SYLLABUS - THIRD SEMESTER (M2S3)

Master Biodiversity, Ecology and Evolution

International Pathway "Evolutionary Biology"

TITLE OF UNIT: Population genomics (Camille Roux, Tenured Researcher CNRS)

NUMBER of ECTS: 3
Number of hours: **Lectures/Tutorials: 24h**
Personal workload (hours expected to be dedicated to, including supervised projects): **48 hours**

Description of the module

General aims

- Simulating genomes from populations experiencing different demographic histories (contraction, expansion, migration).
- Be able to statistically test alternative scenarios in evolution to understand patterns of polymorphism (intrapopulation) and divergence (interspecies) in genomes.
- Identify in genomes the targets of natural selection.

Content summary

- Measure molecular diversity within populations whose genomes have been sequenced and understand the demographic history responsible for the observed pattern. Students will learn to describe real data sets and simulate different scenarios to identify the most realistic ones.
- Measure the divergence between different species and understand the demographic events that have occurred since ancestral separation.
- While demographic history impacts the entire genome, natural selection acts locally on the patterns of polymorphisms by rapidly fixing an advantageous allele, or by maintaining different alleles over long evolutionary periods or by eliminating deleterious mutations. Selection can also eliminate or promote the gene flow from another population. In this module we will see how to identify these different targets of selection.

Expected knowledge and skills:

- Extract information from genomes.
- Simulate genomes according to different historical and selective hypotheses.
- Statistically test the relevance of the different scenarios.

EVALUATION MODE (final exam, oral defense, report,...)	Ratio of the final grade
Final exam: Small research project and short presentation	**100%**
Ongoing assessment	**0%**

TITLE OF UNIT: Evolutionary genomics (Éléonore Durand, Associate Professor)

NUMBER of ECTS: 3
Number of hours: **Lectures: 18h, Tutorials: 9h**
Personal workload (hours expected to be dedicated to, including supervised projects): **45 hours**

Description of the module

General aims

- Better apprehend the content, organization and diversity of genomes.

- Acquire knowledge about the molecular and evolutionary processes (both adaptive and nonadaptive), that have led to the observed genome structure and organization of the information encoded whithin.
- Be able to understand and discuss comparative genomics studies, including their advantages and drawbacks.

Content summary
- How are genomes organized across various organisms (size, content, structure...)?
- What are the molecular and evolutionary processes underlying the genetic diversity and genome dynamics? Types of mutations, rate of emergence of new mutations and their effects at the molecular, phenotypic and fitness levels, evolution of the mutation rate, genetic signatures of natural selection.
- Where do new genes come from?
- How do non-genic regions evolve?
- Structural variations
- Evolution of regulatory networks

Expected knowledge and skills:
- Describe and understand how genomes are organized and evolve across various organisms (model and non-model species)
- Be able to discuss the molecular and evolutionary processes involved in generating the observed genome architecture
- Know the common methods to identify and analyze variation in genomes

EVALUATION MODE (final exam, oral defense, report,...)	Ratio of the final grade
Final exam (written evaluation on theoretical courses, applied courses and/or interpretation of scientific documents)	**70%**
Ongoing assessment (data analysis and small reports or oral presentations)	**30%**

TITLE OF UNIT: Macroevolution (Céline Poux, Associate Professor)

NUMBER of ECTS: 3
Number of hours: **Lectures: 18h**, **Practicals: 6h**
Personal workload (hours expected to be dedicated to, including supervised projects): **48 hours**

Description of the module

General aims
The objectives of this Teaching Unit are to give the students the theoretical and practical tools needed to understand and study the processes that have shaped the evolutionary history of groups of organisms, including diversification and trait evolution. Another goal is to develop student's critical thinking skills when reading scientific articles about paleontology and comparative phylogenetics.

Content summary
- Macroevolution: contribution of Paleontology:
* Modalities and Tempo of evolution
    1. Speciation: Emergence of species, speciation modalities
    2. The seventh evolutionary models
    3. Synthesis and model comparison to the fossil record
* Evolution and Development: Heterochronies
- Phylogenetic comparative methods to study macroevolution:
    1. Dating methods
    2. Reconstruction of ancestral characters and biogeographic history
    3. Trait evolution modelling
    4. Rate of diversification
- Metabarcoding
- History and Epistemology of Evolutionary Sciences

Expected knowledge and skills:
- Understanding paleontological and comparative studies
- Knowing the tools used for such studies
- Being able to analyze phylogenetic data
- Being able to understand and discuss the outcomes of the analyses
- Knowing the various controversies and major historical event in the history of Evolutionary Sciences.

EVALUATION MODE (final exam, oral defense, report,...)	Ratio of the final grade
Final exam (on theoretical courses, applied courses and/or interpretation of scientific documents**).**	**70%**
Ongoing assessment (short scientific report on a case study)	**30%**

TITLE OF UNIT: GLM Statistics (Sylvain Billiard, Associate Professor)

NUMBER of ECTS: 3
Number of hours: **Tutorials: 18h.**
Personal workload (hours expected to be dedicated to, including supervised projects): **54 hours**

Description of the module

General aims
Being able to analyze biological data and address ecological and evolutionary questions with Generalized Linear Models with Random and/or Fixed effects.

