.g. a system simulation).
Be able to develop/debug a program in Python.

Program:

Main data types (integers, real numbers, lists, character strings, dictionaries, tuples)

- - Loops, comparisons, tests
- - Modules
- - Input/output management with files
- - Functions
- - Regular expressions Python classes

EC 103 Biostatistics and R programming (3 ECTS)
Coordinator: L. REGAD

Title: Biostatistics and R programming
Teaching coordinator: L. Regad

Knowledge objectives: The purpose of the education provided is to provide students with basic biostatistics training.

Targeted skills: Master the statistical bases of biological data exploration, and processing in R language.

Programme:
Reminders of probabilities, introduction to biostatistics

Estimation and statistical inference

Classical tests, Student test, Chi2 test, Pearson's correlation coefficient test

Analysis of variance and introduction to factorial designs

Non parametric tests

Introduction to learning techniques supervised by the methods of CART / or Factorial plan

or

EC 104 Tutored project in biostatistics and R (3 ECTS)
Coordinators: AC CAMPROUX & A. BADEL

Title: Tutored project in Biostatistics and R
Teaching coordinators: AC Camproux & A.Badel

Knowledge objectives: At the end of the training, students will be able to determine the statistical analysis that can answer the biological question asked, and implement this analysis.

Conclude on the statistical and biological results of their study

Targeted skills: Appropriately apply the concepts of biostatisitics and R programming to solve a biological problem. Analysis of biological files from FP in biology

Programme: Tutored project in biostatistics and R

EC 105: English communication (1 ECTS)
Coordinator: Teachers from EILA (Université Paris Cité)

Title: Communication in english
Teaching coordinator: ELAAE teacher
Program: Disciplinary English
Practice written and spoken English.

Targeted skills:
In-depth knowledge of English for science.
Program:
Online training in English specialty, scientific understanding and writing.

UE 2 Chemistry (12 ECTS)
Coordinator: Department Chemistry Professor? and O. Taboureau

EC 200 Chemistry ROS (Reactivity and organic synthesis) (3 ECTS)
coordinator: F. CHAU

Title : Reactivity and organic synthesis
Teaching coordinator: F. Chau
Teachers: F. Chau

Knowledge objectives:

To provide students with molecular chemistry tools to:
- understand chemical/biochemical/biological processes and the reactivity of natural/synthetic molecules.
- know how to master the main reaction mechanisms of organic chemistry, and apply them to the synthesis of target molecules.

Targeted skills:

- understand chemical/biochemical/biological processes and the reactivity of natural/synthetic molecules.
- know how to master the main reaction mechanisms of organic chemistry, and apply them to the synthesis of target molecules.

Program

- Stereochemistry of organic compounds.
- Electronic and steric effects.
- Reactivity of chemical functional groups of biomolecules: hydroxyl, carbonyl, carboxyl, amine, thiol, and phosphate.
- Chemistry of large classes of organic molecules: description, reactivity, and applications.

EC 201 Biological Chemistry (3 ECTS)
Responsable : O. Reinaud

Title: Biological Chemistry
Teaching coordinator: O. Reinaud
Teachers: O. Reinaud

Knowledge objectives: Knowledge, at the molecular level, of the principles governing the reactivity of metal ions in biological media (transport, hydrolytic catalysis, redox catalysis) Reactive Mechanism at the Active Site.

Targeted skills: Knowledge of the main molecular tools available to a given biological system to achieve a given transformation. Know how to use the principles of coordination chemistry to propose a reaction mechanism in a biological environment. To master the formalism describing the exchanges of electrons during redox reactions.

