I3 Master's

« Immunology & Immuno-Intervention »

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Nantes Université

INTRODUCTION

The I^3 Master's Program – Immunology and Immuno-Intervention provides **in-depth training in immune system function, its dysregulation, and its therapeutic manipulation in human disease**. It is designed for students from diverse backgrounds in biology and health sciences who wish to develop strong expertise in immunopathology and immuno-intervention.

The program is delivered within a world-class scientific environment, fostering close interactions between research laboratories, clinical departments, and a dynamic biotechnology ecosystem, fostering both fundamental and translational research.

The Master I^3 offers unique expertise in several key areas :

- Immunopathology of chronic inflammatory and autoimmune diseases, cancer, transplantation, and sepsis
- Innovative Immunotherapies applied to oncology, infectious diseases, and inflammation
- Systems immunology approaches (immunometabolism, neuroimmunology, immune aging).

Over the two-years programme, students can tailor their training by selecting among three possible tracks: clinical research, experimental research, omics data research and analysis.

Experimental research track: Designed for students wishing to pursue careers in academic research or biomedical research in industry

- It develops key skills in scientific reasoning, experimental methodologies and critical analysis of data in life and health sciences.
- It emphasises experimental design, mastery of laboratory techniques, and rigorous interpretation of scientific results.

Clinical research track: Designed for students wishing to transform today's knowledge into tomorrow's treatments

- It develops the skills required to design and conduct clinical trials, and to evaluate new therapies or medical devices.
- It focuses on clinical trial methodology, clinical data analysis and regulatory aspects of health.

Research and analysis of omics data : Designed for students wishing to specialise in bioinformatics and omics data analysis

- It develops the skills required to explore complex relationships among genes, proteins, metabolites and other biomolecules.
- It focuses on multidimensional approaches, cutting-edge computational tools, and integrative interpretation of omics datasets.

Why choose this Master's programme?

- A **dedicated teaching program focused on immunology**
- A world-class environment, with **human health-related research laboratories integrated within Nantes University Hospital (CHU Nantes)**, closely linked to clinical research
- **Early laboratory immersion**, starting in the first year (M1), to develop expertise, autonomy, and hands-on research experience
- **High-impact medical research**, oriented toward therapeutic innovation and translation into clinical practice
- **Personalised support**, with tutoring and individualized guidance for professional project development

- **Numerous internship opportunities**, in France and internationally, within renowned academic and hospital teams

The I^3 Master's program benefits from an exceptional environment, fostering innovation and cutting-edge research through collaboration with **three internationally renowned laboratories:**

- INCIT
- CRCI2NA
- CR2TI

A dynamic ecosystem, with several biotech companies specializing in immunology based in Nantes.
A unique collaboration **between clinicians and researchers at the heart of Nantes University Hospital (CHU Nantes)**, ensuring strong interaction between fundamental research and clinical applications.

MASTER'S PROGRAMME COORDINATORS

- Laetitia Gautreau Rolland
- Jérôme Martin
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TEACHING LOCATION

Teaching takes place at **Nantes Université**, within:

- the Faculty of Science and Technology,
- the Faculties of Medicine and Pharmacy.

SKILLS ACQUIRED AND CAREER OPPORTUNITIES

At the end of the I3 Master's programme, students will have mastered the following skills:

- **Conducting research** and analysing bibliographic and technological resources.
- **Designing** biology and health **projects** in their field of specialisation.
- Developing experimental expertise in health biology.
- **Analysing scientific data** derived from basic, clinical, or pharmacological research.
- **Communicating scientific findings** through oral presentations, technical reports and scientific publications.

Upon completion of the I3 Master's, graduates can pursue a wide range of carreers depending on their chosen specialisation :

Experimental Research : Biological engineer, project manager, R&D engineer.

Clinical Research: Clinical research associate, clinical trial coordinator.

Omics Research and Data Analysis : Biological engineer, project manager, multi-omics data processing engineer, bioanalyst, R&D engineer.

Sectors of Activity : Academic laboratories, R&D companies, start-ups, hospitals

Students may pursue a career in **research** by undertaking a PhD.

PhD training can be undertaken in France or abroad, with various funding opportunities available, including:

- Partnership with company collaborative agreements
- Funding from calls for proposals by **Graduate school Health Sciences and Technologies** and its network,
- Other institutional or private funding sources.

JOIN THE I3 MASTER'S PROGRAMME

Scholarship
A **welcome grant of €1,500** is awarded to international students enrolled in the programme.
Students may also apply for:

- The Eiffel Excellence Scholarship,
- Other scholarships offered by their embassies or national organisations.

Students on the **I3** programme who undertake an **internship abroad** may also be eligible for a mobility grant in the form of a monthly allowance rangin from **€500 to €700**, subject to eligibility criteria.

How to apply?
Admission requirements and application procedures are detailed in the **programme information sheet**, available on the **Nantes University website**[1].

[1] https://sciences-techniques.univ-nantes.fr/formations/masters/graduate-programme-immunology-and-immuno-intervention-masters-degree

I3 MASTER PROGRAMME 1st year

Teaching units specific to the I3 programme (18 ECTS)

■ Applied immunology

Number of hours: 24 hrs
Year/Semester: Master's Year 1 / Semester 1
Language: French/English

Objectives
The two courses are described below

Content

- **Immunology – cancerology**
- **Immuno-inflammation**

Teaching methods
Face -to-face

■ Immunology-Cancerology (lecture)

Number of hours: 16 hrs
Year/Semester: Master's 1 / Semester 1
Language: French/English

Objectives

- Identify the cellular and molecular components of the anti-tumour immune response.
- Classify tumour escape mechanisms.
- Describe current strategies for cancer immunotherapy.
- Explain the mechanisms of normal and pathological inflammation.

Content

- Immunity and cancer
- Tumour antigens
- Anti-neoantigen T-cell responses
- Tumour microenvironment
- Immune evasion
- Monoclonal antibodies
- Cancer vaccination
- Adoptive cell transfer
- Ionising radiation and immunity

Teaching methods

- Face-to-face lectures and tutorials.
- Regular surveys (formative assessment)
- Provision of a toolkit (visual aids)

- Self-assessments exercises and online discussion forum

■ Immuno-inflamation (Lectures)

Number of hours: 8 hrs
Year/Semester: Master's 1 / Semester 1
Language: French/English

Objectives

- Identify the major cellular and molecular actors involved inflammatory responses.
- Understand phsyiological and dysregulated inflammatory mechanisms.
- Describe associated therapeutic strategies.

Content

- Chronic inflammatory diseases
- Anti-infectious responses
- Hypersensitivity reactions

Teaching methods

Face-to-face, polls, toolkit, forum, self-assessments.

Bibliography

Immunologie - Le cours de Janis Kuby (Edition Dunod)
Immunologie » Jean-Pierre Revillard (Edition DeBoeck)
Immunobiologie » Charles Janeway et Kenneth Murphy (Edition DeBoeck)

■ Fondamental immunology

Number of hours: 21 hrs
Year/Semester: Master's 1 / Semester 1
Language: French

Objectives

- Deepen understanding of the immune system.
- Explain the activation mechanisms and functions of immune cells.
- Become familiar with the main animal models used in immunology.

