## 8.5 Master's Programme in Bioinformatics

**Degree Programme of Computer Science and Engineering**
**Degree: Master of Science in Technology – M.Sc. (Tech) 120 ECTS**
**Major: Bioinformatics (T3012)**

**Professor in charge:**     **T-61 Prof. (pro tem) Harri Lähdesmäki**
                        **T-61 Prof. Samuel Kaski**
                        **T-122 Prof. Heikki Mannila (vv)**
 **Other contact person at TKK: Lecturing Researcher N.N.**
 http://www.cs.helsinki.fi/mbi

### Bioinformatics as a Discipline
Bioinformatics is a new field of science that seeks answers to the questions of life, raised by biology and medicine, with computational means. It is possible to study the infective potential of a virus by modelling its three-dimensional surface structure. The function of genes can be uncovered by a computational study of DNA sequences. The utilization of renewable resources for example biofuel production can be improved by metabolic modelling. Machine learning can be used to seek cellular mechanisms of cancer from gene expression and metabolomics data.

Analysis of measurement data is of vital importance in modern research in biology and medicine. Understanding such data requires both robust statistical modelling and methods which are computationally feasible.

In general terms, bioinformatics is computer-aided collecting, processing and analysing of biological and medical information. Mathematics, statistics and computer science methods provide the foundation of bioinformatics, but it is necessary to have a thorough understanding of both the application area and methods. Thus, a bioinformatician often acts as an important mediator between the methodological and biological sciences.

Helsinki University of Technology (TKK) and the University of Helsinki (HY) offer excellent opportunities for bioinformatics studies. Research in bioinformatics at the institutions is of the highest quality in Europe. The universities have extensive contacts to universities and research institutes abroad. This guarantees a wide range of options for student exchange and post-graduate studies.

### Employment of Bioinformaticians
Universities and other research institutes employ bioinformaticians in various research positions. Biotechnology companies have also been employing bioinformaticians as specialists in growing numbers. Biological and medical research groups require bioinformaticians for data analysis tasks and development of biodatabases. Furthermore, bioinformatics research groups need more theoretically oriented bioinformaticians for developing new statistical and computational bioinformatics methods. The current state of employment is very good: it has

been estimated that the need for bioinformaticians will greatly exceed the number of bioinformaticians currently employed.

## Organization

The Master's Degree Programme in Bioinformatics (MBI) is organized jointly by the University of Helsinki and Helsinki University of Technology. At the University of Helsinki, member faculties are the Faculties of Science, Biosciences, Medicine, and Forestry and Agriculture. At Helsinki University of Technology, the programme is organized by the Faculty of Information and Natural Sciences.

The teaching is given by people working on the cutting edge of bioinformatics research. For instance, people from three research units chosen to be Centres of Excellence by the Academy of Finland have a central role in the development and implementation of the programme.

## Degrees

The basic degree offered by the MBI programme is Master of Science (in HY: MSc, filosofian maisteri; in TKK: MSc (Tech), diplomi-insinööri), with bioinformatics as the major subject. The scope of the degree is 120 credits, and requires a suitable Bachelor's level degree as a prerequisite.

The MSc degree consists of a minimum of 70 credits of advanced studies in bioinformatics and a minimum of 40 credits of minor subject studies, including biology, computer science and mathematics. Both the MSc degree and the MSc (Tech) degree have been designed to be as similar as possible. The biological minor subject courses are offered by the Faculties of Biosciences, Medicine as well as Forestry and Agriculture at the University of Helsinki.

The intended time to complete the degree is two years. The detailed structure of the MSc degree is described in the section on degree requirements.

## Student Counselling and the Personal Study Plan

Students are required to make a personal study plan (HOPS) as part of their MSc degree, which is approved by the special tutor of the programme and the supervising professor. The personal study plan is to be approved by the end of the first period of the first year of study in the Programme. The study plan will be updated when needed as the studies progress.

In particular, it is important that the minor subject studies are planned to complement the previous studies in the Bachelor's degree, so that the methodological studies and biological studies form a meaningful whole.

Counseling for students is given by the following people:

University Lecturer Esa Pitkänen, Special Tutor of the Programme, Computer Science (HY)
University Lecturer Sirkka-Liisa Varvio, Computer Science (HY)
Professor Harri Lähdesmäki (TKK)
Lecturing Researcher N.N. (TKK)
More information can be found on the web pages on student counseling:

http://www.cs.helsinki.fi/mbi/counselling.html

**Degree requirements 2009-2011**
Students who have obtained the right to study in the Master's Degree Programme in Bioinformatics in 2009 in Helsinki University of Technology will follow these requirements.

