UNIVERSITÉ DE FRIBOURG
UNIVERSITÄT FREIBURG

Curriculum for the award of the Degree of

Master of Science in Bioinformatics and Computational Biology

Accepted by the Faculty of Science and Medicine on 30.05.2022
Revised version of 15.04.2024

FACULTÉ DES SCIENCES ET DE MÉDECINE
MATHEMATISCH-NATURWISSENSCHAFTLICHE UND MEDIZINISCHE FAKULTÄT

CONTENTS

1 General Remarks

This curriculum describes all regulations concerning the joint study in Bioinformatics and Computational Biology at the University of Fribourg and the University of Bern. It is based on the ***Fachkonvention BEFRI im Fachbereich Bioinformatik*** signed on January 13, 2012 and the regulations of the Faculty of Science and Medicine as defined in the ***Règlement pour l'obtention des Bachelor of Science et des Master of Science de la Faculté des sciences et de médecine***, which entered into force on 30 May 2022 (hereafter called the *Regulation* for short).

The Regulation of 30 May 2022 for the award of the Bachelor of Science and Master of Science degrees establishes a limit on the duration of Bachelor's and Master's studies, as well as of the minor study programs (see articles 11, 13 and 14) (https://www.unifr.ch/scimed/fr/rules/regulations).

1.1 Academic Title and Study Plan

The Faculty of Science and Medicine of the University of Fribourg awards the following official academic title to students who have successfully completed their studies:

Master of Science in Bioinformatics and Computational Biology (MSc), University of Fribourg

The MSc in Bioinformatics and Computational Biology (subsequently called **MSc)** is organized as a joint degree between the University of Fribourg and the University of Bern, with about half of the courses taught at either University.

The MSc study programme teaches students how to analyse large biological data sets and images through correct use of computer algorithms and statistical tools, and how to model biological processes. The MSc project further allows students to delve deeper into one of the subjects.

The programme not only aims at preparing students for a PhD programme in this research field, but also offers the necessary background to work in bioinformatics in industry, public health or different governmental institutions.

Graduates in possession of a Bachelor degree with at least 90 ECTS credits in bioinformatics, biology, biochemistry, life sciences, biomedicine, mathematics, statistics or computer science from the University of Fribourg or any other Swiss university can directly enrol in the MSc in Bioinformatics and Computational Biology. Holders of a non-Swiss BSc degree, a BSc degree in a different subject or an equivalent BSc degree can be admitted into the programme based on a decision of the Faculty of Science and Medicine. The admission decision is made individually for each case. Provisional admission can be granted and depends on the fulfilment of additional requirements set by the Faculty.

1.2 Course Structure

The course work leading to the MSc degree is subdivided into “**UE**” (from “unité d’enseignement” or “Unterrichtseinheit”), consisting of lectures, exercise classes, practical courses, seminars and specialized projects. To each UE, a number of **ECTS credits** *(European Credit Transfer System)* is assigned. The MSc degree requires a total of 120 ECTS credits (four semesters) where the first three semesters (90 ECTS credits) consists of formal lectures, exercise classes and seminars, followed by a semester devoted to an MSc project lasting six months and terminating with the MSc thesis (30 ECTS).

The purpose of the different UE types is as follows:

- **Lectures** give a formal introduction to the scientific methods and their application in bioinformatics and computational biology and encourage advance thinking in a scientific way.

They help in acquiring the basic knowledge and understanding the fundamental concepts in analysing large biological data sets and in modelling biological processes using computers.
- **Exercise classes** complement the lectures and provide essential help for the understanding and practical application of a lecture’s content. Through them, the student will practise and apply the acquired principles, mathematical and statistical techniques and computer-based algorithms.
- **Laboratory work**, be it experimental or theoretical, is the basis of scientific research. It provides a controlled environment for the hands-on realization of biological measurements. Students with a background different than biology will obtain a basic understanding of experimental design and learn to use instruments commonly used in current biological research.
- **Seminar presentations** are used to expand the student’s knowledge in specialized domains often neglected in the formal courses as well as to begin the development of oral presentation skills for scientific results.
- The preparation of the **Master thesis**, under the supervision of an experienced researcher, is the actual starting point of scientific research.