Content

- T-cell activation
- Antigen presentation to T-cells
- B-cell/T-cell signalling
- NK cells and ILCs
- Unconventional T cells
- Regulatory T cells
- Dendritic cells
- Immune tolerance
- Innate immunity
- Fc receptors
- Animal models

- Metabolism and immunology

Teaching methods
Face-to-face classes

■ Experimental Approaches in Immunology

Number of hours: 10 hrs
Year/Semester: Master's 1 / Semester 2
Language: French

Objectives

- Select the appropriate experimental technique to address an immunological question
- Explain and present experimental findings to an audience.

Content
Illustration of theoretical concepts and main methods used in experimental immunology through exercises focused on the study of the immune response.

Teaching methods
Entirely face-to-face teaching.
Preparation of exercises and oral presentations during tutorials

Bibliography
Immunology – The Course by Janis Kuby' (Dunod)
Immunology by Jean-Pierre Revillard (DeBoeck)
Immunobiology by Charles Janeway and Kenneth Murphy (DeBoeck)

Cross-disciplinary Teaching units, Master's 1 (24 ECTS)

■ Scientific Presentation 1

Number of hours: 0
Year/Semester: Master's 1 / Semester 1
Language: French/English

Objectives
To gain a broad overview of a disciplinary field.
Develop a critical perspective following a scientific presentation. Be able to engage with a specialist in a given field. Design a structured and educational presentation.
Be able to answer scientific questions in a reasoned manner, drawing on the relevant literature.
Build a professional network.

Content
Each GP offers several scientific events during which students will attend lectures by specialists, present their results in the form of oral and poster presentations, and take part in various scientific workshops. These events will provide an opportunity to interact with professionals (academic, clinical and industrial), with students from other GP levels (M2, PhD students), and with alumni. Some of these events may take place remotely.

Some events may be specific to a particular GP with a very distinct thematic focus, whilst others may be shared across all GPs, or some of them, at the discretion of the GP coordinators.

■ Big Data 1-1 — Introduction to Biological data analysis

Number of hours: 24 hours (16 hours lectures, 8 hours practicals)
Year/Semester: Master's 1 / Semester 1
Language: French/English

Objectives
By the end of this Teaching unit, students will be able to:

- **Identify** the key steps in modelling a biological system.
- **Use** different data structures and algorithms to analyse biological data.
- **Use** a digital environment dedicated to biological data analysis.

Content
Lectures

- History and principles of modelling living systems
- Introduction to scripting languages
- Algorithms and data structures
- Manipulation of biological files (FASTA, CSV)
- Sequence manipulation (DNA, RNA, proteins)
- Handling randomness in programming

Practical work

- Extracting biological information from FASTA sequences
- Automated alignments to produce a similarity graph

Teaching methods
Face-to-face lectures, tutorials and practical sessions, with applied exercises.

Bibliography

- Guttag JV. *Introduction to Computation and Programming Using Python*, MIT Press.
- Ekmekci B., McAnany C.E., Mura C. (2016). *An Introduction to Programming for Bioscientists: A Python-Based Primer*, PLOS Computational Biology.

■ Big Data 1-2 — Introduction to Biological data analysis

Number of hours: 24 hours (Lectures: 4 hours, Practical sessions: 20 hours)
Year/Semester: Master's 1 / Semester 1
Language: French/English

Objectives

To practise algorithms and programming,
Analyse genomic sequences,
Implement IT tools for the representation and analysis of biological data

Content

Use of computational and mathematical concepts for the analysis and visualisation of biological data (sequence analysis and descriptive and inferential statistics) alongside familiarisation with a computing environment.

Lectures:

- Introduction to the computing environment
- Introduction to univariate statistical tests
- Introduction to different types of data visualisation

Practical work:

- Analysis of genomic sequences
- Development of scripts to analyse biological data
- Representation and visualisation of biological data

Teaching methods

Face-to-face lectures and practical sessions enable students to acquire theoretical knowledge, put it into practice and implement it on a computer.

Bibliography

Steven Haddock and Casey Dunn. (2010) *Practical Computing for Biologists*. Oxford University Press ISBN: 0878933913
Tiago Antao. (2022) *Bioinformatics with Python Cookbook: Use modern Python libraries and applications to solve real-world computational biology problems.* Packt Publishing. ISBN: 1803236426

■ Omics 1: Introduction to Omics Technologies

Number of hours: 24 (Lectures: 20, Practicals: 4)
Year/Semester: Master's 1 / Semester 1
Language: French/English

Objectives

- Outline the main historical milestones in 'omics' technologies and identify the major issues and challenges of the coming decades in terms of population biology and human health.
- Identify and describe high- and ultra-high-throughput technologies enabling the generation of data analysable by bioinformatics tools: Next-Generation QPCR, Next-Generation Sequencing (^{1st}to^{4th}generation, DNA-seq, RNA-seq), various microarrays and chip-on-chip technologies, and proteomics techniques.
- Gain an introduction to the basic strategies of omics data analysis and be able to list the various experimental or predictive approaches used to interpret this data: classification methods, Gene Ontology, promoter identification, and the identification of regulatory mechanisms.
- Understand the basic principles of human genetics (modes of inheritance, different types of variations in the human genome), and methods for identifying genetic factors associated with rare and common diseases.
- Explore the databases and resources that a biologist uses on a daily basis.

Contents

- Introduction / history of knowledge on genomes, the challenges and prospects of current 'omics' projects and those of the coming decades.

- Medium- and high-throughput omics technologies: Microarrays, Next-generation QPCR, Next-Generation Sequencing (1^{st}to4^{th}generation, ChIP-seq, RNA-seq, single-cell, spatial).
- Strategies for analysing omics data (clustering methods, GO, identification of promoter regions/transcription factors)
- High-throughput proteomic approaches (two-dimensional electrophoresis, mass spectrometry, protein chips, single-protein) and an introduction to metabolomics
- Genomic variation and concepts in human genetics.

Teaching methods
Face-to-face sessions and practical exercises

■ Scientific writing workshops

Number of hours: 24 hrs
Year/Semester: Master's 1 / Semester 1
Language: French

Objectives
Students will learn to:

- **Analyse** raw biological data.
- **Present** results in graphical and statistical form.
- **Compile** complete figures for publication.
- **Write** the various sections of a scientific article.

Content
The Teaching unit covers all stages of producing a scientific publication :

1. Introduction to the principles of publication
2. Processing and analysis of raw data
3. Statistical analysis and graphical representations
4. Organisation of figures
5. Drafting of sections:
    - Results
    - Introduction
    - Discussion
    - Abstract + graphical summary
6. Finalising the article
7. Individual feedback interviews

Teaching methods
- Competency-based learning
- Small-group work and personalised support

■ Genome editing tools — Course

Number of hours: 24 hours
Year/Semester: Master's Year 1 / Semester 1
Language: French/English

Objectives
This Teaching unit introduces genetic engineering tools for manipulating and modifying genomes and gene expression.
Students will be required to:

- **Select** appropriate expression vectors.
- **Design** a viral vectorisation strategy
- **Design** a KD/KO/KI strategy
- **Write** recombinant protein production systems (prokaryotes and eukaryotes).

