BIOINFORMATICS, BACHELOR OF SCIENCE (B.S.) WITH A CONCENTRATION IN QUANTITATIVE/STATISTICAL SCIENCES

This bioinformatics program consists of a core curriculum that provides the basics of biology, chemistry, computer science and statistics, as well as an introduction to the field of bioinformatics. The bachelor’s program in bioinformatics requires breadth of training via VCU Life Sciences’ general education requirements, specific training in the collateral course work and bioinformatics core, and focused training in the areas of biological/genomic sciences, computational sciences or quantitative/statistical sciences through the concentration-specific courses.

Students wishing to pursue the bioinformatics major must apply for admission into the program. High school seniors as well as students transferring to VCU should follow the regular VCU admissions process and deadlines, being sure to indicate clearly in their application that they wish to apply to the bioinformatics program. Continuing VCU students wishing to apply to the program will find information about the application process at csbc.vcu.edu/bioinformatics-programs/undergraduate or by calling the director of undergraduate curricula at (804) 828-0559 or the Center for the Study of Biological Complexity at (804) 827-0026.

Transfer students and continuing VCU students with at least 15 college credits should present a suggested college GPA of 3.0 including relevant course work in science, math or computer science.

Learning outcomes

Upon completing this program, students will know and know how to do the following:

- Present scientific results, both orally and in writing, in a way that makes clear to an appropriate target audience the distinction between what is known (and how) and what is merely suspected between an observation and a conclusion in a way that tells a compelling story
- Will have demonstrated fundamental knowledge of the basic concepts of biology (particularly molecular biology), the physical sciences, mathematics, statistics and computational science and the ability to apply that knowledge within the context of bioinformatics
- Will have demonstrated an ability to identify and analyze bioinformatics problems and strategies to solve said problems
- Will possess an appropriate level of technical knowledge and ability necessary to address a scientific problem by exploiting biological software and datasets and creating simple bioinformatics tools
- Will have demonstrated an ability to identify and access relevant scientific literature and draw from it in a meaningful and critical manner

Degree requirements for Bioinformatics, Bachelor of Science (B.S.) with a concentration in quantitative/statistical sciences

General Education requirements

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNIVERSITY Core Education Curriculum (minimum 21 credits)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UNIV 111</td>
<td>Play course video for Focused Inquiry I</td>
<td>3</td>
</tr>
<tr>
<td>UNIV 112</td>
<td>Play course video for Focused Inquiry II</td>
<td>3</td>
</tr>
<tr>
<td>UNIV 200</td>
<td>Inquiry and the Craft of Argument</td>
<td>3</td>
</tr>
<tr>
<td>Approved humanities/fine arts</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Approved natural/physical sciences</td>
<td>3-4</td>
<td></td>
</tr>
<tr>
<td>Approved quantitative literacy</td>
<td>3-4</td>
<td></td>
</tr>
<tr>
<td>Approved social/behavioral sciences</td>
<td>3-4</td>
<td></td>
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</tbody>
</table>

General education requirements

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>LFSC 301</td>
<td>Integrative Life Sciences Research</td>
<td>3</td>
</tr>
<tr>
<td>MATH 151</td>
<td>Precalculus Mathematics (fulfills University Core quantitative literacy)</td>
<td>4</td>
</tr>
</tbody>
</table>

Select one of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>STAT 212</td>
<td>Concepts of Statistics (preferred)</td>
<td>3</td>
</tr>
<tr>
<td>STAT 210</td>
<td>Basic Practice of Statistics (with program approval)</td>
<td></td>
</tr>
</tbody>
</table>

Foreign language through 102 level or equivalent course or by placement testing | 0-8 |

Total Hours: 27-38

Collateral requirements

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 200</td>
<td>Calculus with Analytic Geometry</td>
<td>4</td>
</tr>
</tbody>
</table>

Select one of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 207</td>
<td>University Physics I (preferred)</td>
<td>4-5</td>
</tr>
<tr>
<td>PHYS 201</td>
<td>General Physics I (may be substituted with program approval)</td>
<td></td>
</tr>
</tbody>
</table>

Total Hours: 8-9

Major core requirements

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOL 151</td>
<td>Introduction to Biological Sciences I</td>
<td>3</td>
</tr>
<tr>
<td>BIOL 152</td>
<td>Introduction to Biological Sciences II</td>
<td>3</td>
</tr>
<tr>
<td>BIOL 300</td>
<td>Cellular and Molecular Biology</td>
<td>3</td>
</tr>
<tr>
<td>BNFO 201</td>
<td>Computing Skills and Concepts for Bioinformatics</td>
<td>3</td>
</tr>
</tbody>
</table>