The Master's Programme in Bioinformatics consists of six study modules:

1. Level 2 module T420-2 Bioinformatics A2 (20 cr)
2. Level 3 module T272-3 Bioinformatics A3 (20 cr)
3. T421-C Biological Special Module for Bioinformaticians C (20 cr) or T279-C Special Module in Computer and Information Science C (20 cr)
4. Methodological principles T901-M (10 cr)
5. Elective studies T901-W (20 cr)
6. Master's thesis T901-D (30 cr)

The courses in the study modules are listed below, the non-TKK course codes are the course codes of the University of Helsinki.

**Level 2 module T420-2 Bioinformatics A2 (20 cr)**
**Professor in charge (TKK):** Prof. Lähdesmäki
**Description of the module:** The module contains basic bioinformatics courses from the University of Helsinki. The aim of the module is to introduce the student to the key research questions and methods in bioinformatics.

| Code | Course | Cr |
|------|--------|-----|
| 582606 | Introduction to Bioinformatics | 4 |
| 582604 | Practical Course on Biodatabases | 4 |
| **Choose from the updated list available on the web to get the total of 20 cr. For example the following are recommended:** | | |
| XXXXX | Introduction to Bayesian Methods and WinBUGS | X |
| 58XXXX | Seminar on Biological Sequence Analysis | 3 |
| 58XXXX | Sequence Evolution and Analysis | 4 |
| XXXXX | Relevant seminars on bioinformatics | X |
| 58XXXX | Regulatory Networks | 4 |
| 58XXXX | Phylogenetic Data Analysis | 6-8 |
| 58XXX | Probabilistic Modeling | X |
| XXXXXX | Complex Networks and Data Mining | X |

| | | |
|---|---|---|
| | Total | 20 |

**Level 3 module T272-3 Bioinformatics A3 (20 cr)**
**Professor in charge:** Prof. Lähdesmäki
**Description of the module:** The module consists of advanced studies in at least one of the subfields of bioinformatics or neuroinformatics. The aim of the module is to provide an advanced understanding of the computational, modeling, and data mining methods for understanding biological and medical systems, analyzing large datasets measured from them, and solving biomedical research problems.

| Code | Course | Cr |
|---|---|---|
| **At least 5 cr from the following:** | | |
| T-61.5050 | High-Throughput Bioinformatics | 5 or 7 |
| T-61.5110 | Modeling Biological Networks | 5 or 7 |
| T-61.5120 | Computational Genomics | 4-7 |
| T-61.6070 | Special Course in Bioinformatics I | 3-7 |
| T-61.6080 | Special Course in Bioinformatics II | 3-7 |
| T-61.5080 | Signal Processing in Neuroinformatics | 5 |
| T-61.5090 | Image Analysis in Neuroinformatics | 5 |
| **Choose from the following to get the total of 20 cr:** | | |
| T-61.3020 | Principles of Pattern Recognition | 4 |
| T-61.3040 | Statistical Signal Modeling | 5 |
| T-61.3050 | Machine Learning: Basic Principles | 5 |
| T-61.5130 | Machine Learning and Neural Networks | 5 |
| T-61.5010 | Information Visualization | 5 |
| T-61.5060 | Algorithmic Methods of Data Mining | 5 |
| T-61.5100 | Digital Image Processing | 5 |
| T-61.5140 | Machine Learning: Advanced Probabilistic Methods | 5 |
| | **Total** | 20 |

**T421-C Biological Special Module for Bioinformaticians C (20 cr)**
**Professor in charge (TKK):** Prof. Lähdesmäki
**Description of the module:** The module consists of biological courses tailored to provide the necessary biological background for studying bioinformatics. The courses are given at the

University of Helsinki. The aim of the module is to provide an understanding of the current research questions in biology and to offer a hands-on experience in studying those questions.

| Code | Course | Cr |
|------|--------|----|
| **This is the recommended list. Alternatives will be specified in the Web.** | | |
| 399672 | Biology for Methodological Scientists | 8 |
| 399673 | Measurement Techniques for Bioinformatics | 6 |
| **Choose from the updated list available on the web to get the total of 20 cr. For example the following are recommended:** | | |
| 812010 | Laboratory Course in Plant Molecular Biology | 5 |
| 81028 | Laboratory Course in Plant Biotechnology | 5 |
| 52714 | Human Genetics | 3 |
| 52746 | Genetic Analysis | 3 |
| 52912 | Genomes | 3 |
| 52920 | Exercises in Bioinformatics | 3 |
| 399671 | Practical Bioinformatics | 8 |
| 52939 | From Genomes to Gene Function | 6 |
| 81055 | Population and Quantitative Genetics | 3 |
| | **Total** | **20** |

### T279-C Special Module in Computer and Information Science C (20 cr)

Content agreed individually with the professor in charge.