Content

- Enzymes and cloning vectors
- Modern cloning methods
- Recombinant protein production (prokaryotes & eukaryotes)
- Viral vectors for gene transfer
- Knockdown / Knockout / Knock-in
- CRISPR-Cas9

Teaching methods

Lectures and active participation.

Bibliography

Principles of Genetic Engineering, Sandy PRIMROSE, Richard TWYMAN, Bob OLD, DE BOECK UNIVERSITÉ

■ Genome manipulation tools — Workshops

Number of hours: 24 hours (practical work 24 hours)
Year/Semester: Master's 1 / Semester 1
Language: French/English

Objectives

Introduction to genetic engineering tools for manipulating and modifying genomes and gene expression.
Be able to:

- **Select** vectors suited to a gene expression strategy.
- **Design** a viral vectorisation strategy.
- **Design** a knock-down, knock-out or knock-in strategy.
- **Develop** oligonucleotide design strategies for: cloning DNA into an expression vector, modifying DNA through directed mutagenesis or the addition of tags.

Contents

- Cloning of a sequence encoding a protein or small RNA (plasmids/viral vectors, constitutive/inducible expression, stable/transient expression, etc.)
- Choice of strategies: Restriction enzymes and modification/PCR/Gibson/Golden Gate/Gateway cloning…
- Expression of native, fused or labelled proteins
- Knockdown (siRNA, shRNA)
- Genome editing via CRISPR-Cas9

Teaching methods

- Setting up a toolkit
- Small-group work
- Use of specialised web tools
- Submission of continuously assessed reports

Bibliography

Primrose, Twyman & Old — *Principles of Genetic Engineering*, De Boeck Université.

■ Bibliographic research tools

Number of hours: 0 hours (introductory Teaching unit)
Year/Semester: Master's 1 / Semester 1
Language: French

Objectives

- **To search** effectively for scientific articles.
- **Use** databases (PubMed, etc.).
- **Manage** references using dedicated software (Zotero).

Content

Introduction to research and bibliography management tools (PubMed, Zotero, etc.). Guidance on formatting and organising bibliographic data within the context of a project

Teaching methods

Training materials + exercises
Library workshops tailored to students' needs

■ Foundations of Organisations and Management I

Number of hours: 24 (lectures)
Year/Semester: Master's 1 / Semester 1
Language: French

Objectives

- **Describe** an organisation.
- **Identify** an organisational problem.
- **Analyse** managerial challenges.
- **Organise** a project.
- **Implement** appropriate management practices.

Content

Two parts:

1. Theoretical and practical foundations for understanding the diversity of organisations and managerial challenges (16 hours)
    - Culture, power, strategy, decision-making, management tools
2. Introduction to project management
    - Objectives, planning, internal/external communication

Methods

Lectures and case studies.

Bibliography

Organisational Theory (A. Desreumaux), EMS Editions: 2015 (3rd ed.)
Organization Theory: Challenges and Perspectives. Mc Aulay et al. (2007) Pearson
Mintzberg on Management: Inside Our Strange World of Organisations (H. Mintzberg), [Management: A Journey to the Centre of Organisations, Free Press [Eyrolles Ed. d'Organisation] 1989 [1998]
Project Management, Garel, G. (2011). La découverte, Repères collection,

Anti-manual of project management: dealing with uncertainties, Thomas Reverdy, 2021, Dunod
Project management practices; 46 tools and techniques for making the right decision, Vincent Drecq, 2020, Dunod

■ Foundations of Organisations and Management II

Number of hours: 24 (tutorials)
Year/Semester: Master's Year 1 / Semester 2
Language: French

Objectives
To be able to:

- **Work** within a highly interdisciplinary group
- **Understand** and use tools for team leadership and collective intelligence
- **Master** the theoretical challenges of in situ design

Content

- Acquire project management and entrepreneurial skills through an intensive two-day interdisciplinary project. Each year, students tackle a theme linked to a major transition (or technological challenge), to which they must provide a response in a format defined by the teaching team (e.g. business project, initiative project, future scenarios, creation of a work of art, etc.)
- In addition to the project work, students will attend various course Teaching units over the two days to acquire new knowledge
- Introduction to the use and challenges of 'Canva'-type tools (economic model, circular model, impact models, etc.). Innovative design course to develop reflexes and the ability to produce prototypes and/or artefactual solutions to a given problem.

Teaching methods
Face-to-face

Bibliography
Lean Startup, Ries, 2012, Pearson
Value Proposition Design, Pigneur et al, 2015, Pearson
58 Tools for Systems Design: Towards Planet-Centred Design, Daumal, 2023 Eyrolles

■ Scientific Communication and English

Number of hours: 24 hours (tutorials)
Year/Semester: Master's 1 / Semester 2
Language: English

Objectives

- Give a presentation in English on a topic of your choice,
- Read an article in English, identify the key points and present them in English.
- Listen to audio or video materials on biology and health issues and summarise them in writing or orally.
- Acquire and use technical vocabulary relating to biology and health.

Methods
Face-to-face and distance learning

Bibliography
Glendinning Eric H et al. *Professional English in Use: Medicine*. Revised edition. Cambridge University Press 2015.

Teaching units for the Experimental Research (RE) track (9 ECTS)

Biological Data Management: Semantic Web

Number of hours: 24 hours (Lectures: 8 hours, Tutorials: 8 hours, Practicals: 8 hours)
Year/Semester: Master's 1 / Semester 2
Language: French/English

Objectives
To be able to:

- Access biomedical data available on the web
- Formulate queries to explore this data
- Modelling medical knowledge using formal languages that can be understood by machines
- Symbolic reasoning based on medical data

Content
The lessons in this course focus on biomedical knowledge graphs:

- Modelling knowledge graphs
- Linked data concepts
- Querying knowledge graphs
- Ontology concepts in biomedicine
- Inference of new knowledge
- Applications of ontology in biomedicine

Teaching methods
Teaching will take the form of lectures based on scientific publications. It will also include the sharing of knowledge, expertise and practical scenarios.

Introduction to Clinical Research

Number of hours: 24hrs
Year/Semester: Master's 1 / Semester 2
Language: French/English

Objectives

To understand the main types of clinical research
To understand the methodological foundations of clinical studies
Understand the sequence of stages in a clinical research project
To learn about the different roles in clinical research and their respective functions within a project.

Content
Principles and types of clinical research (academic, industry-sponsored, translational)
Specific features of clinical research compared to other life sciences experiments (IR/NIR, patients and research, ethics)
Methodological foundations of clinical research
Introduction to clinical pharmacology (development phases) The conduct of a clinical trial from start to finish.

