Programme-specific Section of the Curriculum for the MSc Programme in Bioinformatics at the Faculty of Science, University of Copenhagen 2017

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1 Title, affiliation and language
A shared section that applies to all BSc and MSc Programmes at the Faculty of Science is linked to this programme-specific curriculum.

1.1 Title
The MSc Programme in Bioinformatics with a specialisation in Computational Biology leads to a Master of Science (MSc) in Bioinformatics with specialisation in Computational Biology with the Danish title: Cand.scient. (candidatus/candidata scientiarum) i bioinformatik med specialisering i Computational Biology.

The MSc Programme in Bioinformatics with a specialisation in Computer Science leads to a Master of Science (MSc) in Bioinformatics with the specialisation in Computer Science with the Danish title: Cand.scient. (candidatus/candidata scientiarum) i bioinformatik med specialisering i Computer Science.

1.2 Affiliation
The programme is affiliated with the Study Board for the Biological Area and the students can both elect, and be elected, to this study board.

1.3 Corps of external examiners
The following corps of external examiners is used for the central parts of the MSc Programme:
- Corps of External Examiners for Computer Science (datalogi) with possibility of bringing in examiners from Corps of External Examiners for Biology (biologi).

1.4 Language
The language of this MSc Programme is English.

2 Academic profile
2.1 Purpose
The MSc Programme in Bioinformatics aims to qualify students to work on an interdisciplinary scientific basis with bioinformatics in both the public and private sectors. The specialisations Computational Biology and Computer Science will focus on biological data analysis and method and algorithm development, respectively.

2.2 General programme profile
The first year the student follow both compulsory courses in bioinformatics and courses that complement their competences from their BSc. Hereby, all students will have competences in both molecular biology (biochemistry and biology) and computer science (mathematics and statistics). In addition, the student follows supplementary courses that prepare them for a specialisation during their thesis thereby creating an individual academic profile.

Bioinformatics is the key subject area of the programme. Bioinformatics uses mathematical, statistical and computational techniques in DNA sequence analysis, protein and RNA structural analysis, genomics and analysis of high-output data to solve biological problems.

2.3 General structure of the programme
The MSc Programme is set at 120 ECTS.

The MSc Programme in Bioinformatics consists of the following elements:
- Specialisation, 120 ECTS, including the thesis.
The student must choose one of the following specialisations:

- Computational Biology
- Computer Science

2.4 Career opportunities
The MSc Programme in Bioinformatics qualifies students to become professionals within business functions and/or areas such as:

- A PhD programme
- Pharmaceutical and biotech companies.
- Hospitals.
- Research institutions, public and private, and in universities.

3 Description of competence profiles
Students following the MSc Programme acquire the knowledge, skills and competences listed below. Students will also acquire other qualifications through elective courses and other study activities.

3.1 Computational Biology
On completion of the programme, an MSc in Bioinformatics with a specialisation in Computational Biology has acquired the following:

Knowledge about:

- The fields of biological sequence analysis, molecular phylogeny, structural bioinformatics, systems biology and the bioinformatics aspects of gene expression and proteomics data.
- A wide range of computer programs used in bioinformatics.
- Relevant aspects of genetics, molecular biology, cell biology, mathematics, statistics, computer science and machine learning.
- Bioinformatics scientific literature and knowledge within the subject area.
- The industrial and medical applications of the subject's results.
- The use of computer science methods in molecular biology and how the two fields are integrated.

Skills in/to:

- Process, interpret and evaluate large biological datasets.
- Identify and extract information about complex biological processes from data and identify computational and statistical issues associated with the analysis of such data.
- Use information technology, including databases, scripting languages and programs, in an efficient and appropriate manner, and develop small programs.
- Apply techniques described in the bioinformatics scientific literature and assess their applicability to a given biological problem.
- Understand biological and biomedical experiments and research questions and suggest appropriate bioinformatics and experimental analyzes.
- Communicate knowledge and build bridges in interdisciplinary groups.
- Independently formulate new biological questions, and design computational protocols to systematically address them.

Competences in/to:

- Manage work and development situations that are complex, unpredictable and require new model solutions.
- Independently initiate and implement academic and interdisciplinary partnerships, and assume professional responsibility.
- Taking independent responsibility for their own academic development and specialisation.
- Develop computer programs or scripts for bioinformatics analyses.
- Acquire new computational skills needed for a specific bioinformatics problem.
- Read and understand scientific articles concerning computational methods and machine learning methods.