### T901-M Methodological Principles (10 cr)

Select from the common list of methodological principles courses offered by TKK or from the methodological principles course list of the Degree Programme of Computer Science and Engineering courses to complete 10 cr.

### T901-W Elective studies (20 cr)

| Code | Course | Cr |
|------|--------|----|
| **Compulsory courses (3 cr):** | | |
| Kie-98.xxxx | Foreign language courses | 3 |

| | | |
|---|---|---|
| Any Kie-98.xxxx courses that fulfill the requirements for obligatory foreign language courses: a total of 3 ECTS credits including both oral and written skills. | | |
| **Select any TKK courses to complete 20 credits for the Elective Studies module. The following courses are recommended:** | | |
| T-106.1003 | IT-Services at TKK | 2 |
| Kie-98.7011 | Finnish 1A | 2 |
| Kie-98.7012 | Finnish 1B | 2 |
| | **Total** | **20** |

**T901-D Master's thesis D (30 cr)**

An additional requirement is that the Bachelor's and Master's degree together must contain:
- studies in Biology, Medicine or other suitable subjects, minimum of 25 credits
- studies in Mathematics, Statistics and Computer Science, minimum of 60 credits

<u>Master's Thesis</u>
The Master's thesis is the final thesis done independently by the student for the MSc degree. The extent of the thesis is 30 credits. In the Master's Degree Programme in Bioinformatics, the Master's thesis is written during the second year of studies.

In addition to the written thesis, students are expected to complete a scientific writing course and give their Master's thesis presentation in the Master's thesis seminar of MBI (see below).

The topic of the thesis is agreed upon with a professor of the Programme. Usually the topic is related to research problems of a bioinformatics research group. Ideally, the work involves members from both methodological and application fields. The following list provides the names and some research interests of persons working with methodological bioinformatics. The list serves as a starting point for finding a suitable topic for the Master's thesis.

**Biological data fusion**: Harri Lähdesmäki, Samuel Kaski, Hannu Toivonen
**Biological data mining**: Heikki Mannila, Hannu Toivonen
**Functional genomics**: Liisa Holm, Harri Lähdesmäki, Samuel Kaski, Juho Rousu
**Gene expression data analysis**: Harri Lähdesmäki, Samuel Kaski
**Genetic mapping**: Heikki Mannila, Hannu Toivonen, Esko Ukkonen
**Sequence analysis**: Harri Lähdesmäki, Heikki Mannila, Esko Ukkonen
**Metabolic networks**: Juho Rousu, Esko Ukkonen
**Structured population dynamics, evolution and natural selection, ecological modelling**: Mats Gyllenberg

A more complete list is provided on the web pages of the Programme.

The writing work is divided into three phases. The first phase involves writing a one-page subject proposal where the research question is formulated. During the second phase, a research plan is written. The research plan should already contain most of the literature references of the final thesis. Both the proposal and the research plan must be approved by the instructor of the thesis. Finally, the thesis is written.

### Master's Thesis Seminar
While working on the Master's thesis, the student is expected to participate in the Master's thesis seminar of MBI and present the research plan and give the Master's thesis presentation. In addition, successful completion of the seminar requires attending the seminar presentations of other students. The Master's thesis seminar operates throughout the year.

### Scientific Writing in English
The students are expected to take a course on scientific writing in English during their studies. More details in the web pages.

### General Study Instructions
Bioinformatics studies consist both of lectures and practical work. Major subject studies involve mostly lecture courses, where a lecture course may include practical project work. In minor subject courses in biology, practical work may include either computer classes, laboratory work (wetlab), or both.

### Lecture Courses
A lecture course typically contains lectures and exercises. As a general rule of thumb, a student should spend double the amount of time used for lectures and exercises for each course. In addition, attention should be paid to fulfilling the prerequisites before attending the course. Passing a lecture course usually requires completion of a sufficient number of exercises, and passing the course exam. An alternative way to pass a course is by a separate exam.

### Laboratory Courses ("wetlab")
Sufficient skills for further biological laboratory work will be provided during the courses Biology for Methodological Scientists and Measurement Techniques for Bioinformatics. The student is required to take these courses if he or she has not taken equivalent courses earlier.

