BIOINFORMATICS, MASTER OF SCIENCE (M.S.)

Program goals

The VCU Center for Biological Data Science created and administers the Master of Science in Bioinformatics degree program to provide interested students with two options:

1. The Master of Science in Bioinformatics thesis option is a traditional research- and thesis-oriented master's degree. The mission of this research-oriented degree program is to prepare students for research careers in university, foundation or industry laboratories; and completion of a thesis provides problem-solving skills required for a research career. In addition to course work, students complete a substantial original research project with a VCU faculty mentor and write a thesis describing that work. This degree program prepares students for employment in an academic, industrial or government environment and for Ph.D. training programs.
2. The Master of Science in Bioinformatics non-thesis option is a Professional Science Master's degree program. The mission of this professionally oriented program is to train graduates for leadership roles in bioinformatics, biotechnology, biomedicine and other sectors of the life sciences. The program imparts interdisciplinary knowledge, skills and experience in the biological, quantitative and information sciences, and engages students in the practices of business and entrepreneurship in collaboration with the commercial and public bioscience sectors. In addition to course work featuring both bioinformatics and business fundamentals, students participate in a summer externship at an industrial or government setting. This degree program not only prepares students with advanced training in bioinformatics, but also in workplace skills valued by employers.

Students enter the program from a variety of academic backgrounds (biology, chemistry, computer science, mathematics/statistics, etc.) assisted by flexible "bridge curricula" designed to help them meet program prerequisites. Students will have an effective exposure to the biotech industry and other career options and to real-life applications of their learning.

The Master of Science in Bioinformatics degree program will prepare students to:

1. **Synthesize and apply interdisciplinary subject matter:** The M.S. in Bioinformatics degree program seeks to provide students with the skills and knowledge required to advance into Ph.D. training programs and research positions in universities, government labs or industry. The program provides a framework for the progressive development of a mastery of the interdisciplinary subject matter pertinent to bioinformatics and an ability to synthesize this information and apply it to key areas of investigation and experimentation in bioinformatics.
2. **Design, implement and interpret experimental approaches:** The program relates the above framework to the development of the ability to design, implement and interpret experimental approaches.
3. **Develop communication skills:** In addition, the program will develop skills in oral and written communication of interdisciplinary science concepts, experimental design, results and interpretation.

Student learning outcomes

1. **Oral communication skills:** The candidate will demonstrate the achievement of an appropriate level of oral communication skills with respect to the content, organization, logical flow, presentation and appropriate use of language incorporating the use of visual aids, as measured by rubric.
2. **Written communication skills:** The candidate will demonstrate the achievement of an appropriate level of written communication skill with respect to grammar, syntax, spelling and use of vocabulary to effectively present information, including the use of figures, tables and citations, as measured by rubric.
3. **Experimental design competency:** The candidate will demonstrate the achievement of an appropriate level of competence in the ability to appraise, modify, and/or create and implement bioinformatics experimental protocols and to design and develop experiments, as measured by rubric.
4. **Problem-solving skills:** The candidate will demonstrate an appropriate level of ability to analyze scientific problems including pertinent datasets and design and develop appropriate methods to solve said problems, as measured by rubric.
5. **Integrated knowledge of bioinformatics:** The candidate will demonstrate an appropriate level of knowledge of fundamentals of molecular biology, computational science, statistics and a more detailed understanding of an individual area of internship research, including an appropriate familiarity with the research literature, as measured by rubric.

VCU Graduate Bulletin, VCU Graduate School and general academic policies and regulations for all graduate students in all graduate programs

The VCU Graduate Bulletin website documents the official admission and academic rules and regulations that govern graduate education for all graduate programs at the university. These policies are established by the graduate faculty of the university through their elected representatives to the University Graduate Council.

It is the responsibility of all graduate students, both on- and off-campus, to be familiar with the VCU Graduate Bulletin as well as the Graduate School website (http://www.graduate.vcu.edu/) and academic regulations in individual school and department publications and on program websites. However, in all cases, the official policies and procedures of the University Graduate Council, as published on the VCU Graduate Bulletin and Graduate School websites, take precedence over individual program policies and guidelines.