1.3 Acquired Skills

The aim of the studies leading to the award of a MSc in Bioinformatics and Computational Biology is to deepen knowledge and perfect competence in the chosen fields and, at the same time, develop skills in planning and executing research, present and communicate research both orally and in written form in scientific English. Thus, at the end of the study programme, the students will have shown that they can apply their knowledge to accomplish a research project and will have learned how to work independently, or how to integrate into an interdisciplinary research team. The award of the degree requires creative and self-critical talents as well as the ability to communicate ideas and work in English.

1.4 Course Assessment (UE) and Accreditation of ECTS Credits

Acquisition of ECTS credits occurs via three steps: assessment of individual UEs, grouping of UEs into a validation package, and awarding the respective ECTS credits for the completed package.

Assessment is generally made by a written exam of 60 to 120 minutes in length. However, oral exams of 15 to 60 minutes in length are also possible. The marks range from 6 (highest mark) to 1 (lowest mark). An exam marked below 4 can be repeated, but only once, and at the earliest during the next exam session. In the case of a repetition, the examiners may decide to replace a written exam by an oral exam of 15 to 60 minutes in length. Such a change has to be communicated to the students at least one week prior to the exam.

Assessment of **exercises, laboratory work and seminars** may consist partly or in total on criteria assessed during the UE, for instance through assessment of laboratory work, presentations, written projects or based on the number of submitted exercise papers or the number of correctly solved exercises. Assessing exercises or laboratory work jointly with an associated lecture is possible.

Students are informed at the beginning of a course about the type and duration of the assessment and evaluation criteria. Permission to sit the exam associated with a formal lecture can be subject to the successful completion of the lecture's corresponding exercise class, as specified in the appendix of this document.

A **validation package** comprises multiple, separately assessed, UEs. The art. 24 and 27 of the Regulation determines the number of these packages whereas this curriculum determines their content.

The conditions for validation of ECTS credits are described in Art. 25 of the Regulation.

After the validation, upon request, the Dean's office will issue transcripts of records in which exam results and awarded credits are acknowledged (Art. 28 and 30 of the Regulation), provided the exam fee has been paid.

Exams occur during the official exam sessions in spring, summer, or autumn, and are subject to a fee. Students register for each exam via the students' web portal MyUniFR (https://my.unifr.ch) within the stipulated delays according to the on-line procedure and using their university account and password.

1.5 Teaching Languages

All courses of the MSc programme in Bioinformatics and Computational Biology are taught in English. Also, all exams and written work (e.g. Master's thesis) have to be in English.

1.6 Ethics and Science

Ethical principles are an integral part of a scientific education. Accepted international conventions must be respected during research and all scientific writing work, be that a project, a lecture, a thesis, or a report. In particular, every external source of information (articles, lectures, web pages, etc.) must be correctly cited.

1.7 Regulations and Additional Information

Detailed information about studying Bioinformatics can be found in the documents referenced on the web page https://www.unifr.ch/scimed/en/plans which can also be obtained from the Office of the Department of Biology, chemin du Musée 10, CH-1700 Fribourg.

2 Master of Science (MSc)

[Version 2024, validation packages: PV-SBI-0000019, PV-SBI-0000020, PV-SBI-0000021]

The MSc programme in Bioinformatics and Computational Biology requires 120 ECTS credits to be completed, and is expected to take 24 months. The first three semesters (90 ECTS credits) consist primarily of courses, exercises, laboratory work and seminars designed to strengthen and complete the student's knowledge in bioinformatics and computational biology, but also in proper scientific conduct and skills like research communication. The courses are organised both at the University of Fribourg and the University of Bern and can be complemented with additional courses offered at the University of Fribourg or under the BeNeFri agreement. The MSc degree is completed by a research project of 30 ECTS credits which includes the writing of a Master thesis (SBC.07500).