Teaching methods

Face-to-face lectures and tutorials enable students to acquire theoretical knowledge and put it into practice

Exploring metabolism in diseases

Number of hours: 24 (lectures: 17 hours, tutorials: 7 hours)
Year/Semester: Master's 1 / Semester 2
Language: French

Objectives

- To gain a general understanding of integrated and cellular metabolism
- Be able to distinguish between homeostatic and pathological metabolism Be familiar with current approaches to the study of metabolism
- Propose an appropriate approach based on the question posed
- To present this information in a short oral presentation

Contents

General concept of energy metabolism (2 hours 40 minutes) Xavier Prieur: Fundamental principles of cellular metabolism, energy substrates and cellular phenotype (examples from metabolic diseases, oncology and immunology), energy supply and exchange, and inter-organ communication; concept of metabolic flexibility

Assessment of cellular metabolism (2 hours 40 minutes) (Claire Pecqueur): Various techniques for analysing mitochondrial activity and oxygen consumption. Exploration of fluxomic approaches to decipher the active metabolic pathway. Analysis of a cell's dependence on and preferences for substrates in different situations (fasting or post-meal, normal or tumourigenic, activated or at rest, etc.)

An integrated view of in vivo metabolism (4 hours):
Kinetic studies of labelled molecules – In vivo fluxomics (Khadija Ouerram) PET and metabolic imaging (18-F glucose tracking) (see Françoise Kraeber Bodéré)
In vivo metabolic phenotyping (Xavier)

Systems biology of metabolic data (4 hours) (Mikael Croyal, Yann Guitton, Damien Eveillard): Metabolomic, lipidomic and high-throughput metabolite analysis: principles of analytical chemistry (mass spectrometry, NMR, etc.), analysis of metabolic networks using big data.

Metabolic stress and cellular remodelling (4 hours): Cellular stress and metabolism (Xavier Prieur), Hypoxia resistance and metabolic switching (Claire Pecqueur), overview of immunometabolism (Aurélie Moreau)

Tutorial: 6.40 am
An integrated approach: A typical Cell Metabolism or Nature Metabolism article examining a key phenomenon. Students will be able to choose from a selection of articles based on their specialisation (cardiometabolic, nutrition/health, immunometabolic, or oncometabolic)
Tutorial 1: 1 hour 20 minutes after reading, summarise the scientific question in a graphical abstract (1 hour 20 minutes)
Tutorial 2: highlight a method
Presentation session: 4 hours, flash poster
Exam: a scientific question is posed -> propose an experimental design to answer the question.

Teaching methods

Lectures – Tutorials: analysis of articles and flash poster presentations

Genome manipulation tools: practical sessions

Number of hours: 24 hours (lectures: 2 hours, practicals: 22 hours)
Year/Semester: Master's 1 / Semester 2
Language: French/English

Objectives

This Teaching unit aims to illustrate and enable the use of tools for manipulating and modifying genomes.

- Design a knockout strategy
- Implement a CRISPR/Cas9 strategy (2020 Nobel Prize) to achieve a genetic knockout.
- Analysing and presenting experimental results
- Integrate their experimental results into a broader context

Content

Gene editing using the CRISPR/Cas9 technique has transformed research practices in many laboratories. It is currently used to deactivate or manipulate genes. This technology is employed in these practical exercises to knock out a gene in E. *coli*.

The steps are as follows:

- Analysis of the GFP sequence
- Definition of crRNA sequences enabling the silencing of GFP.
- Construction of an expression plasmid enabling the expression in bacteria of an sgRNA targeting GFP and Cas9.
- Co-transformation of E. *coli* bacteria with plasmids encoding GFP, an sgRNA targeting GFP and Cas9.
- Induction of GFP expression with or without sgRNA and Cas9 in bacteria
- Observation and analysis of differences in GFP expression.
- Performing a T7 endonuclease assay to analyse the silencing of the eukaryotic P53 gene

Teaching methods

Practical work in pairs in a fully equipped laboratory allowing experiments to be carried out under professional conditions

Bibliography

Principles of Genetic Engineering, Sandy PRIMROSE, Richard TWYMAN, Bob OLD, DE BOECK UNIVERSITY Publishing

Stem Cells and Organoids

Number of hours: 24 hours (Lectures: 16 hours, Tutorials: 8 hours)
Year/Semester: Master's 1 / Semester 2
Language: French/English

Objectives

Identify the hypothesis and experimental approach in an article
Search for bibliographic resources
Analyse and interpret scientific results

Content

Lecture section

- Human stem cells (General concepts: developmental biology and cell fate – Pluripotency – foetal and adult stem cells)
- Multicellular systems derived from stem cells (introduction to organoids, impact of environmental changes on organoids, complex organoids derived from pluripotent stem cells, 3D culture models

Tutorial section:

- Application of stem cell culture processes
- Identification of hypotheses and the experimental approach in a selected article
- Analysis of the results of a scientific study, selection of articles following a literature review

Teaching methods
Lectures and tutorials, both face-to-face and online

🟦 Innovative Strategies in Therapy

Number of hours: 24 (Lectures: 14, Tutorials: 10)
Year/Semester: Master's 1 / Semester 2
Language: French

Objectives

- identify the key stages of proof-of-concept studies in the clinical development of a biotherapy
- form a reasoned opinion on a range of therapies, including gene therapies, cell therapies, drug therapies and immunotherapies
- assess the need for multidisciplinary knowledge in developing a healthcare treatment
- summarise a research topic and discuss it with students and academic staff as part of a summary presentation based on the analysis of two scientific articles.

Content
Lecture component – 14.67 hours
Following an introductory lecture, two examples of therapeutic strategies currently in use will be presented for each of the associated topics:
Cell therapies following allogeneic haematopoietic stem cell transplantation
Gene therapy for SCID-X
Generation of monoclonal antibodies for therapeutic use
Transfer of genetically modified lymphocytes
From skeletal pathophysiology to reconstruction
Duchenne muscular dystrophy
Faecal transplantation
Phage therapy
Cardiovascular stem cells
Cardiovascular pharmacotherapy
Tutorial session – 9.33 hours: Two articles related to a given topic will be distributed to a group of 2 to 3 students, who will be required to present them in the form of graphic summaries.

Teaching methods
All classes will be delivered face-to-face.
Face-to-face or online surveys will be conducted at the start of the semester to assess prerequisites in immunology and/or physiology, and then regularly during the course to ensure that students understand the key concepts. Videos and photos (toolkit) will be made available on Madoc to illustrate the lectures and techniques.

Self-assessment tests and sample exam questions will be provided, and an online forum will be set up to facilitate a Q&A exchange between teaching staff and students. Students will work independently and prepare summaries of two articles in both written and graphical formats.