Visit the academic regulations section for additional information on academic regulations for graduate students. (http://bulletin.vcu.edu/academic-regs/)

Degree candidacy requirements

A graduate student admitted to a program or concentration requiring a final research project, work of art, thesis or dissertation, must qualify for continuing master's or doctoral status according to the degree candidacy requirements of the student's graduate program. Admission to degree candidacy, if applicable, is a formal statement by the graduate student's faculty regarding the student's academic achievements and the student's readiness to proceed to the final research phase of the degree program.

Graduate students and program directors should refer to the following degree candidacy policy as published in the VCU Graduate Bulletin for complete information and instructions.

Visit the academic regulations section for additional information on degree candidacy requirements. (http://bulletin.vcu.edu/academic-regs/grad/candidacy/)

Graduation requirements

As graduate students approach the end of their academic programs and the final semester of matriculation, they must make formal application to graduate. No degrees will be conferred until the application to graduate has been finalized.

Graduate students and program directors should refer to the following graduation requirements as published in the Graduate Bulletin for a complete list of instructions and a graduation checklist.

Visit the academic regulations section for additional information on graduation requirements. (http://bulletin.vcu.edu/academic-regs/grad/graduation-info/)

Apply online today. (https://www.vcu.edu/admissions/apply/graduate/)

Admission requirements

Degree:	Semester(s) of entry:	Deadline dates:	Test requirements:
M.S.	Fall	Jul 1	
	Spring	Nov 15	

Special requirements

- International students requiring temporary U.S. visas should apply by April 1 for fall admission and Sept. 1 for spring admission.

In addition to the general admission requirements of the VCU Graduate School (http://bulletin.vcu.edu/graduate/study/admission-graduate-study/admission-requirements/), applicants are encouraged to include in their personal statements, and request that their referees also discuss, one or more examples of creative and analytical contributions they have made to a recent research project (preferred) or to a challenging course assignment.

Because of the interdisciplinary nature of bioinformatics, applications are welcomed from students with various academic backgrounds, such as biology, biotechnology, molecular biology, computer science, mathematics or statistics. Our program provides “bridge curricula” to strengthen students’ preparation for graduate study in bioinformatics.

Degree requirements

Prerequisites and bridge curricula for master’s programs

While an ideal preparation for the bioinformatics master’s programs would include substantial work in molecular biology, computer science, mathematics and statistics, the program has been designed to provide “bridge curricula” to accommodate academically strong students with majors in any one of these or related disciplines. These students would develop with the assistance of their advisers a “bridge curriculum” of largely undergraduate courses to meet the prerequisites for the program and prepare them for graduate-level work.

Program prerequisites are listed below. In general, students will not need to address the set corresponding to their undergraduate majors, but will usually need to address the other two sets. It is expected that all bridge course work will be completed during the first year. While bridge courses may be completed prior to initiating the graduate program, this is not required, and most students are able, through advising, to complete bridge courses alongside graduate course work during the first year of the program.

1. **Biology/genomic prerequisites:** an introductory knowledge of biochemistry and molecular biology, one semester of organic chemistry (e.g. CHEM 301), cell biology (e.g.BIOL 300) and an undergraduate course in molecular biology or genetics
2. **Computational science prerequisites:** an introductory knowledge of computer science, including at least one general computer programming language, met by taking structured programming (e.g. CMSC 255) and data structures and advanced programming (e.g. CMSC 256)
3. **Quantitative/statistical prerequisites:** an introductory knowledge of mathematics/statistics, met by taking calculus I (e.g. MATH 200) and at least one undergraduate course in statistics

Thesis research

In addition to general VCU Graduate School graduation requirements (http://bulletin.vcu.edu/academic-regs/grad/graduation-info/), students in the M.S. program must perform a credible original investigation under the supervision of their major advisers and the Graduate Advisory Committee. Students must develop and write short proposals in consultation with their major advisers and GAC. The project must be approved by the student’s GAC, based on a short (10-page) paper submitted by the student. This paper will include background on the project, including a review of the literature, the purpose, specific aims and rationale of the project, a statement about the specific hypothesis to be investigated, and proposed methods and statistical analyses.

