BIOINFORMATICS, BACHELOR OF SCIENCE (B.S.) WITH A CONCENTRATION IN COMPUTATIONAL 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 computational 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 Play course video for Focused Inquiry I</td>
<td>Focused Inquiry I</td>
<td>3</td>
</tr>
<tr>
<td>UNIV 112 Play course video for Focused Inquiry II</td>
<td>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>
</tr>
</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>
<tr>
<td>Select one of the following:</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>STAT 212</td>
<td>Concepts of Statistics (preferred)</td>
<td></td>
</tr>
<tr>
<td>STAT 210</td>
<td>Basic Practice of Statistics (with program approval)</td>
<td></td>
</tr>
<tr>
<td>Foreign language through 102 level or equivalent course or by placement testing</td>
<td>0-8</td>
<td></td>
</tr>
</tbody>
</table>

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>
<tr>
<td>Select one of the following:</td>
<td></td>
<td>4-5</td>
</tr>
<tr>
<td>PHYS 207</td>
<td>University Physics I (preferred)</td>
<td></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>
<tr>
<td>Select one of the following:</td>
<td></td>
<td>2</td>
</tr>
<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</td>
<td></td>
</tr>
<tr>
<td>Select one of the following:</td>
<td></td>
<td>2</td>
</tr>
<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</td>
<td></td>
</tr>
</tbody>
</table>
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
CHEM 102  General Chemistry II  3
CHEM 301  Organic Chemistry  3
CMSC 255  Introduction to Programming  4

STAT 314  Applications of Statistics  3-4
or STAT 321  Introduction to Statistical Computing  3-4

Total Hours  42-43

Concentration-required courses

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMSC 256</td>
<td>Data Structures and Object Oriented Programming</td>
<td>4</td>
</tr>
<tr>
<td>CMSC 302</td>
<td>Introduction to Discrete Structures</td>
<td>3</td>
</tr>
<tr>
<td>CMSC 355</td>
<td>Software Engineering: Specification and Design</td>
<td>3</td>
</tr>
<tr>
<td>CMSC 401</td>
<td>Algorithm Analysis with Advanced Data Structures</td>
<td>3</td>
</tr>
<tr>
<td>MATH 211</td>
<td>Mathematical Structures</td>
<td>3</td>
</tr>
</tbody>
</table>

Total Hours  16

Concentration electives

Select six concentration elective credits from the list below

Open electives

Select nine to 24 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>BIOL/BNFO 540</td>
<td>Fundamentals of Molecular Genetics</td>
<td>3</td>
</tr>
<tr>
<td>BNFO 491</td>
<td>Special Topics in Bioinformatics</td>
<td>1-4</td>
</tr>
<tr>
<td>BNFO 492</td>
<td>Independent Study (variable)</td>
<td>1-4</td>
</tr>
<tr>
<td>BNFO 496</td>
<td>Undergraduate Teaching Assistantship in Bioinformatics</td>
<td>1-2</td>
</tr>
<tr>
<td>BNFO 497</td>
<td>Research and Thesis (variable)</td>
<td>1-4</td>
</tr>
<tr>
<td>BNFO 591</td>
<td>Special Topics in Bioinformatics</td>
<td>1-4</td>
</tr>
<tr>
<td>CMSC 409</td>
<td>Artificial Intelligence</td>
<td>3</td>
</tr>
<tr>
<td>CMSC 411</td>
<td>Computer Graphics</td>
<td>3</td>
</tr>
<tr>
<td>CMSC 508</td>
<td>Database Theory</td>
<td>3</td>
</tr>
</tbody>
</table>

1
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.
Bioinformatics, Bachelor of Science (B.S.) with a concentration in computational sciences

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<thead>
<tr>
<th>Course</th>
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<th>Hours</th>
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</thead>
<tbody>
<tr>
<td>ENVS 201</td>
<td>Earth System Science (or other approved natural/physical sciences course)</td>
<td>3</td>
</tr>
<tr>
<td>LFSC 301</td>
<td>Integrative Life Sciences Research</td>
<td>3</td>
</tr>
</tbody>
</table>

