BIOINFORMATICS, MASTER OF SCIENCE (M.S.)

Program goals

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

1. A traditional "thesis master's," including the development, implementation, writing and presentation of a coherent research project under the supervision of a graduate faculty member. This degree is most appropriate for students committed to initiating research careers in a variety of settings, including students considering pursuing later work toward a Ph.D.
2. A "professional science master's" option, with project-oriented research, including completion of a 10- to 12-week full-time externship in an industrial, government or academic site, usually during the summer between the first and second years of the bioinformatics program. This degree is most appropriate for students who wish to work in industrial/commercial settings.

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 Graduate study section for additional information on academic regulations for graduate students. (http://bulletin.vcu.edu/graduate/study/general-academic-regulations-graduate-students)

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 Graduate study section for additional information on degree candidacy requirements. (http://bulletin.vcu.edu/graduate/study/general-academic-regulations-graduate-students/degree-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 Graduate study section for additional information on graduation requirements. (http://bulletin.vcu.edu/graduate/study/general-academic-regulations-graduate-students/graduation-requirements)

Apply online at graduate.admissions.vcu.edu (http://graduate.admissions.vcu.edu).

Admission requirements

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

Special requirements

- International students requiring temporary U.S. visas should apply by April 1 for fall admission, Oct. 1 for spring admission or Feb. 1 for summer 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
2. **Computational science prerequisites:** an introductory knowledge of discrete mathematics (e.g. MATH 211) and 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/graduate/study/general-academic-regulations-graduate-students/graduation-requirements), 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 CSBC 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 CSBC 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/graduate/study/general-academic-regulations-graduate-students/graduation-requirements), 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

Core		
BIOL/BNFO 540	Fundamentals of Molecular Genetics	3
BNFO 501	Introduction to Physical Implementation of Databases	1
BNFO 508	Introduction to Bioinformatics Research	2
BNFO 600	Basic Scripting Languages	2
BNFO/BIOL 601	Integrated Bioinformatics	3
BNFO 690	Seminars in Bioinformatics	1
BNFO 697	Directed Research in Bioinformatics (six credits minimum)	6
CMSC 508	Database Theory	3
OVPR 601	Scientific Integrity	1
Electives		
Select courses from recommended electives below		12
Total Hours		34

Recommended electives

BIOL/BNFO 541	Laboratory in Molecular Genetics
BIOS 567	Statistical Methods for High-throughput Genomics Data I
BNFO 591	Special Topics in Bioinformatics
BNFO 592	Independent Study
BNFO 620	Bioinformatics Practicum
BNFO 621	Business and Entrepreneurship Essentials for Life Scientists
BNFO 637	Networks Biology
BNFO 691	Special Topics in Bioinformatics
BNFO 691	Special Topics in Bioinformatics (genomics and phylogenetics)
BNFO 692	Independent Study
CLSE 562	Advanced Systems Biology Engineering
CMSC 501	Advanced Algorithms
MICR/BNFO 653	Advanced Molecular Genetics: Bioinformatics
PHYS 591	Topics in Physics (modeling, computing and biocomplexity)

Total graduate credit hours required (minimum) 34

Non-thesis option (professional science master's)

Core		
BIOL/BNFO 540	Fundamentals of Molecular Genetics	3
BNFO 501	Introduction to Physical Implementation of Databases	1
BNFO 600	Basic Scripting Languages	2
BNFO/BIOL 601	Integrated Bioinformatics	3
BNFO 620	Bioinformatics Practicum	3
BNFO 621	Business and Entrepreneurship Essentials for Life Scientists	3
BNFO 690	Seminars in Bioinformatics	1
BNFO 700	Externship in Bioinformatics	2
CMSC 508	Database Theory	3
OVPR 601	Scientific Integrity	1
Electives		
Select courses from recommended electives below		12
Total Hours		34

Recommended electives

BIOL/BNFO 541	Laboratory in Molecular Genetics
BIOS 567	Statistical Methods for High-throughput Genomics Data I
BNFO 591	Special Topics in Bioinformatics
BNFO 592	Independent Study
BNFO 637	Networks Biology
BNFO/MICR 653	Advanced Molecular Genetics: Bioinformatics
BNFO 691	Special Topics in Bioinformatics
BNFO 691	Special Topics in Bioinformatics (genomics and phylogenetics)
BNFO 692	Independent Study
CLSE 562	Advanced Systems Biology Engineering
CMSC 501	Advanced Algorithms
MICR/BNFO 653	Advanced Molecular Genetics: Bioinformatics
PHYS 591	Topics in Physics (modeling, computing and biocomplexity)

Total graduate credit hours required (minimum) 34

Graduate program director

Gregory A. Buck, Ph.D.
Director, Center for the Study of Biological Complexity
gabuck@vcu.edu
(804) 827-0026

Additional contact

Allison A. Johnson, Ph.D.
Assistant director, Center for the Study of Biological Complexity
aajohnson@vcu.edu
(804) 828-6782

Program website: csbc.vcu.edu/bioinformatics-programs (http://csbc.vcu.edu/bioinformatics-programs)