

A blue-tinted background image of a DNA double helix. Superimposed on the helix is a vertical column of DNA base sequences in a light blue font, containing letters A, T, C, and G.

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 06.04.2020

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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 April 6th, 2020 (hereafter called the *Regulation* for short).

The Regulation of 6 April 2020 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 programmes (see articles 10, 11a, 12a, 13 and 31) (<https://www3.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 biology, biochemistry, life sciences, 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 **ECTS¹ points** is assigned, which, following successful completion of the course (e.g., exams) are converted into ECTS credits (see Section 1.3). The MSc degree requires a total of 90 ECTS credits (three semesters) where the first full year (60 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.

The purpose of the different UE types is as follows:

¹ ECTS stands for *European Credit Transfer and Accumulation System*. One ECTS point corresponds to some 30 hours of work (see https://ec.europa.eu/education/resources/european-credit-transfer-accumulation-system_en)

- **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. 22 and 24 of the Regulation determines the number of these packages whereas this curriculum determines their content.

ECTS points are credited according to art. 23 of the Regulation if:

- the weighted average of the exam marks of a validation package is at least 4. The weighting is determined by the number of ECTS points assigned to a UE, and
- the assessment criteria for UE not subject to formal examinations (practical work exercises, seminars, etc.) are met.
- no mark is equal to 1.0.

After satisfying those conditions, a package is considered validated and the corresponding ECTS points are converted into ECTS credits and attributed to the student. Upon request, the Dean's office will issue transcripts of records in which exam results and awarded credits are acknowledged (Art. 26 and 27 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 <http://www3.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 2020, validation packages: PV-SBI-0000006, PV-SBI-0000005]

The MSc programme in Bioinformatics and Computational Biology requires 90 ECTS credits to be completed, and is expected to take 18 months. The first year (60 ECTS credits) consists 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 in total which includes the writing of a Master thesis.

2.1 MSc Course Units

The first year consists of two semesters with mandatory courses amounting to 46 ECTS credits in total. Out of these, 7 ECTS credits are awarded for one of two possible modules:

- Module A teaches students basic programming skills.
- Module B 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 module A. Students with a BSc in mathematics, statistics, computer science or equivalent follow module B.

Semester 1 (autumn)

Code	Title of UE	tot. h.	ECTS
Module A (7.5 ECTS)			
SBC.07110	Introduction to UNIX and BASH (lecture with exercises)	5 days	2.5
-*	Basic programming for non-informaticians (lecture with exercises)	56	5
Module B (7 ECTS)			
-*	Biology for non-biologists (lecture with practical course)	84	7
Compulsory courses (18.5 ECTS)			
-*	Applied biostatistics I (lecture with excercises)	46	4
SBC.07107	Bioinformatics (practical course, <i>in silico</i>)	5 days	3
SBC.07108	Introduction to R (lecture with excercises)	3 days	1.5
SBC.07109	Programming with R (lecture with exercises)	2 days	1
-*	“Omics”, from genomes to metabolomes	28	3
-*	Cancer genomics (lecture with exercises)	6 days	3
SMA.03556	Selected chapters of modelling (lecture)	28	3
Total			25.5/26

Semester 2 (spring)

Code	Title of UE	tot. h.	ECTS
Compulsory Courses (28 ECTS)			
–*	Applied biostatistics II (lecture with exercises)	56	4
–*	Bioinformatics algorithms	28	3
SBC.07111	Research seminars in bioinformatics	28	2
–*	Evolutionary genomics (lecture with exercises)	6 days	3
–*	Mass spectrometry to systems biology	28	3
SBL.06002	Classical models in biology (lecture)	28	3
SBL.06003	Classical models in biology (exercises)	14	1
SBC.07102	Machine learning (lecture with exercises)	42	4
–*	Introduction to Signal and Image Processing	42	5
Total			28

The compulsory courses are complemented with 14 ECTS credits obtained in the first and/or second semester through a combination of specialized courses taken from other MSc or BSc programmes of the Faculties of Science of the Universities of Fribourg and Bern to fill particular needs and/or an individual term project. The choice of lectures requires the approval of the study advisor of this MSc programme.