Approved humanities/fine arts course (University Core Curriculum Tier II)

### Term Hours: 15

#### Spring semester

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMSC 355</td>
<td>Software Engineering: Specification and Design</td>
<td>3</td>
</tr>
<tr>
<td>STAT 212</td>
<td>Concepts of Statistics</td>
<td>3</td>
</tr>
</tbody>
</table>

Approved social/behavioral sciences (University Core Curriculum Tier II)

#### Term Hours: 3

#### Select one of the following:

- PHYS 207 | University Physics I (preferred)                                    | 5     |

#### PHYS 201 | General Physics I (may be substituted with program approval)        | 4     |

#### Term Hours: 17

#### Senior year

#### Fall semester

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>BNFO 492</td>
<td>Independent Study (or other concentration elective)</td>
<td>3</td>
</tr>
<tr>
<td>CMSC 401</td>
<td>Algorithm Analysis with Advanced Data Structures</td>
<td>3</td>
</tr>
</tbody>
</table>

Select one of the following:

- STAT 321 | Introduction to Statistical Computing or Applications of Statistics | 3-4   |

Open elective

#### Open elective or foreign language

#### Term Hours: 15-16

#### Spring semester

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>BNFO 420</td>
<td>Applications in Bioinformatics (University Core capstone)</td>
<td>3</td>
</tr>
</tbody>
</table>

#### Open elective or foreign language

#### Open electives

#### Term Hours: 15

### Total Hours: 120-121

- Bioinformatics (BNFO) (p. 3)
- Life sciences (LFSC) (p. 4)

### 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.

#### 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.

#### BNFO 292. Independent Study. 1-2 Hours.

Semester course; variable hours. 1-2 credits. May be repeated for a maximum total of 6 credits. Prerequisite: permission of instructor. A course designed to provide an opportunity for independent readings of the bioinformatics literature under supervision of a staff member.

#### BNFO 300. Molecular Biology Through Discovery. 3 Hours.

Semester course; 3 lecture hours. 3 credits. The course aims to expand students’ "ignorance," a prerequisite for success in science, by confronting them with the interface between the known and the unknown, stressing the process by which the boundary is traversed. It will do so using as the raw material the study of molecular biology, an essential groundwork for bioinformatics.

#### BNFO 301. Introduction to Bioinformatics. 3 Hours.

Semester course; 3 lecture hours. 3 credits. Prerequisites: BNFO 201 and BNFO 300 or permission of instructor. The course will present a practical and theoretical introduction to the tools and techniques needed to obtain and interpret a variety of genome-related data types. The course will include several bioinformatic methods underlying nucleotide and protein sequence alignment, statistical methods for data visualization in R, the types of experimental results commonly encountered in bioinformatics data analysis and the public databases where these data can be accessed. Crosslisted as: BIOL 351.

#### BNFO 380. Introduction to Mathematical Biology. 4 Hours.

Semester course; 3 lecture and 2 laboratory hours. 4 credits. Prerequisites: MATH 200 and BIOL 151, or permission of instructor. An introduction to mathematical biology. Various mathematical modeling tools will be covered and implemented in a range of biological areas. Additionally, the collaborative research process will be presented and discussed. Crosslisted as: MATH 380/BIOL 380.

#### BNFO 420. Applications in Bioinformatics. 3 Hours.

Semester course; 2 lecture and 2 laboratory hours. 3 credits. Prerequisites: CMSC 245 or 255 and BNFO 301. Capstone course. Students will integrate biological, computational and quantitative skills to complete bioinformatics projects in a professional team-problem-solving context. Course includes explicit instruction in the conduct of research as well as a review of applicable strategies, methods and technologies. Written and oral presentation is emphasized, with systematic feedback and practice opportunities provided.
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.

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; 3 lecture 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.