3.2 Computer Science

On completion of the programme, an MSc in Bioinformatics with a specialisation in Computer Science has acquired the following:

Knowledge about:
- The fields of biological sequence analysis, molecular phylogeny, structural bioinformatics, systems biology and the bioinformatics aspects of gene expression and proteomics data.
- A broad range of standard algorithms used in Bioinformatics, in particular in the analysis of biological sequences.
- Relevant aspects of genetics, molecular biology, cell biology, mathematics, statistics, computer science and machine learning.
- Scientific literature and knowledge within the subject area of Bioinformatics.
- The algorithmic basis for a wide range of popular bioinformatics methods.
- Relevant techniques in machine learning, algorithms, statistical modelling and large scale data analysis.
- The use of machine learning, algorithms and probabilistic models in bioinformatics.
- Algorithms relevant to bioinformatics.
- Machine learning relevant to bioinformatics.
- How molecular biology and computer science are integrated in modern scientific practice.

Skills in/to:
- Process, interpret and evaluate large biological datasets.
- Identify and extract information about complex biological processes from data and identify computational and statistical issues associated with the analysis of such data.
- Use information technology, including databases and programs, in an efficient and appropriate manner, and develop small programs.
- Apply techniques described in the bioinformatics scientific literature and assess their applicability to a given biological problem.
- Independently analyze, implement and improve on bioinformatics methods.
- Scaling of existing methods and software for large amount of data.
- Apply and implement modern machine learning methods to bioinformatics problems.
- Design and implement algorithms and machine learning solutions to problems in bioinformatics.
- Read and understand scientific articles in the field of bioinformatics and molecular biology.

Competences in/to:
- Manage work and development situations that are complex, unpredictable and require new model solutions.
- Independently initiate and implement academic and interdisciplinary partnerships, and assume professional responsibility.
• Take independent responsibility for his/her own academic development and specialisation.
• Develop computer programs or scripts for bioinformatics analyses.
• Communicate and collaborate with biologists and biochemists.
• Search and gain new knowledge on the relevant biology needed to solve a problem in bioinformatics.
• Design new bioinformatical methods, using modern machine learning methods and algorithms were needed, to address biological problems.
• Evaluate the computational complexity of various solutions a problem in bioinformatics.

4 Admission requirements
With a Bachelor’s degree in Natural Sciences and IT from the University of Copenhagen the student is granted reserved access and guaranteed a place on the MSc Programme in Bioinformatics if the student applies before the application deadline during the first application period after the completion of the Bachelor’s degree.

4.1 Applicants with a Bachelor’s degree in Natural Sciences and IT
Applicants with a Bachelor’s degree in Natural Sciences and IT from the University of Copenhagen are directly academically qualified for admission to the MSc programme.

4.2 Applicants with a related Bachelor’s degree
Applicants with a Bachelor’s degree in Biology, Biology-Biotechnology, Biochemistry, Molecular Biomedicine, Computer Science, Physics or Mathematics from the University of Copenhagen are directly academically qualified for admission to the MSc Programme.

4.3 Applicants with a Bachelor’s degree within the field of science or technical science
Applicants with a Bachelor’s degree within the field of science or technical science from the University of Copenhagen or other Danish or international universities may also be admitted if the programme includes the following:

• Courses in molecular biology, genetics and biochemistry corresponding to a minimum of 30 ECTS.

or

• Courses in statistics, computer science, mathematics and physics corresponding to a minimum of 30 ECTS.

4.3 Other applicants
The Faculty may also admit applicants who, after an individual academic assessment, are deemed to possess educational qualifications equivalent to those required in Subclauses 4.1-3.

4.4 Language requirements

4.4.1 Applicants from Nordic universities
Applicants with a Bachelor’s degree from Nordic universities must as a minimum document English language qualifications comparable to a Danish upper secondary school English B level.

4.4.2 Non-Nordic applicants
Applicants with a non-Nordic Bachelor’s degree must be able to document English proficiency corresponding to an IELTS test score of minimum 6.5 or a TOEFL test score of minimum 83 (Internet-based).
5 Prioritisation of applicants
If the number of qualified applicants to the programme exceeds the number of places available, applicants will be prioritised as follows:

1) Applicants with a Bachelor’s degree in Natural Sciences and IT from the University of Copenhagen seeking admission by way of direct extension of their completed BSc programme.