Bibliography

Principles of Genetic Engineering, Sandy Primrose et al. (DeBoeck Publishing)
Immunology - The Course by Janis Kuby and Judy Owen et al. (Dunod Publishing)
"*Fundamentals of Basic and Clinical* Immunology" by Abul K. Abbas et al. (Elsevier)

Teaching Teaching units for the Clinical Research (RC) track (9 ECTS)

Practical Approach to Clinical Research

Number of hours: 24 (Lectures: 10, Tutorials: 14)
Year/Semester: Master's 1 / Semester 2
Language: French/English

Objectives

- To understand the context of research involving human subjects
- Grasp the specific characteristics of different therapeutic specialities
- To be familiar with the different types of clinical trials
- Understand the organisation and structure of academic and industrial teams conducting clinical research
- Write a scientific paper in the field of clinical research

Content

Introduction to the context of healthcare, clinical reasoning, human experimentation and evidence-based medicine
Industrial clinical research
Clinical research projects in different contexts
Careers in clinical research
Organisation and activities of a clinical research team
Scientific writing in clinical research

Teaching methods

Face-to-face lectures and tutorials

Introduction to Biostatistics

Number of hours: 24 (lectures: 12, tutorials: 12)
Year/Semester: Master's 1 / Semester 2
Language: French/English

Objectives

To understand the concept of sampling
Master the standard parametric statistical tests
Introduce the limitations of these tests
Begin to critically evaluate the methods used in the literature

Content

Mathematical basics and probability concepts

Introduction to statistics (concepts of sampling variation, concepts of random variables),

Descriptive statistics and confidence intervals

Introduction to parametric inference tests (Student's t-test, Chi-squared test, Pearson's correlation, etc.)

Teaching methods

Face-to-face lectures and tutorials

Introduction to Clinical Research

Number of hours: 24 (lectures: 14, tutorials: 10)
Year/Semester: Master's 1 / Semester 2
Language: French/English

Objectives

To understand the main types of clinical research
To understand the methodological foundations of clinical studies
Understand the sequence of stages in a clinical research project
To learn about the different roles in clinical research and their respective functions within a project

Content

Principles and types of clinical research (academic, industry-sponsored, translational)
Specific features of clinical research compared to other life sciences experiments (IR/NIR, patients and research, ethics)
Methodological foundations of clinical research
Introduction to clinical pharmacology (development phases)
The conduct of a clinical trial from start to finish

Teaching methods

Face-to-face lectures and tutorials

Teaching units: Research and Analysis of omics data (RA) track (9 ECTS)

Omics 2-1: Genomic data analysis

Number of hours: 24 (Lectures: 5 hours, Tutorials: 19 hours)
Year/Semester: Master's 1 / Semester 2
Language: French/English

Objectives

Use a computing server by learning simple commands in the Bash language
Use tools to analyse raw data from high-throughput DNA sequencing
Align sequences (reads) to a reference genome using the appropriate tools
Identify and interpret genetic variations using detection methods

Content

Part 1: Epidemiological genetics

· Genome-wide association studies (GWAS)

Part 2: Analysis of high-throughput genomic data (“NGS”)

· Introduction to bioinformatic analysis of NGS data

· NGS file formats and key Bash commands

· From fastq files to VCF files: Alignment, visualisation of reads and detection of genetic variants

· Interpretation of genetic variants

· Introduction to rare variant association studies and enrichment tests (burden tests)
Rare variant association studies

Teaching methods

Lectures and practical sessions in the computer lab

🟦 Omics 2-2: Functional genomics analysis

Number of hours: 24 (Lectures: 5, Tutorials: 3, Practical sessions: 16)
Year/Semester: Master’s 1 / Semester 2
Language: French/English

Objectives

- To understand and apply experimental designs for transcriptome, proteome and metabolome exploration protocols.
- Carry out and evaluate primary analyses, i.e. conversion of raw data, annotations, sample quality assessment, selection of tools, and testing for batch effects, specific to transcriptomics, proteomics and metabolomics.
- Generate and evaluate exploratory data analyses (PCA, clustering, correlations).
Assess and perform differential analyses and evaluate the results obtained.
- Formulate hypotheses on differential factors using enrichment methods (Gene Oncology, Gene Set Enrichment Analysis, MetaboAnalyst, etc.) and association with covariates (cellular, clinical, etc.).
- Through group presentations in English, students will develop an appreciation for the scientific method, cultivate an ability to synthesise information, share and exchange information with colleagues, and summarise and communicate the main objectives and results drawn from scientific articles.
- Apply the knowledge acquired on advanced omics analysis methods by carrying out a small-group educational project based on this learning.

Content

Lectures (4 x 1 hour 20 minutes)

1) Introduction to the analysis of ‘omics’ data:
• Introduction/refresher on the basic methods of functional genomics analysis;
• Gaining an overview of an analysis protocol and an introduction to interpreting the expected results;
• Development of an experimental design for a standard "omics" exploration protocol.

2) So-called "bulk" transcriptomic analysis:

• Presentation of the “bulk RNA sequencing” method and the format of the data generated;

• Understanding the specific analytical aspects of this type of protocol and the expected results.

3) So-called “single-cell” transcriptomic analysis:

• Presentation of the ‘single-cell sequencing’ method and the format of the data generated;

• Understanding the specific analytical considerations for this type of protocol and the expected results.

4) Proteomic and metabolomic analyses:

• The different modes of analysis;

• Interpretation of results from proteomic and metabolomic methods;

• Introduction to the processing of these types of data.

Tutorials (2 hours 40 minutes)

Presentation of an article (multi-omic data) at the end of the semester.

Practical sessions (4 x 4 hours)

• Primary analyses and experimental designs

• Exploratory analyses and formulation of functional hypotheses

• Differential analyses and interpretations

• Completion of a sub-group project with presentation.

Teaching methods

Lectures and practical sessions in the computer lab

🟦 Biological Data Management – Semantic Web

Number of hours: 24 (Lectures: 8, Tutorials: 8, Practical sessions: 8)
Year/Semester: Master’s 1 / Semester 2
Language: French/English

Objectives

By the end of this course, students will:
• Be able to access biomedical data available on the web
• Formulate queries to explore this data
• Model medical knowledge using formal languages that can be understood by machines
• Reason symbolically about medical data

Content

The teaching for this Teaching unit focuses on biomedical knowledge graphs available on the web:
• Modelling knowledge graphs
• Concepts of linked data
• Querying knowledge graphs
• Concepts of ontology in biomedicine
• Inference of new knowledge Applications of ontology in biomedicine

Teaching methods
Lectures and practical sessions: face to face

Work experience (9 ECTS)

Study and research work for the placement, and presentation

Number of hours: 0
Year/Semester: Master's Year 1 / Semester 2
Language: English

Objectives
Students must find their own placement, which requires them to put their communication skills into practice (CV, cover letter, interview). However, a number of placements in laboratories (mainly university laboratories in Nantes) and hospital departments (mainly the Nantes University Hospital) will be offered to students. The aim of the placement is to enhance the student's professional profile.

By the end of this course, students will be able to:

- **conduct** research and produce a literature review on a given topic (analysis of articles from scientific journals in English)
- **carry out** experimental protocols, having understood all the steps involved
- independently **master** the techniques learnt during their placement
- **keep** a laboratory notebook in accordance with good laboratory practice
- **critically analyse** the results of their experiments
- **present** their work clearly, accurately and rigorously in the form of an oral presentation
- **answer** questions from the examination panel.