Select one of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
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</thead>
<tbody>
<tr>
<td>BIOZ 151</td>
<td>Introduction to Biological Science Laboratory I (with program approval)</td>
<td></td>
</tr>
<tr>
<td>LFSC/BNFO 251</td>
<td>Phage Discovery I (preferred)</td>
<td></td>
</tr>
</tbody>
</table>

Select one of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOZ 152</td>
<td>Introduction to Biological Science Laboratory II (with program approval)</td>
<td></td>
</tr>
<tr>
<td>LFSC/BNFO 252</td>
<td>Phage Discovery II (preferred)</td>
<td></td>
</tr>
</tbody>
</table>
Bioinformatics, Bachelor of Science (B.S.) with a concentration in quantitative/statistical sciences

BNFO 300 Molecular Biology Through Discovery 3
BNFO 301/BIOL 351 Introduction to Bioinformatics 3
BNFO 420 Applications in Bioinformatics (University Core capstone) 3

CHEM 101 General Chemistry I 4
& CHEZ 101 and General Chemistry Laboratory I 4
CHEM 102 General Chemistry II 3
CHEM 301 Organic Chemistry 3
CMSC 255 Introduction to Programming 4

STAT 314 Applications of Statistics 4

Total Hours 43

Concentration-required courses

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 201</td>
<td>Calculus with Analytic Geometry</td>
<td>4</td>
</tr>
<tr>
<td>MATH 307</td>
<td>Multivariate Calculus</td>
<td>4</td>
</tr>
<tr>
<td>MATH 310</td>
<td>Linear Algebra</td>
<td>3</td>
</tr>
<tr>
<td>STAT 321</td>
<td>Introduction to Statistical Computing</td>
<td>3</td>
</tr>
</tbody>
</table>

Total Hours 14

Concentration electives

Select eight concentration electives from the list below

Open electives

Select five to 20 open elective credits

Total minimum requirement 120 credits

Concentration electives

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOS/STAT 513</td>
<td>Mathematical Statistics I</td>
<td>3</td>
</tr>
<tr>
<td>BIOS/STAT 514</td>
<td>Mathematical Statistics II</td>
<td>3</td>
</tr>
<tr>
<td>BIOS 524</td>
<td>Biostatistical Computing</td>
<td>3</td>
</tr>
<tr>
<td>BIOS 543</td>
<td>Graduate Research Methods I</td>
<td>3</td>
</tr>
<tr>
<td>BIOS 544</td>
<td>Graduate Research Methods II</td>
<td>3</td>
</tr>
<tr>
<td>BIOS 546</td>
<td>Theory of Linear Models</td>
<td>3</td>
</tr>
<tr>
<td>BNFO/MATH/BIOL 380</td>
<td>Introduction to Mathematical Biology</td>
<td>4</td>
</tr>
</tbody>
</table>

BNFO 491 Special Topics in Bioinformatics (variable) 1
BNFO 492 Independent Study (variable) 1
BNFO 496 Undergraduate Teaching Assistantship in Bioinformatics 1-2
BNFO 497 Research and Thesis (variable) 1
BNFO/BIOL 540 Fundamentals of Molecular Genetics
CMSC 256 Data Structures and Object Oriented Programming 4
MATH 211 Mathematical Structures 3
STAT 309 Introduction to Probability Theory 3
STAT 421 Applied Statistical Computing Using R 3

STAT 441 Applied Statistics for Engineers and Scientists 3

May be taken only with adviser’s permission

What follows is a sample plan that meets the prescribed requirements within a four-year course of study at VCU. Please contact your adviser before beginning course work toward a degree.

Freshman year

Fall semester

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOL 151</td>
<td>Introduction to Biological Sciences I</td>
<td>3</td>
</tr>
<tr>
<td>BNFO 251</td>
<td>Phage Discovery I</td>
<td>2</td>
</tr>
<tr>
<td>or LFSC 251</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MATH 151</td>
<td>Precalculus Mathematics (approved quantitative literacy, University Core Curriculum Tier II)</td>
<td>4</td>
</tr>
</tbody>
</table>

UNIV 101     | Introduction to the University                      | 1     |
UNIV 111     | Play course video for Focused Inquiry I             | 3     |

Open elective

Term Hours: 3

Spring semester

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOL 152</td>
<td>Introduction to Biological Sciences II</td>
<td>3</td>
</tr>
<tr>
<td>BNFO 252</td>
<td>Phage Discovery II</td>
<td>2</td>
</tr>
<tr>
<td>or LFSC 252</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CHEM 101</td>
<td>General Chemistry I</td>
<td>4</td>
</tr>
</tbody>
</table>
& CHEZ 101 and General Chemistry Laboratory I
MATH 200     | Calculus with Analytic Geometry                     | 4     |