2) Applicants based on grades and courses taken (biology, molecular biology, biochemistry, mathematics, physics and computer science) relevant to bioinformatics. If different grading systems make comparison impossible, applicants will be prioritised on the basis of an individual evaluation by the Admission Committee.

3) Applicants with a Bachelor’s degree within the field of science or technical science based on the interdisciplinary nature of their education, i.e. priority will be given to applicants whose Bachelor’s degree include courses in biology, molecular biology, biochemistry, mathematics, physics and computer science.

4) Other applicants.

If the number of qualified applicants within a category exceeds the number of places available, applicants will be prioritised according to the following criteria (listed below in prioritised order):

- The relevance of courses taken and previous experience within bioinformatics.

6 Structure of the programme
The compulsory subject elements, restricted elective subject elements and the thesis constitute the central parts of the programme (Section 21 of the Ministerial Order on Bachelor and Master’s Programmes (Candidatus) at Universities).

Before the beginning of the MSc Programme the student must choose a specialisation.

6.1 Computational Biology
The specialisation is set at 120 ECTS and consists of the following:

- Compulsory subject elements, 52.5 ECTS
- Restricted elective subject elements, 22.5 ECTS
- Elective subject elements, 15 ECTS
- Thesis, 30 ECTS

6.1.1 Compulsory subject elements
All of the following subject elements are to be covered (52.5 ECTS)

<table>
<thead>
<tr>
<th>Subject Element</th>
<th>Title</th>
<th>Block</th>
<th>ECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>NBIK10017U</td>
<td>RNA Biology</td>
<td>Block 1</td>
<td>7.5 ECTS</td>
</tr>
<tr>
<td>NDAK14008U</td>
<td>Programming Massively Parallel Hardware</td>
<td>Block 1</td>
<td>7.5 ECTS</td>
</tr>
</tbody>
</table>
6.1.4 Elective subject elements
15 ECTS are to be covered as elective subject elements.
All subject elements at MSc level may be included as elective subject elements in the MSc Programme.

BSc subject elements corresponding to 15 ECTS may be included in the MSc Programme.

Projects outside the course scope may be included in the elective section of the programme with up to 15 ECTS. The regulations are described in Appendix 5 to the shared section of the curriculum.

Projects in practice may be included in the elective section of the programme with up to 15 ECTS. The regulations are described in Appendix 4 to the shared section of the curriculum.

6.1.5 Thesis
The MSc Programme in Bioinformatics with a specialisation in Computational Biology includes a thesis corresponding to 30 ECTS, as described in Appendix 2 to the shared curriculum. The thesis must be written within the academic scope of the MSc programme.

6.1.6 Academic mobility
The curriculum makes it possible to follow subject elements outside the Faculty of Science.

The academic mobility for the MSc Programme in Bioinformatics with a specialisation in Computational Biology is placed in block 1+2 of the 2nd year.

Academic mobility requires that the student follows the rules and regulations regarding pre-approval and credit transfer.

In addition the student has the possibility to arrange similar academic mobility in other parts of the programme.
6.2 Computer Science
The specialisation is set at 120 ECTS and consists of the following:
- Compulsory subject elements, 37.5 ECTS
- Restricted elective subject elements, 37.5 ECTS
- Elective subject elements, 15 ECTS
- Thesis, 30 ECTS

6.2.1 Compulsory subject elements
All of the following subject elements are to be covered (37.5 ECTS):

<table>
<thead>
<tr>
<th>Subject Code</th>
<th>Subject Name</th>
<th>Block</th>
<th>ECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>NBIA05008U</td>
<td>Biological Sequence Analysis</td>
<td>Block 1</td>
<td>7.5 ECTS</td>
</tr>
<tr>
<td>NBIK14031U</td>
<td>Molecular Biology for Non-life Scientists</td>
<td>Block 1</td>
<td>7.5 ECTS</td>
</tr>
<tr>
<td>NDAA09023U</td>
<td>Advanced Algorithms and Data Structures</td>
<td>Block 1</td>
<td>7.5 ECTS</td>
</tr>
<tr>
<td>NBIA05014U</td>
<td>Structural Bioinformatics</td>
<td>Block 2</td>
<td>7.5 ECTS</td>
</tr>
<tr>
<td>NDAK15007U</td>
<td>Machine Learning</td>
<td>Block 2</td>
<td>7.5 ECTS</td>
</tr>
</tbody>
</table>