Research projects will be based on ongoing research in the laboratories of faculty in the Center for Biological Data Science and across both campuses of VCU and the Virginia BioTechnology Research Park. Students in the program may perform research on the broad range of subjects, from molecules to ecosystems, studied by CBDS faculty.

Students shall prepare a written thesis describing the completed research performed during their tenure in the M.S. in Bioinformatics program following the format of the Graduate School Thesis and Dissertation Manual (http://graduate.vcu.edu/media/graduate-school/docs/pdf/ThesisandDissertationManualUPDATED5-18-16.pdf). An oral defense, consisting of a public presentation of the thesis and a committee meeting to discuss the thesis, under the direction of the GAC but open to all faculty members, shall be scheduled to examine the student’s research, thesis and underlying fundamental knowledge of the discipline encompassed by the student’s research. Announcement of the oral defense, including the candidate’s name, thesis title and the day, place and time of the defense, shall be made at least 10 working days in advance of the defense.

Non-thesis (professional science master’s) externship

In addition to general VCU Graduate School graduation requirements (http://bulletin.vcu.edu/academic-regs/grad/graduation-info/), students enrolled in the non-thesis, professional science master’s option complete a 10- to 12-week full-time externship at an industrial, government or academic site, usually during the summer between the first and second years of the bioinformatics program. In preparation for this externship,

students will enroll in BNFO 620 and BNFO 621 in the semester preceding their externships. Upon initiating the externship, each student must develop and write a short proposal or prepare a PowerPoint presentation outlining the plans for the externship for review by the student's GAC. Research projects will be based on ongoing research in the laboratories of the participating external advisers. Students in the program may perform computational research on a broad range of subjects, from molecules to ecosystems, encompassing the field of bioinformatics.

In the semester following the externship experience, non-thesis students shall prepare written papers (~10 pages) describing the completed research performed during their externships following the format of the Graduate School's Thesis and Dissertation Manual (http://graduate.vcu.edu/media/graduate-school/docs/pdf/ThesisandDissertationManualUPDATED5-18-16.pdf). The paper should include background on the project, including a review of the literature, the purpose, specific aims and rationale of the project, the specific hypotheses investigated, description of the methods and statistical analyses implemented, results, discussion/conclusions, and a bibliography. An oral defense, consisting of a public presentation of the paper and a committee meeting to discuss the results, under the direction of the GAC but open to all faculty members and the adviser of the externship, shall be scheduled to examine the student's underlying fundamental knowledge of the disciplines encompassed by the student's externship. Announcement of the oral defense, including the candidate's name, project title, and the day, place and time of the defense, shall be made at least 10 working days in advance of the defense.

Curriculum requirements

Thesis option

Course	Title	Hours
Program core		
BIOL/BNFO 540	Fundamentals of Molecular Genetics	3
BNFO 531	Quantitative Methods in Bioinformatics	3
BNFO 600	Basic Scripting Languages	3
BNFO 601	Integrated Bioinformatics	4
BNFO 620	Bioinformatics Practicum	3
BNFO 690	Seminars in Bioinformatics	1
Additional requirements		
BNFO 508	Introduction to Bioinformatics Research	2
BNFO 697	Directed Research in Bioinformatics (six credits minimum)	6
OVPR 601	Scientific Integrity	1
or OVPR 602	Responsible Scientific Conduct	
or OVPR 603	Responsible Conduct of Research	
Electives		
Select courses from recommended electives below.		8
Total Hours		**34**

The minimum number of graduate credit hours required for this degree is 34.