Program:

I. Presentation of the bio-inorganic domain
II. Regulation, transmission of information: alkaline and alkaline earth
III. Hydrolytic processes: hydrolysis of peptides, phosphodiesters, urea
IV. Electron transfer
V. Dioxygen transport and activation

EC 202 Chemistry: chirality - non covalent bonds (3 ECTS)
Responsables : F. MAUREL, O. TABOUREAU

Title : Chemistry: chirality – non covalent bonds.
Teaching coordinators : F. Maurel, O. Taboureau
Teachers: F. Maurel & M. Seydou

Knowledge objectives:

Presentation of the main non-covalent interactions that are established within biological systems or in biological ligand - macromolecule complexes. The focus is on the characteristics and distinctive features (nature and intensity) of these interactions. The aim is to show how these forces are distinguished by their nature and their intensity of covalent chemical bonds, which leads them to play an essential role in ensuring the three-dimensional structures of living molecules, or to guide the interaction of a small molecule in a biological receptor (protein or DNA). We will show how it is possible to translate the characteristics of each of these forces into suitable potentials. Finally, strategies for implementing these terms in molecular modelling calculations will be introduced. A practical part on computer will allow concrete cases to be addressed where each one of these forces plays a particular role.

Targeted skills:

Presentation of the main non-covalent interactions that are established within biological systems or in biological ligand - macromolecule complexes.

Program:

- - Introduction to chemistry
- - Basics of chemistry such as atoms, chemical functions, and heterocycles useful for drug development. Preferred conformations, and reactive groups will also be introduced.

EC 203 NMR for molecules (3 ECTS)
Coordinator: N. Giraud

Title: NMR
Teaching coordinator: N. Giraud
Teachers: N. Giraud

Knowledge objectives:
Providing students with the concepts and theoretical tools to understand pulsed NMR (1D and 2D). Teaching them how to analyze, exploit, and discuss the analytical content of NMR spectra to determine the structure of organic molecules (either natural or synthetic), and notably biomolecules.

Targeted skills:
– assimilate / explain / discuss the theoretical concepts of NMR: acquisition of a 1D and 2D NMR experiment, relaxation mechanism, nOe, dyanmics …
– deciphering and implementing a pulse sequence
– analyzing 2D maps recorded on synthetic or natural molecules to determine their structure.

Program
After a brief review of the fundamentals of this spectroscopy, this lecture will introduce the main features of NMR pulse sequences. A simplified theoretical formalism based on Bloch equations will be developed to describe and understand the the evolution of macroscopic nuclear magnetization under different regimes (precession, relaxation, spin echo …-).

Heteronuclear NMR will also be addressed: the sensitivity and the quality of the data that are available for a selection of heteronucleic in the field of organic chemistry will be discussed.
Multi-dimensional NMR will also be introduced, and the fundamental concepts of multi-dimensional data acquisition and processing will be introduced for 2D pulse sequences. The main homo- and hetero-nuclear correlation experiments will be presented (COSY, TOCSY, NOESY, HSQC).
Finally, nuclear spin relaxation will be introduced, as well as chemical exchange.
Tutorials will allow for completing theoretical concepts with exercises focused on applications, and analyses of spectra recorded on real samples (structure determination from experimental spectra).
Practicals will allow students for applying the acquired knowledge to the acquisition of data targeting dynamic and/or structural analysis.

UE3 Molecular Modelling and Chemoinformatics (8 ECTS)
Coordinator: O. TABOUREAU

EC 301 Chemoinformatics I (3 ECTS)
Coordinator: J. DIHARCE

Title: Chemoinformatics
Teaching coordinator: J. Diharce
Teachers: J. Diharce and V.K. Tran Nguyen

Knowledge objectives:
The objective of this module is to introduce students to the field of chemoinformatics and its application in Drug Design.

Targeted skills:
Introduction to chemoinformatics. Chemical representation, chemical descriptors, visualization. Introduction to analysis methods.

Program:
- Chemical representation (1D, 2D, 3D)
- Chemical database
- Chemical descriptors and pharmacophores.
- Visualization of descriptors and molecules
- Similarity of molecules and cluster
- Introduction to Structure-Activity Methods (QSAR)
- Virtual screening
- SMILES
- Conformational analysis

EC 302 Chemoinformatics II: ADME/chemometry (2 ECTS)
Coordinator: O. TABOUREAU

Title: ADME/chemometrics
Teaching coordinator: O. Taboureau
Teachers: O. Taboureau & V.K. Tran Nguyen

Knowledge objectives:
The objective of this module is to give an introduction to the ADMET properties and to propose tools

that can predict in advance the possible problems of ADMET (Administration-Distribution-Metabolism- Excretion-Toxicity) associated with a small molecule.