This 'Work Placement' Teaching unit is designed as an introduction to the professional world, under the supervision of a placement supervisor, researcher or lecturer-researcher in an academic or industrial setting, in France or abroad. It takes place at the end of the second semester, over an eight-week period that forms part of the study programme.

This professional training Teaching unit takes several forms, depending on the student's career path:

- either an internship in a research laboratory or in a company whose field of activity is related to the biological sciences and the career profile chosen by the student (experimental research, biological data analysis)
- or an internship in a hospital department for students who have chosen the Clinical Research career path.
- or a literature review on a research topic in biology

Teaching methods
Students are supervised by a placement supervisor within the host organisation.
Each student is supported by a tutor from the teaching team who ensures the internship runs smoothly.
To help students write their placement report, a thesis writing guide is available on the university's Moodle learning platform.

I3 MASTER PROGRAMME 2nd Year

The year comprises:

- specialised teaching units,
- the design of a research project,
- a 6-month internship
- work placements.

Teaching units specific to the I3 programme (12 ECTS)

Keys to success for healthcare students

Number of hours: 24 hrs (lectures: 24)
Year/Semester: Master 2 / Semester 3
Language: French

Objective: to provide students with the necessary knowldege required for successful completion of the second year of the Master's programme

Content
This Teaching unit is designed to provide students from health-related curricula who enter the programme with the necessary revision and foundations for their success.
Concepts related to data analysis and handling will be delivered via a blended learning approach. Specific refresher courses (cell biology, biochemistry, molecular biology, immunology, animal models) will also be offered to students.

Teaching methods
Hybrid, face-to-face, round table

Innovative Concepts in Immunology

Number of hours: 24hrs
Year/Semester: Master's 2 / Semester 3
Language: French / English

Objectives

- Contextualise a research problem based on existing scientific data
- Formulate a scientific strategy, including the research question and a multidisciplinary experimental approach
- Critically evaluate results in light of the literature
- Propose ideas for the future direction of the project and/or the dissemination of results

Content
Each topic will focus on an innovative concept in immunology and be led by an expert researcher. Students will give oral presentations in small groups on an article related to the topic, which they will have studied in advance. The researcher will then summarise the three articles presented per session and guide the students in developing their critical thinking skills

Teaching methods
Face-to-face

Immunopathology

Number of hours: 24 hrs (Lecture)
Year/Semester: Master's 2 / Semester 3
Language: French

Objectives

To understand the cellular and molecular mechanisms driving immune-mediated diseases and anti-infectious immune responses, and their implications for translational and clinical research.

Content

The course will be delivered by researchers who are experts in their field, in the form of lectures and seminars.

The programme comprises three sections:

- Immunity and Systems
- Autoinflammatory and autoimmune diseases
- Anti-infectious responses

Teaching methods

In the form of critical reading of articles

Bibliography

The Biology of Cancer by Robert Weinberg & Janeway's Immunobiology

🟦 Immunotherapies

Number of hours: 24 hours (lectures: 24 hours)
Year/Semester: Master's/Semester 3
Language: French/English

Objectives

- Explain the different immunological strategies developed to combat cancer
- Categorise these strategies
- Apply these strategies to new research areas
- Integrate major advances in immunology relevant to oncology
- Propose appropriate experimental approaches.

Content

As part of this Immunotherapies Teaching unit, teaching will be delivered by researchers who are experts in their field in the form of lectures.

The programme comprises two sections :

- Cancer Immunotherapy
- Cell and gene therapies (for CMD I3)

Methods

Teaching will take the form of lectures, with extensive use of examples drawn from scientific publications. Teams comprising researchers and hospital practitioners will be formed to best illustrate the 'bench-to-bedside' concept.
The teaching will take place in person.

Bibliography

The Biology of Cancer by Robert Weinberg & Janeway's Immunobiology.

🟦 Immune Disorders and Therapies

Number of hours: 48 hrs
Year/Semester: Master's 2 / Semester 3

Language: French

Content
Immunopathology
Immunothérapies

Teaching methods
Face-to-face

Cross-disciplinary Teaching units (6 ECTS)

Journal Club

Number of hours: 24 hrs
Year/Semester: Master 2 / Semester 3
Language: French / English

Objectives

- Conduct literature review in biomedical research;
- Design a research project in this field;
- Determine the most appropriate strategies for its implementation;
- Present this project and a relevant scientific publication orally;
- Defend and argue in favour of the project presented and the chosen scientific publication.

Content
The student will give an oral presentation of the research project they will develop during their placement, placing it (1) in an international context, supported by a relevant scientific publication (not from their host laboratory), and (2) in the context of their host team.

Teaching methods
The requirements will be clarified during an introductory lecture.

Interdisciplinary Project – Management I

Number of hours: 21
Year/Semester: Master 2 / Semester 3
Language: French / English

Objectives

- Acquisition of specific tools for project management in uncertain situations
- Responding to a call for proposals
- Knowing how to plan and organise over time
- Managing a team in a situation of uncertainty
- Knowledge and understanding of the technological, human and societal challenges associated with transitions
- Critical and analytical perspective on technologies
- Basic knowledge of local, national and international innovation systems.

Content
As part of this Teaching unit, students will deepen their knowledge and skills in project management and explore the major

contemporary challenges of innovation and technology management, as well as transitions.
Two themes will be covered:

- Contemporary project management practices (tutorials/practical work): you will build on the knowledge acquired during semesters 1 and 2: an in-depth understanding of research organisation through calls for proposals and the inherent difficulties, discovering and applying contemporary project management tools, discovering agile methods for operating in conditions of uncertainty, etc.
- Innovation management in transitions (lecture): you will explore key concepts through elements of general culture, and will also develop a critical and relevant perspective on both theoretical and more topical subjects (the role of technology in transitions, understanding innovation processes, the challenges of disseminating and gaining acceptance for innovations and technologies in society, taking ecological constraints into account in innovation models, etc.). In particular, you will address three themes in this course: the question of the definition and feasibility of managing innovation; the question of spatial anchoring within innovation ecosystems; and the question of paradigm shifts (growth, ecology, frugality, etc.) through innovation.

Teaching methods
Face-to-face

Bibliography

• *Project Management*, Garel, G. (2011). La découverte, Repères collection,
• *Antimanual de management de projet : composer avec les incertitudes*, Thomas Reverdy, 2021, Dunod
• *The Essentials of Innovation Management*. Tellier, A. (2022). Editions Ellipses.
• *Innovation Management*. Afuah, A. (2003). New York: Oxford University Press.
• *Project Management Practices; 46 Tools and Techniques for Making the Right Decision*, Vincent Drecq, 2020, Dunod

Interdisciplinary Project – Management II – Professional Integration

Number of hours: 24 hrs
Year/Semester: M2 / S3
Language: French / English

Objectives
The learning outcomes are achieved in two stages:
- interview with a professional in a real-life scenario (recruitment agency): preparing a CV based on a job description
- debriefing of stage 1 with the course leaders via an individual appointment

Content
Teaching unit on support for professional integration – preparing for and conducting interviews with professionals.