Recommended electives

Course	Title	Hours
BNFO 591	Special Topics in Bioinformatics	
BNFO 541	Laboratory in Molecular Genetics	
BNFO 592	Independent Study	
BNFO 621	Business and Entrepreneurship Essentials for Life Scientists	
BNFO 691	Special Topics in Bioinformatics	
BNFO 692	Independent Study	
CMSC 501	Advanced Algorithms	
BNFO 653	Advanced Molecular Genetics: Bioinformatics	
CMSC 508	Database Theory	
CMSC 516	Advanced Natural Language Processing	
CMSC 510	Regularization Methods for Machine Learning	
HGEN 603	Mathematical and Statistical Genetics	
HGEN 611	Data Science I	
HGEN 612	Data Science II	
BIOS 543	Graduate Research Methods I	
BIOS 544	Graduate Research Methods II	
BIOL 605	Diversity and Inclusion in Science	
BIOL 603	Fundamentals of Scientific Leadership	
BIOL 516	Population Genetics	
Any 500- or 600-level courses in BIOL, BIOC, BIOS, BNFO, CMSC, ENVS, HGEN, LFSC, STAT with adviser and program director approval		

Non-thesis option (professional science master's)

Course	Title	Hours
Program core		
BIOL/BNFO 540	Fundamentals of Molecular Genetics	3
BNFO 531	Quantitative Methods in Bioinformatics	3
BNFO 600	Basic Scripting Languages	3
BNFO 601	Integrated Bioinformatics	4
BNFO 620	Bioinformatics Practicum	3
BNFO 690	Seminars in Bioinformatics	1
Additional requirements		
BNFO 621	Business and Entrepreneurship Essentials for Life Scientists	3
BNFO 700	Externship in Bioinformatics	2
OVPR 601	Scientific Integrity	1
or OVPR 602	Responsible Scientific Conduct	
or OVPR 603	Responsible Conduct of Research	
Electives		
Select courses from recommended electives below.		11
Total Hours		**34**

The minimum number of graduate credit hours required for this degree is 34.

Recommended electives

Course	Title	Hours
BNFO 591	Special Topics in Bioinformatics	
BNFO 541	Laboratory in Molecular Genetics	
BNFO 592	Independent Study	
BNFO/MICR 653	Advanced Molecular Genetics: Bioinformatics	
BNFO 691	Special Topics in Bioinformatics	

BNFO 692	Independent Study
CMSC 501	Advanced Algorithms
CMSC 508	Database Theory
CMSC 510	Regularization Methods for Machine Learning
CMSC 516	Advanced Natural Language Processing
BIOL 516	Population Genetics
BIOL 603	Fundamentals of Scientific Leadership
BIOL 605	Diversity and Inclusion in Science
BIOS 543	Graduate Research Methods I
BIOS 544	Graduate Research Methods II
HGEN 603	Mathematical and Statistical Genetics
HGEN 611	Data Science I
HGEN 612	Data Science II

Any 500- or 600-level courses in BIOL, BIOC, BIOS, BNFO, CMSC, ENVS, HGEN, LFSC, STAT with adviser and program director approval.

Accelerated opportunities

The department offers opportunities for qualified undergraduate students to earn both an undergraduate and graduate degree in a minimum of five years by completing approved graduate courses during the senior year of their undergraduate program. See the individual program page for concentrations in the Undergraduate Bulletin for details.

- B.S. in Bioinformatics with a concentration in biological/genomics sciences and M.S. (http://bulletin.vcu.edu/undergraduate/vcu-life-sciences/center-study-biological-complexity/bioinformatics-bs-concentration-biological-genomic/)
- B.S. in Bioinformatics with a concentration in computational sciences and M.S. (http://bulletin.vcu.edu/undergraduate/vcu-life-sciences/center-study-biological-complexity/bioinformatics-bs-concentration-computational/)
- B.S. in Bioinformatics with a concentration in quantitative/statistical sciences and M.S. (http://bulletin.vcu.edu/undergraduate/vcu-life-sciences/center-study-biological-complexity/bioinformatics-bs-concentration-quantitative-statistical/)

Contact
Allison A. Johnson, Ph.D.
Associate professor and graduate program director
aajohnson@vcu.edu
(804) 828-6782

Program website: cbds.vcu.edu/academics/graduate (https://cbds.vcu.edu/academics/graduate/)