Elective courses, semester 1 or 2 (suggestions only)

Code	Title of UE	tot. h.	ECTS
SBC.07150	Term project°	–	3
SBC.07151	Term project°	–	4
SBC.07152	Term project°	–	5
SIN.00220	Data processing and visualization	56	6
SIN.08608	Pattern recognition	42	5
SBC.07104	Introduction to protein structure and protein homology modelling §	14	1.5
SBC.07105	Introduction to docking of small molecules to large macromolecules and molecular graphic §	14	1.5
SBL.00119	Molecular genetics of model organism development	28	3
SBL.00216	Introduction to statistics with R – Model selection	12	1
SBL.00425	Metagenomic data analysis	14	1
–*	Introduction to R programming and analyses	–	2.5
–*	Programmierung 1	–	5
–*	Beyond genetic inheritance	28	3
–*	Genomics of microorganisms	14	1.5
–*	Mass spectrometry to systems biology (practicals)	14	0.5
–*	Seminar and journal club in Population genetics and Bioinformatics	28	2

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

§ Must be taken together

° Only one *Term project* can be chosen

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

Semester 3 (autumn or spring)

Code	Title of UE	tot. h.	ECTS
SBC.07500	Master thesis	–	30
Total			30

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:

- *Introduction to UNIX and BASH* (SBC.07110): The students will 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.*Introduction to R* (SBC.07108): 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”.
- *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. Basic knowledge of Linux and Python is required.
- *Biology for non-biologists*: The goal of this course is a basic understanding of the molecules students will be dealing with later in the curriculum, such as DNA, RNA and proteins, as well as the basic cellular processes in which these molecules are involved. An important part of this course are guided lab-practicals aimed at introducing basic laboratory techniques which are important to understand potential sources of errors and contaminations when analysing the resulting data.
- *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.
- *Cancer genomics*: Besides a biological and medical introduction to cancer, this course focuses on genomic approaches to characterize, understand, and detect cancer. This 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.
- *Selected chapters of modelling* (SMA.03556): 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.
- *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.
- “Omics”, from genomes to metabolomes: The lecture intends to give an overview of the concepts in systems biology and of the omics-methods and their applications in basic and applied research.
- *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”.

- *Bioinformatics 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.
- *Machine learning*: 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.
- *Evolutionary genomics*: This course introduces the evolutionary processes that shape the genetic diversity observed today and present statistical approaches to infer the evolutionary history of populations, species and groups of species from genomic data. The lecture is paired with practical courses that will allow students to play with some of the most important inference methods in population genetics and phylogenetics using real data.
- *Mass spectrometry to systems biology* : 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*: 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.
- *Introduction to signal and 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.
- The lecture with exercises SBL.00425 teaches *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 analyze and represent these data. SBC.07111 or equivalent is a prerequisite to access this course.

2.2.2 Research seminar

In the spring, a research seminar is organized, in which every week an external speaker is invited to expose the students to current research conducted in the field of genomics and proteomics.

2.2.3 Term Project

During the first semester, students are required to complement the compulsory courses with specialized courses from other curricula and by performing a term project. Between 3 and 5 ECTS credits have to be taken as a term project, which should focus on an experimental or theoretical work performed within one of the research groups present at Berne 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 MSc Exams and Assessment

All UEs of the first year of study are collectively assessed under the name of “validation package PV-SBI.0000006”, and gives the student 60 ECTS credits, if successful. 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.

2.4 Master's Thesis and Exam

The second validation package of the Master's programme (PV-SBI.0000005, 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 second semester and will last over the entire 3rd 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 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 document. An additional oral presentation is encouraged. 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 and the written thesis. PV.SBI-0000005 will be validated only for marks of 4 and above. If a work is judged insufficient, a second PV.SBI-0000005 project is offered to the student, on a different subject.

2.5 Admission Regulations for the Master Programme

2.5.1 Admission Procedure

Admission to the Masters programme 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://www3.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 programme” and can begin the Master programme only after having fulfilled the requirements initially set for the pre-master. Final acceptance to the Master programme for a qualifying student depends on the successful completion of the additional requirements.

2.6 Rules for Completion and Final Grade

Successful completion of the PV-SBI.0000006 and PV-SBI.0000005 validation packages results in the right to the title **Master of Science in Bioinformatics and Computational Biology, University of Fribourg (MSc)**.