Targeted skills:
Understanding and using ADMET tools to optimise the design of a molecule and to limit or avoid side effects or toxic associated with it. (KNIME)

Program:
- Chemical descriptors and ligand-based pharmacophores
- Training and practical of KNIME
- Description of ADMET properties
- Use of tools to predict the sites of metabolism, groups of reactive and toxic atoms, protein targets associated with side effects.
- Evaluation of the potential risks associated with a molecule and how to optimize the design of this molecule.

EC 303 Option in drug design / chemoinformatics (3 ECTS)
Coordinator: O. TABOUREAU

Title: Option in Drug Design / Chemoinformartics
Teaching coordinator: O. Taboureau
Teachers: invited professors, researchers…

Knowledge objectives:
Discovery of useful tools and technologies for drug design, QSAR, deep learning, structural bioinformatics, thermodynamic approach…

Targeted skills:
Learn about tools/softwares used in chemoinformatics and molecular modelling.

SEMESTER S2 UNIVERSITY DEGLI STUDI DI MILANO (30 ECTS)

UE1 PROGRAMMING IN C (6 ECTS)
Coordinator: C. LORENZO

Title: Programming in C
Teaching coordinator: C. Lorenzo
Program:
Basic aspect of C programming. Language for numerical analysis and statistics purposes.
Generalities about programming languages. Source files and executable files. Compilers. Variable types. Input-output operations. While and for loops. Conditional constructs. Pointers. Array manipulation. String manipulation.

Targeted skills:
To be able to write and execute simple codes in C

UE2 STRUCTURAL BIOLOGY AND ENZYMOLOGY (6 ECTS)
Coordinator: MR VANONI

Title: Structural Biology and Enzymology

Teaching coordinator: Mr Vanoni

Program:
Structural Biology and Enzymology Introduction to the identification of biological drug targets by bioinformatic, genomic, transcriptomic, and proteomic techniques. Criteria for the validation of pharmacological targets. Molecular recognition and nature of ligand binding sites. Structure-function
Synthetic Techniques Applied to the Design and Synthesis of Biologically Active Principles Expanded role of chemistry in all phases spanning the initial concept idea, the rational design, the synthesis, and the structural optimisation of a pharmacologically active molecule.

Targeted skills:
Structural biology and enzymology in structural design, synthesis and structural optimisation of a pharmacologically active molecule.

UE3 MEDICINAL CHEMISTRY (6 ECTS)
Coordinator: L. BELVISI

Title: Medicinal chemistry

Teaching coordinator: L. Belvisi

Program:
Principal phases of drug action. Pharmacokinetics: Absorption, Distribution, Metabolism, and Excretion of drugs. Pharmacodynamics: the molecular targets of drugs and the receptor concept.
Principal phases of drug discovery and development process. LEAD identification.

Targeted skills:
Knowledge on Principal phases of drug action

UE4 SIMULATION, MODELLING AND BIOMOLECULES (6 ECTS)
Coordinator: S. PIERACCINI

Title: Simulation, Modelling and Biomolecules

Teaching coordinator: S. Pieraccini

Program:
Molecular mechanics principles. The concept of atom type. Force fields functional form. Molecular dynamics. Integration of Newton equations. Periodic boundary conditions. Calculation of non bonded terms. Setup of an MD simulation. The sampling problem. Application to the protein folding problem

Targeted skills:
Molecular modelling for Biomolecules, molecular dynamics, and sampling simulation

UE5 Chemometrics (6 ECTS)
Coordinator: L. BELVISI

Title: Chemometrics

Teaching coordinator: L. Belvisi

Program:
The concept of chemometrics and how informatics is applied in data analysis related to chemical information.

Targeted skills:
Data analysis and machine learning applications