2.1 MSc Course Units

The courses consist of compulsory courses organized in one **preparatory** (7 ECTS) and **four compulsory modules** (77.5 ECTS). These are complemented by a module consisting **of elective courses** (5.5 ECTS). SA, Fall Semester; SP, Spring semester. The numbering of the semesters refers to students starting in Fall.

All UE are assessed under two validation packages, consisting of the following modules:

1. PV-SBI.0000019, 39.5 ECTS, consisting of the modules:
    a. Computer Science, 23.5 ECTS
    b. Statistics, 16 ECTS
2. PV-SBI.0000020, 50.5 ECTS, consisting of the modules:
    a. Preparatory Computer Science, 7 ECTS*
    b. Preparatory Biology, 6 ECTS*
    c. Genomics, 19.5 ECTS
    d. Bioinformatic Applications, 18.5 ECTS
    e. Elective courses, 5.5 ECTS

* Only one of the preparatory modules can be chosen

The specific assessment criteria for each individual UE is specified in the appropriate appendices to the curricula on assessment modalities in Biology, Mathematics and Biochemistry.

Preparatory Modules (6 ECTS)

To account for the diverse background of students, 6 ECTS credits are awarded for one of two possible modules:

- **Preparatory Computer Science** teaches students basic programming skills.
- **Preparatory Biology** introduces students to basic biological and biochemical processes and teaches basic laboratory skills.

The goal of these modules is to homogenize the knowledge of all students. Therefore, students with a BSc in biology, biochemistry, life sciences or equivalent follow the module "Preparatory Computer Science". Students with a BSc in mathematics, statistics, computer science or equivalent follow the module "Preparatory Biology".

Module "Preparatory Computer Science"

Code	Title of UE	Semester	tot. h.	ECTS
SBL.30007	Mathematical Concepts for Bioinformatics	SA (1st)	14	1
–*	Basic Programming for Non-informaticians	SA (1st)	56	5
Total				**6**

* Course offered by the University of Bern. See https://www.philnat.unibe.ch/

Module "Preparatory Biology"

Code	Title of UE	Semester	tot. h.	ECTS
_*	Molecular biology and genetics for non-biologists (lecture)	SA (1st)	5 days	2.5
_*	Molecular biology and genetics for non-biologists (practical)[a]	SA (1st)	56	4.5
Total				**7**

[a] May be replaced by "Molecular biology and genetics for non-biologists (practical)" offered by the University of Bern

* Course offered by the University of Bern (see: https://www.philnat.unibe.ch/)

Compulsory Modules (77.5 ECTS)

Module "Computer Science"

Code	Title of UE	Semester	tot. h.	ECTS
SBC.07110	Introduction to UNIX and BASH	SA (1st)	5 days	2.5
SBL.30001	Introduction to R	SA (1st)	4 days	2
SBC.07109	Programming with R	SA (1st)	2 days	1
_*	Introduction to Digital Sustainability	SA (1st)	2 days	1
_*	Introduction to High-Performance Computing	SA (1st)	2 days	1
_*	Introduction to Data Science with Python	SP (2nd)	28	5
_*	Introduction to Image Analysis	SP (2nd)	42	3
_*	Bioinformatic Algorithms	SA (3rd)	28	3
_*	Introduction to Artificial Intelligence	SA (3rd)	10 days	5
Total				**23.5**

* Course offered by the University of Bern (see: https://www.philnat.unibe.ch/)

Module "Statistics"

Code	Title of UE	Semester	tot. h.	ECTS
_*	Applied Biostatistics I (lecture with exercises)	SA (1st)	28+28	4
–*	Applied Biostatistics II (lecture with exercises)	SP (2nd)	28+28	4
SBL.30002	Machine Learning	SP (2nd)	10 days	5
SMA.07010	Stochastic models in bioinformatics	SA (3rd)	28	3
Total				**16**

* Course offered by the University of Bern (see: https://www.philnat.unibe.ch/)

Module "Genomics"