### Registration for the Courses and Examinations
Students register for courses and separate examinations offered by Helsinki University of Technology with the following registration system: https://oodi.tkk.fi/.
Students register for courses and separate examinations offered by the University of Helsinki according to the registration practices in the department organizing the course. At the Department of Computer Science, the web address of the registration system is http://ilmo.cs.helsinki.fi, and at the Department of Mathematics and Statistics, the address is http://ilmo.cs.helsinki.fi/matematiikka.

## Teaching Schedule

Teaching is given in four periods that are slightly different between TKK and HY:
TKK:
I 7.9. - 23.10.2009
II 2.11. - 11.12.2009
III 18.1. - 5.3.2010
IV 15.3. -  7.5.2010

HY:
I 7.9 - 25.10.2009
II 2.11 - 20.12 .2009
III 18.1. - 7.3.2010
IV 15.3.  - 23.5.2010

Each period consists of six weeks of teaching, followed by an exam week.

## Advanced Internship

The degree includes a highly recommended advanced internship phase. The internship position is intended to be either in a research group or in a company working in a related field. The aim of the internship is to familiarise the student with real-world bioinformatics and with people working with it. The internship position is agreed on with the student counsellor as a part of the study plan. Some available positions for the internship will be announced on the MBI web page: http://www.cs.helsinki.fi/mbi/internship.

## Grading

All courses are graded either on the six-step scale 0–5 or the two-step scale fail/pass. The lowest passing grade is 1/5, for which the student usually needs to gain half the maximum points. For the highest grade 5/5, the student usually needs at least 5/6 of the maximum points.

## Teaching Language

The teaching language in the Programme is primarily English. Exceptions are noted in the Teaching programme.

## Course Descriptions

Available from the programme's webpages: www.cs.helsinki.fi/mbi

## Maturity Test

At Helsinki University of Technology, the maturity test is required only if the student has not already given one at the Bachelor level.

## Post-graduate Studies

Post-graduate studies aiming for a Doctor of Science in Technology, Licenciate of Technology,

Doctor of Philosophy or Licenciate of Philosophy degree are typically pursued in conjunction with research groups working in the field of Bioinformatics.

A list of such groups can be found on the web pages of the Master's programme.

<u>The Graduate School in Computational Biology, Bioinformatics, and Biometry: ComBi</u>

The Graduate School in Computational Biology, Bioinformatics, and Biometry (ComBi) is a post-graduate programme jointly offered by the Universities of Helsinki, Tampere and Turku as well as Helsinki University of Technology. The school was established at the beginning of 1998, and the Department of Computer Science at the University of Helsinki is the coordinating institution. The research goal of ComBi is to develop computational, mathematical, and statistical methods and models for natural sciences. The thesis projects are carried out in close cooperation with one or more research groups in the application fields (such as biochemistry, molecular biology, genetics and biotechnology, ecology, research into evolution and systematics, geography and economics). More information including activities, application deadlines, funding of studies, etc. may be acquired from the director of the graduate school, Academy Professor Heikki Mannila (UH), and from the general secretary Heikki Lokki (UH) as well as electronically on the web page [http://www.cs.helsinki.fi/combi/](http://www.cs.helsinki.fi/combi/) or by email to [combi@cs.helsinki.fi](mailto:combi@cs.helsinki.fi).

ComBi is a partner programme in Bioinformatics Research and Education Workshop (BREW). BREW aims to introduce PhD students to the work modes of international conferences at an early stage in their PhD work, to bring together PhD students and experienced researchers in an atmosphere of cooperation and inspiration, to establish research contacts across Europe, to be utilized in the student's subsequent research and to contribute to the development of bioinformatics education and to the formation of the research community across Europe. More information on BREW is available on the ComBi web page.

<u>Other related graduate schools</u>

The following list includes graduate schools that offer postgraduate programmes in fields related to bioinformatics in the Helsinki region. Contact information for graduate schools can be found on the MBI web pages.

Biomaterial Graduate School
Clinical Drug Trials Graduate School
Finnish Graduate School in Plant Biology
Finnish Graduate School of Neuroscience
Functional Research in Medicine Graduate School
Graduate School in Computational Methods of Information Technology (ComMIT)
Graduate School in Pharmaceutical Research
Helsinki Biomedical Graduate School
Helsinki Graduate School in Biotechnology and Molecular Biology
Helsinki Graduate School in Computer Science and Engineering (HeCSE)
National Graduate School of Clinical Investigation
The Finnish Graduate School on Applied Bioscience: Bioengineering, Food & Nutrition

Environment (ABS)
Viikki Graduate School in Biosciences

## **Teachers**

Please contact teachers during their office hours. Teachers, their contact information and office hours are available at http://www.cs.helsinki.fi/mbi/people.