UNIV 112     | Play course video for Focused Inquiry II            | 3     |

Term Hours: 16

Sophomore year

Fall semester

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>BNFO 201</td>
<td>Computing Skills and Concepts for Bioinformatics</td>
<td>3</td>
</tr>
<tr>
<td>BNFO 300</td>
<td>Molecular Biology Through Discovery</td>
<td>3</td>
</tr>
<tr>
<td>CHEM 102</td>
<td>General Chemistry II</td>
<td>3</td>
</tr>
<tr>
<td>MATH 201</td>
<td>Calculus with Analytic Geometry</td>
<td>4</td>
</tr>
</tbody>
</table>

UNIV 200     | Inquiry and the Craft of Argument                   | 3     |

Term Hours: 16

Spring semester

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOL 300</td>
<td>Cellular and Molecular Biology</td>
<td>3</td>
</tr>
<tr>
<td>BNFO 301</td>
<td>Introduction to Bioinformatics</td>
<td>3</td>
</tr>
<tr>
<td>or BIOL 351</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Term Hours: 16
### Bioinformatics

**BNFO 201. Computing Skills and Concepts for Bioinformatics. 3 Hours.**
Semester course; 3 lecture hours. 3 credits. Prerequisite: MATH 151 or 200 with a minimum grade of C, or satisfactory score on the VCU Mathematics Placement Test within the one-year period immediately preceding the beginning of the course. An introduction to computation in bioinformatics, including basics of data representation, and computer organization, as well as programming in Python or other appropriate scripting language. Bioinformatics applications in the literature will be discussed. Guest speakers will share bioinformatics career experiences and opportunities.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>BNFO 201</td>
<td>Computing Skills and Concepts for Bioinformatics</td>
<td>3</td>
</tr>
</tbody>
</table>

**BNFO 251. Phage Discovery I. 2 Hours.**
Semester course; 4 laboratory hours. 2 credits. Corequisite: BIOL 151 or 152. An exploratory laboratory where students will purify phage from soil, visualize phage using electron microscopy and isolate genomic material for nucleic acid sequencing. Registration by override only. Crosslisted as: LFSC 251.

**BNFO 252. Phage Discovery II. 2 Hours.**
Semester course; 4 laboratory hours. 2 credits. Corequisite: BIOL 151 or 152. An exploratory laboratory where students will learn about the genomes of viruses infecting bacteria. Students will be given the genome sequence of a novel virus, which will be the basis for a series of computer-based analyses to understand the biology of the virus and to compare it with other viruses that infect the same host. Registration by override only. Crosslisted as: LFSC 252.

**Junior year**

**Fall semester**
- **BNFO 492** Independent Study (or other concentration elective) 4 Hours.
- **CHEM 301** Organic Chemistry 3 Hours.
- **LFSC 301** Integrative Life Sciences Research 3 Hours.
- **MATH 310** Linear Algebra 3 Hours.

**Spring semester**
- **CMSC 255** Introduction to Programming 4 Hours.
- **STAT 314** Applications of Statistics 4 Hours.
- **Approved humanities/fine arts course (University Core Curriculum Tier II)** 3 Hours.
- **Select one of the following:**
  - **PHYS 207** University Physics I (preferred) 5 Hours.
  - **PHYS 201** General Physics I (may be substituted with program approval) 4 Hours.

**Senior year**

**Fall semester**
- **STAT 321** Introduction to Statistical Computing 3 Hours.
- **Approved social/behavioral sciences course (University Core Curriculum Tier II)** 3 Hours.
- **Concentration elective** 3 Hours.
- **Open elective or foreign language** 3 Hours.

**Spring semester**
- **BNFO 420** Applications in Bioinformatics (University Core capstone) 3 Hours.
- **Open elective or foreign language** 3 Hours.
- **Open electives** 9 Hours.

**Total Hours:** 120 Hours.

- Bioinformatics (BNFO) (p. 3)
- Life sciences (LFSC) (p. 4)
BNFO 440. Computational Methods in Bioinformatics. 3 Hours.
Semester course; 2 lecture and 2 laboratory hours. 3 credits.
Prerequisites: CMSC 255 and 256, BNFO 301, or permission of instructor.
An introduction to mathematical and computational methods in bioinformatics analysis. Topics include but are not limited to operating systems, interfaces, languages, SQL, search algorithms, string manipulation, gene sequencing, simulation and modeling, and pattern recognition. Students will be exposed to Maple, Matlab, SPSS, E-cell, BioPerl, Epigram and C as part of the requirements of this course.