Teaching methods
Role-play and individual interviews

Teaching units for the Experimental Research (RE) track (12 ECTS)

Big Data 2 – Multivariate Analysis

Number of hours: 24 hours (Lectures: 8 hours, Tutorials: 16 hours)
Year/Semester: Master's 2 / Semester 3
Language: French / English

Objectives
To learn multivariate analysis techniques
To learn data discrimination techniques
To learn data regression techniques
To learn data classification techniques

Content
Implement data analysis techniques in Python
Using the results of the implementation to identify relevant biological findings
Introduction to multivariate data analysis
Introduction to Python programming libraries for applying multivariate analyses

Innovative Therapeutic Strategies II

Number of hours: 24 hrs (Lectures: 12, Tutorials: 2, Practical sessions: 10)
Year/Semester: Master's 2 / Semester 3
Language: French / English

Objectives
- Identify the key stages of proof-of-concept studies in the clinical development of a biotherapy
- Form a reasoned opinion on a range of therapies, including gene therapies, cell therapies, drug therapies and immunotherapies
- Appreciate the need for multidisciplinary knowledge to develop a medical therapy

Content
Lectures: presentation of new strategies currently being developed to treat a disease in fields related to the various postgraduate programmes.
Speakers will be invited to begin by tracing the history of the development of treatments and tools:

New bioactive microbial metabolites for therapy, next-generation CAR-T cells for cancer, enhancement of anti-cancer therapies
Tutorial: introductory/presentation session
Practical work: preparation sessions during which students must read the articles, submit a detailed outline, and then prepare their poster. The poster is to be handed in at the end of the practical work.

Teaching methods
All teaching will take place in person.
Video and photographic material (toolkit) will be made available on Madoc to illustrate the lessons and techniques.
Self-assessment tests and sample exam questions will be provided, and an online forum will be set up to facilitate a Q&A exchange between teaching staff and students. Students will work independently and prepare a poster.

Industry and Technology

Number of hours: 24 (lectures: 24)
Year/Semester: Master 2 / Semester 3
Language: French / English

Objectives

- Select the information required to develop an appropriate experimental approach based on their knowledge and the literature
- Identify the most appropriate complementary research techniques to develop a research project
- Apply these techniques to a research project
- Determine their limitations in the implementation of a research project.

Students will also gain an understanding of careers within the industry and how the skills acquired during the Master's programme can be applied in practice.

Content

The aim of this Teaching unit is to present innovative technologies in biomedical research within the context of research projects conducted by various laboratories in Nantes. It will focus on two main areas:
- a technological component: new technological approaches in biomedical research, such as transgenesis using the CRISPR/Cas9 approach, high-throughput sequencing and its applications, multi-parameter analysis via cell imaging or flow cytometry, and IPs, through various research projects;
- an industrial component: various speakers will be invited (former students of the Nantes Master's programme, start-ups, biotechnology companies, etc.) to present their professions and career paths.

Teaching methods
Lectures and round-table discussions

Animal Models and Integrated Physiology

Number of hours: 24 hours (lectures)
Year/Semester: Master's 2 / Semester 3
Language: French / English

Objectives

- To provide students with a solid foundation in integrative biology and the essential knowledge for an ethical and scientific approach to the use of animals in biomedical research (in the fields of anatomy, behaviour, ecology, environmental footprint, evolution, genetics, genomics and pathophysiology).
- To promote the integrative analysis of animals, particularly in the context of the post-genomic era, at the interface of organoid, in vitro and in silico approaches.
- To understand the latest fundamental and methodological advances, as well as the most recent conceptual principles, for the study of genes and their products, including their integrated regulation, their pathophysiological implications, and their use as therapeutic targets and in innovative therapies.

Content
Introduction
From the genome to integrative biology/The rational use of animals/Legislation and ethics in experimental animal research/From the genome to integrative biology
Integrated genomics

- Transgenic, Knock-Out and Knock-In rodents and immunophenomics.
- Spontaneous genetic model for aetiological, pathophysiological and therapeutic approaches to human genetic diseases
- High-throughput study of gene function (zebrafish, Xenopus)
- Genetic modelling and evolution (animal and human phylogeny, choice of animal model) Models of environmental and post-transcriptional regulation
- Epigenetic mechanisms of gene expression control and programming
- MicroRNAs, physiological and pathological roles
- Roles of extracellular vesicles in intercellular communication
- Nutritional imprinting

- Nuclear medicine and phenotypic imaging
- Cognitive models of pathophysiology and therapeutic approaches
- Interface between the autonomic nervous system and the immune system
- Environmental factors
- Large animal models (translational and precision medicine, osteoarticular repair, transplantation
- In vivo approaches in animal imaging

Teaching methods
Lectures/Courses

Teaching units for the Clinical Research (RC) track (12 ECT)

🟦 Design, implementation and conduct of a clinical trial

Number of hours: 48 (Lectures: 38 hours, Tutorials: 10 hours)
Year/Semester: Master's 2 / Semester 3
Language: French / English

Objectives
• To understand the major developments (current or anticipated) in various fields of healthcare and health research
• Master the fundamental knowledge required to understand and implement a clinical research protocol using innovative concepts in the fields of healthcare, biomedical research and clinical research practice
• Integrate innovative clinical research approaches in an appropriate and relevant manner into a protocol currently being designed
• Master the scientific process for designing a clinical trial
• Incorporate regulatory compliance into the design of a clinical trial
• Understand and master good clinical practice for the conduct of a clinical trial

Content
Introduction (The value and benefits of clinical research)
Essential tools for clinical research
Technical and regulatory approach
Compiling a bibliography
Good clinical practice: the complete FORMEDEA course (to be completed and validated independently)
Developing a clinical research protocol (in response to a call for tenders)
Sources of funding for a clinical trial
Letter of intent (LOI) and clinical research protocol
Protocol design (formulation of the research question, choice of experimental design, evaluation criteria, appropriate statistical analyses based on the objective, inclusion and exclusion criteria, drafting of the flow chart)
Knowing how to draw up a study budget
Implementation and conduct of a clinical trial:
Evaluation and preparation
Conducting a clinical trial: Promotion and Investigation
Personal project: drafting a letter of intent
Innovations in healthcare
Scientific innovations: Genetics, epigenetics, genomics, transcriptomics, microbiota
Organisational innovations: 4P Medicine, pharmaceutical industry, drug development models, ethical and legal aspects
Innovations in clinical research practice: Patient-centred outcomes, telemedicine, innovative study design,

pharmacoepidemiology, imaging, electronic case report forms and data management, big data, remote study monitoring, assessment of tolerability and toxicity

Teaching methods
Lectures, seminars, small-group workshops, e-learning… Face-to-face, student-led seminars
Distance learning: Course preparation/summary and role as facilitator for mini-seminars (application of organisational skills, summarising scientific topics, coordination, communication, critical thinking)

