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 (https://cbds.vcu.edu/academics/undergraduate-studies/) on the center’s website 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>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></td>
<td>3</td>
</tr>
<tr>
<td>Approved natural/physical sciences</td>
<td></td>
<td>3-4</td>
</tr>
<tr>
<td>Approved quantitative literacy</td>
<td></td>
<td>3-4</td>
</tr>
<tr>
<td>Approved social/behavioral sciences</td>
<td></td>
<td>3-4</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>3</td>
<td></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 I</td>
<td>4</td>
</tr>
<tr>
<td>Select one of the following:</td>
<td>4-5</td>
<td></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>2</td>
<td></td>
</tr>
<tr>
<td>BIOL 251</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>2</td>
<td></td>
</tr>
<tr>
<td>BIOL 252</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
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**

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

Select six concentration elective credits from the list below

Total Hours   6

**Open electives**

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Select nine to 24 open elective credits</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Term Hours:   9-24

The minimum total of credit hours required for this degree is 120.

**Freshman year**

<table>
<thead>
<tr>
<th>Fall semester</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOL 151   Introduction to Biological Sciences I</td>
<td>3</td>
</tr>
<tr>
<td>BNFO 201   Computing Skills and Concepts for Bioinformatics</td>
<td>3</td>
</tr>
</tbody>
</table>
| BNFO 251 or LFSC 251   Phage Discovery I
            or Phage Discovery I | 2    |
| MATH 151   Precalculus Mathematics (approved quantitative literacy, University Core Curriculum Tier II) | 4    |
| UNIVERS 101   Introduction to the University | 1    |
| UNIVERS 111   Focused Inquiry I
            Play course video for Focused Inquiry I | 3    |

Term Hours:   16

<table>
<thead>
<tr>
<th>Spring semester</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOL 152   Introduction to Biological Sciences II</td>
<td>3</td>
</tr>
</tbody>
</table>
| BNFO 252 or LFSC 252   Phage Discovery II
            or Phage Discovery II | 2    |
| CHEM 101 & CHEZ 101   General Chemistry I
            and General Chemistry Laboratory I | 4    |
| MATH 200   Calculus with Analytic Geometry I | 4    |
| UNIVERS 112   Focused Inquiry II
            Play course video for Focused Inquiry II | 3    |

Term Hours:   16

**Sophomore year**

<table>
<thead>
<tr>
<th>Fall semester</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>BNFO 300   Molecular Biology Through Discovery</td>
<td>3</td>
</tr>
<tr>
<td>CHEM 102   General Chemistry II</td>
<td>3</td>
</tr>
<tr>
<td>CMSC 255   Introduction to Programming</td>
<td>4</td>
</tr>
<tr>
<td>MATH 211   Mathematical Structures</td>
<td>3</td>
</tr>
</tbody>
</table>

Term Hours:   13

<table>
<thead>
<tr>
<th>Spring semester</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOL 300   Cellular and Molecular Biology</td>
<td>3</td>
</tr>
</tbody>
</table>
| BNFO 301 or BIOL 351   Introduction to Bioinformatics
            or Introduction to Bioinformatics | 3    |
| CMSC 256   Data Structures and Object Oriented Programming   | 4    |
| UNIVERS 200   Inquiry and the Craft of Argument | 3    |

Term Hours:   13

**Junior year**

<table>
<thead>
<tr>
<th>Fall semester</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM 301   Organic Chemistry</td>
<td>3</td>
</tr>
<tr>
<td>CMSC 302   Introduction to Discrete Structures</td>
<td>3</td>
</tr>
</tbody>
</table>
| ENVS 201   Earth System Science (or other approved natural/physical sciences course
            University Core Curriculum Tier II) | 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.
Bioinformatics, Bachelor of Science (B.S.) with a concentration in computational sciences

LFS 301 Integrative Life Sciences Research 3
Approved humanities/fine arts course (University Core Curriculum Tier II) 3

Spring semester
CMSC 355 Software Engineering: Specification and Design 3
STAT 212 Concepts of Statistics 3
Approved social/behavioral sciences (University Core Curriculum Tier II) 3
Concentration elective 3
Select one of the following: 5
PHYS 207 University Physics I (preferred) 5
PHYS 201 General Physics I (may be substituted with program approval) 4

Fall semester
BNFO 492 Independent Study (or other concentration elective) 3
CMSC 401 Algorithm Analysis with Advanced Data Structures 3
STAT 321 Introduction to Statistical Computing 3
or STAT 314 Applications of Statistics 4
Open elective 3
Open elective or foreign language 3

Senior year
BNFO 391 Special Topics in Bioinformatics 1-4 Hours.
BNFO 392 Independent Study 1-2 Hours.

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

Total Hours: 120-121

The minimum total of credit hours required for this degree is 120.

• Bioinformatics (BNFO) (p. 3)
• Life sciences (LFS) (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 202. Molecular Biology Through Discovery. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: MATH 151 or 152. An introductory 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: LFS 251.

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 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: LFS 252.

BNFO 290. Introduction to Mathematical Biology. 4 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: MATH 151 or 152. An introductory, detailed study of a selected topic in bioinformatics unavailable as an existing course. 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 420. Special Topics in Bioinformatics. 1-4 Hours.
Semester course; 1-4 lecture hours. 1-4 credits. May be repeated for a maximum total of 12 credits. An introductory, detailed study of a selected topic in bioinformatics unavailable as an existing course. 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 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 literature under supervision of a staff member.

BNFO 302. 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: LFS 252.

BNFO 492. 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 392. Independent Study. 1-2 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 393. Special Topics in Bioinformatics. 1-4 Hours.
Semester course; 1-4 lecture hours. 1-4 credits. May be repeated for a maximum total of 12 credits. A detailed study of a selected topic in bioinformatics unavailable as an existing course. 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 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; 1-4 lecture hours. 1-4 credits. May be repeated
for a maximum total of 12 credits. A detailed study of a selected topic in
bioinformatics unavailable as an existing course. 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 191. Special Topics in Integrative Life Sciences. 1-4 Hours.
Semester course; 1-4 lecture hours. 1-4 credits. May be repeated
for credit with different topics. A 100-level study of a selected topic
in integrative life sciences. 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.

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
gene 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 391. Special Topics in Integrative Life Sciences. 1-4 Hours.
Semester course; 1-4 lecture hours. 1-4 credits. May be repeated
for credit with different topics. A 300-level study of a selected topic
in integrative life sciences. 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.
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.

LFSC 491. Special Topics in Integrative Life Sciences. 1-4 Hours.
Semester course; 1-4 lecture hours. 1-4 credits. May be repeated for credit with different topics. A 400-level study of a selected topic in integrative life sciences. 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.