BNFO 491. Special Topics in Bioinformatics. 1-4 Hours.
Semester course; variable hours. 1-4 credits. Prerequisites: permission of instructor and adviser. An introductory, detailed study of a selected topic in bioinformatics unavailable as an existing course. Students will find specific topics and prerequisites for each special topics course listed in the Schedule of Classes. If multiple topics are offered, students may elect to take more than one. Adviser's approval is required for counting each special topics course toward meeting specific requirements of the B.S. program.

BNFO 492. Independent Study. 1-4 Hours.
Semester course; variable hours. A minimum of three hours of supervised activity per week per credit is required. 1-4 credits. May be repeated for a maximum total of 6 credits. Prerequisite: BIOL 218. Projects should include data collection and analysis, learning bioinformatics-related research techniques, and mastering experimental procedures, all under the direct supervision of a faculty member. A final report must be submitted at the completion of the project. Graded as pass/fail.

BNFO 496. Undergraduate Teaching Assistantship in Bioinformatics. 1-2 Hours.
Semester course; variable hours. 1-2 credits. May be repeated for a maximum total of 2 credits. Prerequisites: permission of instructor and a minimum grade of B in the course the student will TA. Student will work with course instructor to implement course objectives. Typical duties involve media preparation, answering questions, providing feedback on course assignments and peer mentoring. Provides exposure to the practice, possibilities, rewards and responsibilities of the act of teaching.

BNFO 497. Research and Thesis. 1-4 Hours.
Semester course; variable hours. A minimum of three hours of supervised activity per week per credit is required. 1-4 credits. May be repeated for a maximum total of 6 credits. Prerequisites: BIOL 218, junior or senior status. Projects should include data collection and analysis, learning bioinformatics-related research techniques, and mastering experimental procedures, all under the direct supervision of a faculty member. A written thesis of substantial quality is required at the completion of the research.

Life Sciences

LFSC 101. Academic and Career Options in Life Sciences. 1 Hour.
Semester course; 1 lecture hour. 1 credit. Students interested in the life sciences at VCU are faced with an enormous variety of academic options from bioinformatics and biomedical engineering to exercise science and nursing. Students outside of these programs have post-graduate opportunities in the life sciences, such as health care administration and government policy. This course will introduce students to an overview of all of the academic programs in life sciences available at VCU and their associated potential career options. Graded as pass/fail.

LFSC 251. Phage Discovery I. 2 Hours.
Semester course; 4 laboratory hours. 2 credits. Corequisite: BIOL 151 or 152. An exploratory laboratory where students will purify phage from soil, visualize phage using electron microscopy and isolate genomic material for nucleic acid sequencing. Registration by override only. Crosslisted as: BNFO 251.

LFSC 252. Phage Discovery II. 2 Hours.
Semester course; 4 laboratory hours. 2 credits. Corequisite: BIOL 151 or 152. An exploratory laboratory where students will learn about the genomes of viruses infecting bacteria. Students will be given the genome sequence of a novel virus, which will be the basis for a series of computer-based analyses to understand the biology of the virus and to compare it with other viruses that infect the same host. Registration by override only. Crosslisted as: BNFO 252.

LFSC 301. Integrative Life Sciences Research. 3 Hours.
Semester course; 2 lecture and 1 recitation hours. 3 credits. Pre- or corequisite: UNIV 200 or HONR 200. Students will leave this course knowing enough about science and the process of science to feel confident in critically evaluating scientific information and/or embarking on their own process of discovery with a faculty mentor. They will gain an appreciation of the interdisciplinary and complex nature of life sciences and will hone their critical thinking about how science interacts with and informs society.

LFSC 307. Community Solutions: Multiple Perspectives. 3 Hours.
Semester course; 2 lecture and 1 recitation hours. 3 credits. Prerequisite: PSYC 101. Explores possibilities for addressing social concerns of the Richmond community by understanding the complex nature of social issues as essential to their successful amelioration via perspectives of life and social sciences. Toward this end, expertise from the social sciences, the life sciences and the community are integrated. Includes a service-learning experience (a 20-hour volunteer requirement). Crosslisted as: PSYC 307.

LFSC 401. Faith and Life Sciences. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: UNIV 200 or HONR 200. Open to students of any school or program. Explores the complex relationships between faith traditions and the life sciences. Topics include epistemology, impact of life sciences on ideas of fate and responsibility, limits of science and technology, and scientific and religious perspectives on human origins, consciousness, aggression, forgiveness, health, illness and death. Crosslisted as: RELS 401.