6.2.2 Restricted elective subject elements
37.5 ECTS are to be covered as subject elements from the following list:

<table>
<thead>
<tr>
<th>Subject Code</th>
<th>Subject Name</th>
<th>Block</th>
<th>ECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>NBIK10007U</td>
<td>RNA Biology</td>
<td>Block 1</td>
<td>7.5 ECTS</td>
</tr>
<tr>
<td>NDAK14008U</td>
<td>Programming Massively Parallel Hardware</td>
<td>Block 1</td>
<td>7.5 ECTS</td>
</tr>
<tr>
<td>NBIK15022U</td>
<td>Advanced Topics in Bioinformatics</td>
<td>Block 1</td>
<td>7.5 ECTS</td>
</tr>
<tr>
<td>NDAK15014U</td>
<td>Advanced Topics in Machine Learning</td>
<td>Block 1</td>
<td>7.5 ECTS</td>
</tr>
<tr>
<td>NDAK10005U</td>
<td>Medical Image Analysis</td>
<td>Block 1</td>
<td>7.5 ECTS</td>
</tr>
<tr>
<td>NDAK14003U</td>
<td>Discrete Optimization</td>
<td>Block 1</td>
<td>7.5 ECTS</td>
</tr>
<tr>
<td>NMAK14029U</td>
<td>Statistics for Bioinformatics and eScience (StatBIE)</td>
<td>Block 2</td>
<td>7.5 ECTS</td>
</tr>
<tr>
<td>NDAK14009U</td>
<td>Parallel Functional Programming</td>
<td>Block 2</td>
<td>7.5 ECTS</td>
</tr>
<tr>
<td>NDAK15017U</td>
<td>Interactive Data Exploration</td>
<td>Block 2</td>
<td>7.5 ECTS</td>
</tr>
<tr>
<td>NDAK10009U</td>
<td>Computational Geometry</td>
<td>Block 3</td>
<td>7.5 ECTS</td>
</tr>
<tr>
<td>NDAA09009U</td>
<td>Numerical Optimization</td>
<td>Block 3</td>
<td>7.5 ECTS</td>
</tr>
<tr>
<td>NDAK14007U</td>
<td>Applied Programming</td>
<td>Block 4</td>
<td>7.5 ECTS</td>
</tr>
<tr>
<td>NDAK14005U</td>
<td>Randomized Algorithms</td>
<td>Block 4</td>
<td>7.5 ECTS</td>
</tr>
<tr>
<td>NBIA07023U</td>
<td>Bioinformatics of High Throughput Analyses</td>
<td>Block 4</td>
<td>7.5 ECTS</td>
</tr>
<tr>
<td>NBIK10013U</td>
<td>Individual Project in Bioinformatics</td>
<td>Block 1-5</td>
<td>15 ECTS</td>
</tr>
<tr>
<td>NBIK10005U</td>
<td>Bioinformatics Project 1</td>
<td>Block 1-5</td>
<td>7.5 ECTS</td>
</tr>
<tr>
<td>NBIK10008U</td>
<td>Bioinformatics Project 2</td>
<td>Block 1-5</td>
<td>7.5 ECTS</td>
</tr>
<tr>
<td>NBIK10009U</td>
<td>Bioinformatics Project 3</td>
<td>Block 1-5</td>
<td>7.5 ECTS</td>
</tr>
<tr>
<td>NBIK10010U</td>
<td>Bioinformatics Project 4</td>
<td>Block 1-5</td>
<td>7.5 ECTS</td>
</tr>
</tbody>
</table>

6.1.4 Elective subject elements
15 ECTS are to be covered as elective subject elements.
All subject elements at MSc level may be included as elective subject elements in the MSc Programme.

BSc subject elements corresponding to 15 ECTS may be included in the MSc Programme.

Projects outside the course scope may be included in the elective section of the programme with up to 15 ECTS. The regulations are described in Appendix 5 to the shared section of the curriculum.

Projects in practice may be included in the elective section of the programme with up to 15 ECTS. The regulations are described in Appendix 4 to the shared section of the curriculum.
6.1.5 Thesis
The MSc Programme in Bioinformatics with a specialisation in Computer Science includes a thesis corresponding to 30 ECTS, as described in Appendix 2 to the shared curriculum. The thesis must be written within the academic scope of the MSc programme.