Code	Title of UE	Semester	tot. h.	ECTS
SBC.07107	Bioinformatics (practical course, in silico)	SA (1st)	6 days	3
_*	RNA-Sequencing	SA (1st)	6 days	3
_*	Cancer Genomics	SA (1st)	6 days	3
SBL.20034	Evolutionary Genomics	SP (2nd)	6 days	3
_*	Genome and Transcriptome Assembly	SA (3rd)	4 days	2
SBL.30004	Organization and annotation of Eukaryote genomes	SA (3rd)	6 days	3
_*	Genomics of Microorganisms	SP (2nd)	14	1.5
SBL.00425	Metagenomics Data Analysis	SP (2nd)	14	1
Total				**19.5**

* Course offered by the University of Bern (see: https://www.philnat.unibe.ch/)

Module “Bioinformatic Applications”

Code	Title of UE	Semester	tot. h.	ECTS
SBC.07111	Research Seminar in Bioinformatics[a]	SA (3rd)	28	2
_*	Proteomics and Metabolomics	SP (2nd)	10 days	5
SBL.06002	Classical models in Biology (lecture)	SP (2nd)	28	3
SBL.06003	Classical models in Biology (exercises)	SP (2nd)	14	1
_*	Computational Epidemiology	SA (1st)	14	1.5
_*	Systems Biology	SA (3rd)	28	3
_*	Precision Medicine	SP (2nd)	28	3
Total				**18.5**

* Course offered by the University of Bern (see: https://www.philnat.unibe.ch/)

[a] May be replaced by “Research Seminar in Bioinformatics” offered by the University of Bern

Elective courses (min. 5.5 ECTS)

The students complete the compulsory modules with elective courses. These courses are meant to complement the background of students and should hence be taken from a different field than that of the bachelor. Only courses agreed with by the study advisor are eligible. The following list contains a series of suggestions only.

Module “Elective Courses” (suggestions only)

Code	Title of UE	Semester	tot. h.	ECTS
SIN.08608	Pattern Recognition	SP (2nd)	42	5
SBC.07104[§]	Introduction to Protein Structure and Protein Homology Modelling	SP (2nd)	14	1.5
SBC.07105[§]	Introduction to docking of small molecules to large macromolecules and molecular graphic	SP (2nd)	14	1.5
SBL.20035	Structure and functions of host-associated microbiota		28	3
SBL.00119	Molecular genetics of model organism development	SA (3rd)	28	3
–*	Programmierung 1	SA (1st)	–	5
–*	Beyond genetic inheritance		28	3
–*	Seminar and journal club in Population genetics and Bioinformatics	SA (3rd)	28	2
_*	Four weeks research project	SA (3rd)	–	7.5
SBC.07153	Four weeks research project	SA (3rd)	–	7.5

* Course offered by the University of Bern (see: http://www.bioinformatics.unibe.ch/)

[§] Must be taken together

Recognition of external credits

If requested by a student, the study advisor can recognize courses taken at other universities for up to 10 ECTS credits.

2.2 Content of the Courses

2.2.1 Compulsory Lectures

The compulsory courses are intended to introduce the students to the current techniques to generate and analyse large data sets in the context of Life Sciences. This is achieved by explaining and demonstrating the techniques with examples, and a large collection of supervised exercises. The following courses constitute the compulsory curriculum:

- *Mathematical concepts for Bioinformatics* (SBL.30007): The course refreshes mathematical concepts important for bioinformatics and machine learning, with a special focus on probability theory and analysis.
- *Introduction to UNIX and BASH* (SBC.07110): The students learn the basics of computing and programming, with an emphasis on UNIX operating system and command-line examples. They will learn BASH scripting using modern tools, including regular expressions.
- *Basic programming for non-informaticians:* This course introduces the basic concepts of programming using Python, explains important algorithms for data storage, searching and sorting, and establishes good programming habits for code readability and code organization.
- *Molecular biology and genetics for non-biologists*: The goal of this course is a basic understanding of the molecules that the students will be dealing with later in the curriculum: DNA, RNA and proteins, as well as the basic cellular processes in which these molecules are involved. An important part of this course is guided practical work in a laboratory, aimed at introducing basic laboratory techniques which are important to understand potential sources of errors and contaminations when analysing the resulting data.
- *Introduction to R* (SBL.30001)*:* This course introduces the basic usage of the statistical programming language R. The focus will be on data structures (vectors, matrices and data frames), import / export of data, basic plotting, writing of functions and scripts for reproducible data analysis. The course will be largely “hands-on” and does not require any prior knowledge on R.
- *Programming with R* (SBC.07109): This course introduces advanced topics in R programming, with a focus on S3 classes and R packages. The course will be largely “hands-on”.
- *Introduction to Digital Sustainability:* This course introduces the concepts and workflows that ensure the long-term storage and usability of digital code and data.
- *Introduction to High-Performance Computing*: This course introduces the use of high-performance computing centers, with a focus on the IBU cluster.
- *Introduction to data science with Python*: This course introduces advanced topics in modern Python programming.
- *Introduction to image processing:* This lecture introduces the core principles of digital image processing and feature detection, which are then used by the students in extensive exercise sessions on biological image data.
- *Bioinformatic Algorithms*: This course introduces algorithms commonly used in bioinformatic applications. The main focus is on searching and matching algorithms, graph algorithms and algorithms used to construct phylogenetic trees.
- *Applied biostatistics I:* This lecture focuses on basic statistics and introduces all the important concepts needed in the courses of the second semester. These include probability theory, probability distributions, hypothesis testing and the basics of both frequentist and Bayesian inference. The course is paired with “hands-on” sessions that will allow students to become familiar with the R programming language and to play with the concepts of the lectures using biological data.
- *Applied biostatistics II:* This course builds on the knowledge obtained in *Applied biostatistics I* and introduces more complex statistical techniques such as working with joint distributions, regression analysis, analysis of variance and clustering approaches. The course is paired with

"hands-on" sessions that will allow students to play with the concepts of the lectures using biological data in "R".

- *Machine learning (SBL.30002):* The aim of this course is to equip the students with the necessary skills to apply machine-learning techniques in their own research. It focuses on numerical techniques such as Expectation Maximization and Markov Chain Monte Carlo, and introduces the use Hidden Markov Models and approximate techniques to analyse genomic data. The course is paired with exercises allowing students to implement these techniques in "R" to analyse biological data.
- *Stochastic models in bioinformatics (SMA.07010):* This course discusses stochastic dynamics in gene networks, drug-receptors interactions and modelling of small molecules. It aims to enable students to pursue their own research using the presented techniques and hence puts a large emphasis on mathematical concepts.
- *Deep Learning in Life Science*: This course introduces deep learning as a technique and teaches how modern deep learning algorithms can be used to solve problems in the life sciences.
- *Bioinformatics (practical course, in silico):* During this course, students will become acquainted with DNA-sequence manipulation using Python and other tools and will assemble a bacterial genome *de novo* and annotate it structurally and functionally. Most of the course is organized as exercise sessions.
- *RNA-Sequencing*: This course introduces the methods and tools used to analyse RNA-sequencing data from both tissues and single cells.
- *Cancer genomics:* Besides a biological and medical introduction to cancer, this course focuses on genomic approaches to characterize, understand, and detect cancer. This course includes practical sessions where students will use next-generation sequencing techniques to detect variants in cancer cells and characterize the detected mutations using gene ontology.
- *Evolutionary genomics (SBL.20034)*: This course examines the main factors that shape the evolution of plant and animal genomes. In particular, it discusses various approaches for assessing patterns of genomic variation in natural populations and the evolutionary and ecological processes affecting them. Students will population genetical statistics and about computational tools for analysing genetic variation at the genome-level, including for example the estimation of genome-wide population structure and tests of selection.
- *Genome and Transcriptome Assembly*: This course introduces the methods and tools used to generate high-quality genome assemblies.
- *Organization and annotation of Eukaryote genomes (SBL.30004)*: This course introduces the methods and tools used to annotate genomes and offers an evolutionary perspective on the interpretation of genomic features.
- *Genomics of microorganisms*: This course gives an overview of the genome organization of microorganisms and introduces the concept of metagenomics.
- *Metagenomics data analysis:* Students will learn the basic principles of metagenomics data analysis and their associated methods. The course will cover the targeted methods (16S, ITS) as well as the Whole Genome/Transcriptome Sequencing methods, both in prokaryotes and eukaryotes. Students will learn which kind of data could be extracted from metagenomics analysis and how to analyse and represent these data. SBC.07111 or equivalent is a prerequisite to access this course.
- *Proteomics and Metabolomics:* This course introduces how proteomic data is acquired by mass spectrometry and analysed to reveal new understandings of biological systems, mainly focusing on protein interactions and genome annotation through proteomics. In addition to the lectures, students will present and discuss relevant articles to improve the understanding behind the algorithms and methods used.
- *Classical models in biology (SBL.06002 & SBL.06003):* The students will learn the basics of modelling using differential equations and stochastic processes in the context of ecology, epidemiology and systems biology (cell and protein and networks). The course is paired with extensive "hands-on" sessions.