Content summary
- GLM basics with R: definition of a linear model, likelihood, deviance, likelihood ratio test, residuals analyses, Akaike information criterion, Bayesian information criterion
- The exponential family
- Mixed effects models
- Temporal and spatial datasets
- Variance heterogeneity
- Dealing with non-independence

Expected knowledge and skills:
Direct abilities:
- Writing a linear model to address a specific question
- Using the software R and various packages to analyze GLMs
- Evaluating the quality of a statistical models
- Interpretation of the results

Indirect abilities:
- Translating a question into a specific method
- Programming in R
- Improving some mathematical skills applied to statistics analysis

EVALUATION MODE (final exam, oral defense, report,...)	Ratio of the final grade
Final exam (Individual report of a real data analysis with GLMs)	**100%**
Ongoing assessment	**0%**

TITLE OF UNIT: Introduction to Bioinformatics (Sylvain Legrand, Associate Professor)

NUMBER of ECTS: 6
Number of hours: **Lectures: 27h, Tutorials: 27h**

Personal workload (hours expected to be dedicated to, including supervised projects): **90 hours**

Description of the module

General aims:

The objective of the module is to discover the basics of bioinformatics through an alternation between theoretical and practical parts, using mainly free web tools

Content summary:

Databases, sequence alignment, gene prediction, protein sequence analysis, phylogeny

Expected knowledge and skills:

- To be able to query databases and make relevant queries
- To understand the data structure
- To be able to choose an alignment software and the parameters adapted to a problem
- To know the algorithmic methods for sequence alignment
- To be able to use Blast software optimally to answer a specific question
- To know the methodology for gene prediction, whether bacterial or eukaryotic
- To know the methodology to analyze a protein sequence: to deduce its potential function, to have an idea of its cellular location
- To understand the main principles of molecular evolution and phylogenetic reconstruction
- To be able to build informative alignments for phylogenetic analysis
- To be able to reconstruct phylogenetic trees in Maximum Likelihood (ML) and Bayesian Inference (BI)

EVALUATION MODE (final exam, oral defense, report,...)	Ratio of the final grade
Final exam (written exam)	**50%**
Ongoing assessment	**50%**

TITLE OF UNIT: Project Management (Sophie Duquesne, Professor, Graduate Programme)

NUMBER of ECTS: 3
Number of hours: **Lectures: 6h, Tutorials: 14h**
Personal workload (hours expected to be dedicated to, including supervised projects): **52 hours**

Description of the module

General aims:

The aim of this course is to provide young scientists the necessary background to highlight the importance of the management in science. It sensitises young scientists to the central role of project management in their professional careers, and that a science project requires effective management in order to maximise its benefit.

Content summary:

Introduction to project management in science
a. Defining science projects
b. Lifecycle of a scientific project
Management of a scientific project
a. Project management processes (project planning and project execution)
b. Concepts and jargon in project management
c. Tools to efficiently manage a scientific project

Expected knowledge and skills:

The master student that followed this course will manage to properly build a scientific project defining clearly the objectives and the relevance of the ideas, making a rational work plan, evaluating the risks and challenges to maximize the chance of success and being able to follow the progress of the project and evaluate the results.

EVALUATION MODE (final exam, oral defense, report,...)	Ratio of the final grade
Final exam	**0%**
Ongoing assessment (case studies)	**100%**

TITLE OF UNIT: Bibliographic project (Xavier Vekemans, Professor)

NUMBER of ECTS: 6
Number of hours: **Lectures: 6h, Practicals: 30h**
Personal workload (hours expected to be dedicated to, including supervised projects): **108 hours**

Description of the module

General aims:
To initiate the student in the search for documents and the realization of a bibliographical synthesis of scientific articles. To inform the student about the functioning of the world of scientific publication. To bring the student to practice reading scientific literature in English in a field close to his/her internship subject. To train the student to make a scientific report and a scientific presentation, and to answer questions from a jury.

Content summary:
-Introduction to bibliographic search engines; access to bibliographic sources and management of a personal bibliographic database.
-Initiation to the way the world of scientific publishing works
-Choosing a subject and carrying out a personal bibliographical research
-Introduction to written and oral expression tools
-Writing and oral defense of a bibliographical synthesis.

Expected knowledge and skills:
- Familiarization with scientific English, and the format of scientific publications
- Access to the main bibliographic sources and search engines
- Create and manage a computerized bibliographic database
- Produce and write a bibliographical synthesis on a theme related to his research internship
- To present orally this bibliographical synthesis, and to answer questions from a jury

EVALUATION MODE (final exam, oral defense, report,...)	Ratio of the final grade
Written report (evaluated by 2 members of the jury)	**70%**
Oral defense (oral presentation and answers to questions evaluated by all members of the jury)	**30%**

TITLE OF UNIT: Research in "Evolution of Mating Systems" (Vincent Castric, research director CNRS)

NUMBER of ECTS: 3
Number of hours: **Tutorials: 22h**
Personal workload (hours expected to be dedicated to, including supervised projects): **50 hours**

Description of the module

General aims:
This course will be focused on the study of molecular bases, genomic consequences and ecological determinants of mating system variations in natural populations.

Content summary:
1. So many ways of doing it: the diversity of molecular mechanisms controlling mating systems

2. Should I stay (outcrossing) or should I go (selfing)? The genomic consequences of mating system transitions
3. The evolution of genomic regions controlling mating systems
4. Into the wild: models integrating ecological and genetic mechanisms of mating system evolution

Expected knowledge and skills:
Integrative biology; Theoretical modeling; Genomics; Evolutionary Ecology

EVALUATION MODE (final exam, oral defense, report,...)	Ratio of the final grade
Ongoing assessment (individual contributions to peer reviewing of recently posted preprints on BiorXiv)	**100%**