Methodology for Clinical Research

Number of hours: 48 (Lectures: 40, Tutorials: 8)
Year/Semester: Master's 2 / Semester 3
Language: French / English

Objectives
• Be able to interpret the results of descriptive statistical analysis
• Be able to interpret the results of statistical modelling
• Be able to identify key findings in a statistical analysis report
• Be able to create the visual elements of an article (tables, figures) and write the results section
• Be able to outline the advantages and limitations of statistical methodologies used in clinical research

Contents
Collecting information: Database, Data management, Review, Reconciliation
Preparing data – Planning
Database creation, Handling missing data, Study design, Analysis population(s), Estimands, Superiority, Non-inferiority and equivalence.
Analysing data, Interpreting results
Interim analyses and multiple testing
Descriptive analysis of results, Concordance, correlation, causality, association, variable selection, Common regression models (interpretation: fit and interaction, propensity scores), bias
Validation of results
Medical, scientific, hospital, administrative and patient perspectives, Writing and publishing an article, Conference presentations, Intellectual property (patents, commercial exploitation), Scientific and economic impact.

Teaching methods
Lectures, seminars, small-group workshops, e-learning…

Teaching units for the Research and Analysis of omics data (RA) track (12 ECTS)

Omics 3: Epigenomics

Number of hours: 24 (Lectures: 15, Tutorials: 9)
Year/Semester: Master's 2 / Semester 3
Language: French / English

Objectives
By the end of this course, students will:
• identify and integrate a new level of gene expression regulation, epigenetics, through theoretical lectures and scientific talks.

• be able to define and describe DNA methylation processes, post-translational modifications of histones, and the roles of non-coding RNAs, and be able to assess the consequences of these mechanisms on gene expression and their implications in pathophysiology.
• will be able to identify and describe methods for analysing epigenetic modifications.
• will be able to use tools for analysing raw data from various applications of NGS (Next Generation Sequencing): ChIP-Seq and/or ATAC-seq, through practical work.

Content
- Epigenetics lecture / Non-coding RNA
• Introduction and epigenetic mechanisms (2 hours 40 minutes)
• Methods for analysing epigenetic modifications (1 hour 20 minutes)
• Non-coding RNAs (3 hours)
• miRNAs (2 hours 40 minutes)

- Lectures (4 x 1 hour 20 minutes): examples of topics covered in the lectures
• Post-GWAS, Mendelian randomisation and epigenetic approaches
• Nutrition and epigenetics
• Epigenetic mechanisms in cancer
• Multi-omics integration

- Practical sessions : Data analysis (3 x 3 hours)
• Practical: ChiP-Seq data analysis
• Practical: ATAC-Seq data analysis
• Practical: Post-GWAS data analysis (Polygenic Risk Score / Mendelian randomisation

Teaching methods
Lectures, talks, practical scenarios

Systems Biology 1

Number of hours: 24 (Lectures: 15 hours, Tutorials: 9 hours)
Year/Semester: Master's 2 / Semester 3
Language: French / English

Objectives
Learn how to model a metabolic network
Learn how to use optimisation methods to analyse metabolic networks
Learn how to model a simple biological phenomenon using ordinary differential equations
Learn how to model a biological network using a graph
Learn how to analyse a biological network from a graph structure perspective
Learn how to manipulate a graph using the Python language

Content
Introduction to graphs and characterisation of graph structure (global properties and centralities)
Introduction to metabolic networks
Introduction to modelling methods, including those derived from physical models such as ODE models, and the manipulation and solution of these models in Python.

Bibliography
Genome-scale models of microbial cells: evaluating the consequences of constraints. Price et al., Nature Reviews, 2004
Basic and applied uses of genome-scale metabolic network reconstructions of Escherichia coli. McCloskey, D et al., Mol. Syst.

Biol., 2013.
Analysis of biological networks. (Wiley Series in Bioinformatics): Björn H. Junker, Falk Schreiber.

Systems Biology 2

Number of hours: 24 hours (Lectures: 15 hours, Tutorials: 9 hours)
Year/Semester: Master's 2 / Semester 3
Language: French / English

Objectives

To learn how to use constraint-based approaches for metabolic engineering.
Model a gene regulation problem using Boolean logic and probabilistic models
Apply Boolean models to infer models from data.
Define a biological pattern and investigate its statistical significance in biological networks
Understand graph clustering algorithms applied to biological networks

Content

Logical models for studying gene regulatory networks and signalling networks (Petri nets, Boolean networks)
Probabilistic models for studying gene regulatory networks and signalling networks (Probabilistic Boolean Networks, Bayesian Networks)
Pattern analysis in biological networks and clustering algorithms for networks

Bibliography

Optknock: a bilevel programming framework for identifying gene knockout strategies for microbial strain optimisation. Burgard AP, Pharkya P, Maranas CD. Biotechnol Bioeng, 2003.
Minimal cut sets in biochemical reaction networks. Klamt S. and Gilles E.D., Bioinformatics, 2004.
Analysis of biological networks. (Wiley Series in Bioinformatics): Björn H. Junker, Falk Schreiber.

Big Data 2: Multivariate Analysis

Number of hours: 24 hours (Lectures: 8 hours, Tutorials: 16 hours)
Year/Semester: Master's 2 / Semester 3
Language: French / English

Objectives

To learn multivariate analysis techniques
To learn data discrimination techniques
To learn data regression techniques
To learn data classification techniques

Content

Implement data analysis techniques in Python
Using the results of the implementation to identify relevant biological findings
Introduction to multivariate data analysis
Introduction to Python programming libraries for applying multivariate analyses

Work experience (30 ECTS)

Master 2 Oral work experience

Year/Semester: Master's 2 / Semester 4

Language: French / English

Objectives

- Conduct a review of relevant literature;
- Apply the theoretical knowledge acquired to the development of a research project;
- Design scientific protocols;
- Select the most appropriate methodologies for implementing a research project;
- Critically analyse scientific results;
- Write and present an informative internship report;
- Defend hypotheses and results effectively during a discussion with an examination panel.

Content

Oral defence

Teaching methods

Immersion

Master 2 Report

Number of hours: 8

Year/Semester: Master 2 / Semester 4

Language: French / English

Objectives

- Conduct a review of relevant literature;
- Apply the theoretical knowledge acquired to the development of a research project;
- Design scientific protocols;
- Select the most appropriate methodologies for implementing a research project;
- Critically analyse scientific results;
- Write and present an informative internship report;
- Defend hypotheses and results effectively during a discussion with an examination panel.

Content

The student will undertake a 6-month placement in a university or private laboratory.

work experience Assessment

Number of hours: 16 (Lectures: 8, Tutorials: 8)

Year/Semester: Master's 2 / Semester 4

Language: French / English

Objectives

Learners will receive an assessment from the professional who supervised them during their placement, providing detailed feedback on their work.

Content

The purpose of this placement assessment form will be explained to students and supervisors. This form, completed by the supervisor, will be used to assess the work carried out by the student during their placement. This assessment will be taken into account in the final placement mark