6.1.6 Academic mobility
Academic mobility requires that the student follows the rules and regulations regarding pre-approval and credit transfer.

The academic mobility for the MSc Programme in Bioinformatics with a specialisation in Computer science is placed in block 3+4 of the 1st year. This means that the curriculum makes it possible to follow subject elements outside the Faculty of Science.

In addition the student has the possibility to arrange similar academic mobility in other parts of the programme.

7 Exemptions
In exceptional circumstances, the study board may grant exemptions from the rules in the curriculum specified solely by the Faculty of Science.

8 Commencement etc.
8.1 Validity
This subject specific section of the curriculum applies to all students enrolled on the programme – see however Appendix 2.

8.2 Transfer
Students enrolled on previous curricula may be transferred to the new one as per the applicable transfer regulations or according to an individual credit transfer by the study board.

8.3 Amendment
The curriculum may be amended once a year so that any changes come into effect at the beginning of the academic year. Amendments must be proposed by the study board and approved by the Dean.

Notification about amendments that tighten the admission requirements for the programme will be published online at www.science.ku.dk one year before they come into effect.

If amendments are made to this curriculum, an interim arrangement may be added if necessary to allow students to complete their MSc Programme according to the amended curriculum.
### Appendix 1 Tables

#### Table - MSc Programme in Bioinformatics with a specialisation in Computational Biology

<table>
<thead>
<tr>
<th>Block 1</th>
<th>Block 2</th>
<th>Block 3</th>
<th>Block 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1st year</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linux and Phyton Programming</td>
<td>Statistics for Bioinformatics and eScience</td>
<td>Population Genetics</td>
<td>Restricted elective</td>
</tr>
<tr>
<td>Biological Sequence Analysis</td>
<td>Structural Bioinformatics</td>
<td>Introduction to Data Science</td>
<td>Bioinformatics of High Throughput Analyses</td>
</tr>
<tr>
<td><strong>2nd year</strong></td>
<td>Restricted elective</td>
<td>Restricted elective</td>
<td>Thesis</td>
</tr>
<tr>
<td>Elective</td>
<td>Elective</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The table illustrates the recommended academic progression. The student is allowed to plan an alternative progression within the applicable rules.

#### Table - MSc Programme in Bioinformatics with a specialisation in Computer Science

<table>
<thead>
<tr>
<th>Block 1</th>
<th>Block 2</th>
<th>Block 3</th>
<th>Block 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1st year</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Molecular Biology for Non-life Scientist</td>
<td>Machine Learning</td>
<td>Restricted elective</td>
<td>Restricted elective</td>
</tr>
<tr>
<td>Biological Sequence Analysis</td>
<td>Structural Bioinformatics</td>
<td>Restricted elective</td>
<td>Restricted elective</td>
</tr>
<tr>
<td><strong>2nd year</strong></td>
<td>Advanced Algorithms and Data Structures</td>
<td>Restricted elective</td>
<td>Thesis</td>
</tr>
<tr>
<td>Elective</td>
<td>Elective</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The table illustrates the recommended academic progression. The student is allowed to plan an alternative progression within the applicable rules.
Appendix 2 Interim arrangements

There are currently no interim arrangements to this curriculum.
Appendix 3 Description of objectives for the thesis

After completing the thesis, the student should have:

Knowledge about:
- Solid interdisciplinary knowledge in the fields of biological sequence analysis, molecular phylogeny, structural bioinformatics, systems biology and the bioinformatics aspects of gene expression and proteomics data.
- Knowledge at the highest international level within an area of specialisation.
- Knowledge of relevant aspects of genetics, molecular biology, cell biology, mathematics, statistics, computer science and machine learning.
- Understanding of bioinformatics scientific literature, and are able to reflect scientifically on knowledge within the subject area and identify scientific problems.
- Familiarity with the industrial and medical applications of the subject's results.

Skills in/to:
- Process, interpret and evaluate large biological datasets.
- Identify and extract information about complex biological processes as well as computer science and statistical issues.
- Use information technology, including databases and programs, in an efficient and appropriate manner, and develop small programs.
- Evaluate and apply techniques described in bioinformatics scientific literature.
- Communicate knowledge and build bridges in interdisciplinary groups.

Competences in/to:
- Manage work and development situations that are complex, unpredictable and require new model solutions.
- Independently initiate and implement academic and interdisciplinary partnerships, and assume professional responsibility.
- Taking independent responsibility for their own academic development and specialisation.