- *Computational Epidemiology:* This course gives an overview of epidemiological models and their use to understand disease dynamics.
- *Systems Biology*: This course introduces the concept of systems biology, along with the methods and tools commonly used to study biological systems.
- *Precision Medicine*: This course gives an overview of the use of bioinformatic tools in precision medicine.

2.2.2 Research Project

7.5 ECTS may be obtained through a four-weeks research project (*SBC.07153*), which should focus on an experimental or theoretical work performed within one of the research groups present at Bern or Fribourg. During the work, the student will become intimately familiar with the experimental techniques and/or theoretical methods applicable to research questions in bioinformatics or computational biology. The results will be written in an extended, detailed report.

2.3 Master's Thesis and Exam

The third validation package of the Master's program (PV-SBI.0000021, 30 ECTS credits) consists entirely of the UE dedicated to the *Master thesis* itself (SBC.07500). This work is foreseen to last six (6) months full time (excluding course work) and may start in the third semester and will last over the entire fourth semester. An extension of an additional 6 months is possible. Such an extension has to be justified to the Study Adviser in written form.

The *Master thesis* project involves real research work that the student will carry out under the supervision of an active researcher in the field, and during which the student's aptitude for fundamental research will begin to develop. The work must be presented as a formal written thesis and an oral presentation. The work will be judged on the same 1 ("totally unacceptable") to 6 ("excellent") scale as the exams by the supervisor based on the research conducted, the oral presentation and the written thesis. PV.SBI-0000021 will be validated only for marks of 4 and above. If a work is judged insufficient, a second PV.SBI-0000021 project is offered to the student, on a different subject.

2.4 Admission Regulations for the Master Programme

2.4.1 Admission Procedure

Admission to the Master program may be granted provided the following two conditions have been met by the applicant:

- Satisfying the University admission requirements as defined in the *Règlement concernant l'admission à l'Université de Fribourg* (https://www.unifr.ch/apps/legal/fr/document/274904),
- The student possesses a Bachelor of at least 90 ECTS credits in biology, biochemistry, life sciences, mathematics, statistics or computer science from the University of Fribourg or an academic degree judged equivalent by the Faculty of Science and Medicine.

For candidates with degrees that are not judged equivalent by the Faculty of Science and Medicine, the Commission for Students' Requests will decide on eligibility (*Commission des requêtes des étudiant-e-s*, Dean's Office, Faculty of Science and Medicine, ch. du Musée 8, CH-1700 Fribourg, Switzerland).

Based on the candidate's academic qualification, the Commission for Students' Requests can accept the application on the condition that additional requirements are fulfilled, provided they are of a minor scope and can be completed simultaneously with the Master studies. Otherwise, access is denied or applicants can be admitted to a “pre-master program” and can begin the Master program only after having fulfilled the requirements initially set for the pre-master. Final acceptance to the Master program for a qualifying student depends on the successful completion of the additional requirements.

2.5 Rules for Completion and Final Grade

Successful completion of the PV-SBI.0000019, PV-SBI.0000020 and PV-SBI.0000021 validation packages results in the right to the title **Master of Science in Bioinformatics and Computational Biology, University of Fribourg (MSc)**.