# BIOINFORMATICS (BNFO)

**BNFO 101. Introduction to Scientific Computing. 1 Hour.**
Semester course; 1 lecture hour. 1 credit. Enrollment is restricted to bioinformatics majors. This course will introduce students to basic principles and skills for using a computer to solve scientific problems. It is hands-on course and does not assume any special prior knowledge or skill with computers. Students completing the course will become familiar with and develop skills and practical knowledge of how to use common computer-based command-line tools and systems critical for effective scientific computing.

**BNFO 125. Disease and Human Ancestry. 3 Hours.**
Semester course; 3 lecture hours. 3 credits. This course introduces the role that disease has played in human existence. A key part of this understanding comes from new DNA sequencing and genomic data analysis tools that provide information about our ancestry and origin, as well as about the ancestry and history of disease organisms that have co-evolved with us. The vast amount of new data has opened controversial doors to social and ethical implications, such as questions of race and discrimination, and teach us how to fight emerging disease at local and global levels. This course will discuss these topics through case examples of different diseases from parasites (e.g., malaria), bacteria (e.g., bubonic plague, tuberculosis and syphilis) and viruses (e.g., smallpox, influenza and AIDS).

**BNFO 191. Special Topics in Bioinformatics. 1-4 Hours.**
Semester course; 1-4 lecture hours. 1-4 credits. May be repeated for a maximum total of nine credits, with the provision that no more than nine combined credits of BNFO 191 and BNFO 193 can apply toward graduation. 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 193. Special Topics in Bioinformatics. 1-4 Hours.**
Semester course; 1-4 lecture hours. 1-4 credits. May be repeated for a maximum total of nine credits, with the provision that no more than nine combined credits of BNFO 191 and BNFO 193 can apply toward graduation. 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. Graded as pass/fail.

**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. 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.

**BNFO 252. Phage Discovery II. 2 Hours.**
Semester course; 4 laboratory hours. 2 credits. 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.

**BNFO 291. Special Topics in Bioinformatics. 1-4 Hours.**
Semester course; 1-4 lecture hours. 1-4 credits. May be repeated for a maximum total of nine credits, with the provision that no more than nine combined credits of BNFO 291 and BNFO 293 can apply toward graduation. 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 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 293. Special Topics in Bioinformatics. 1-4 Hours.**
Semester course; 1-4 lecture hours. 1-4 credits. May be repeated for a maximum total of nine credits, with the provision that no more than nine combined credits of BNFO 291 and BNFO 293 can apply toward graduation. 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. Graded as pass/fail.

**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 STAT 212, 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.

**BNFO 305. Biological Data Science With Python. 3 Hours.**
Semester course; 3 lecture hours. 3 credits. Prerequisite: BNFO 201 with a minimum grade of C. This course serves as an introduction to biological data science using the Python language. Students will learn the fundamentals of probability and statistics, as well as the implementation of common bioinformatic and data science analyses. Students will build upon the basic Python programming skills covered in the prerequisite to learn the principles of data cleaning, wrangling, analysis, statistical testing and visualization by introducing appropriate Python libraries such as NumPy, Pandas, Matplotlib and Biopython.

**BNFO 315. Effective Communication in the Sciences. 3 Hours.**
Semester course; 3 lecture hours. 3 credits. How do we tell our science as a story? This course will explore ways to share science with fellow scientists and the public, including best practices for presenting data, simplifying complex ideas for presentations and sharing science in an accurate and ethical way in different media. Students will experience a hands-on approach to scientific writing and storytelling and hear from guest speakers from varying backgrounds in scientific communication. Communicating about science is an important part of being published, securing funding and building awareness around interests and this course is a first step to honing those skills.

**BNFO 380. Introduction to Mathematical Biology. 4 Hours.**
Semester course; 3 lecture and 2 laboratory hours. 4 credits. Prerequisites: MATH 200 and BIOL 151, both with a minimum grade of C, 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.

**BNFO 391. Special Topics in Bioinformatics. 1-4 Hours.**
Semester course; 1-4 lecture hours. 1-4 credits. May be repeated for a maximum total of nine credits, with the provision that no more than nine combined credits of BNFO 391 and BNFO 393 can apply toward graduation. 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 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 nine credits, with the provision that no more than nine combined credits of BNFO 391 and BNFO 393 can apply toward graduation. 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. Graded as pass/fail.

**BNFO 411. Ethical Issues in Life Sciences. 2 Hours.**
Semester course; 2 lecture hours. 2 credits. This course will introduce fundamentals in ethical conduct with a focus on interdisciplinary application to the life sciences, with attention paid to the design, collection, analysis and dissemination of bioinformatic datasets. Graded as pass/fail.

**BNFO 420. Applications in Bioinformatics. 3 Hours.**
Semester course; 2 lecture and 2 laboratory hours. 3 credits. Prerequisites: BIOL 310, CMSC 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 451. Genomic Medicine. 3 Hours.**
Semester course; 3 lecture hours. 3 credits. Prerequisite: BIOL 300. Genomic medicine is a clinical approach to diagnose and treat patients based on testing that includes an individual's genomic information. This course will provide an introduction to this emerging field and its potential to improve the diagnosis, prevention and treatment of disease. Topics will include key genomic technologies and the computational approaches used to probe genomic data as applied to real clinical examples. The ethical, legal and societal issues in genomic medicine will be explored. This course is geared toward students with a general biology background.

**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, with the provision that no more than 12 combined credits of BNFO 491 and BNFO 493 can apply toward graduation. 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 493. 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, with the provision that no more than 12 combined credits of BNFO 491 and BNFO 493 can apply toward graduation. 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. Graded as pass/fail.

**BNFO 496. Undergraduate Teaching Assistantship in Bioinformatics. 1-2 Hours.**
Semester course; 1-2 field experience hours. 1-2 credits. May be repeated for a maximum total of two credits. Enrollment requires 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. Graded as pass/fail.

**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.

**BNFO 501. Introduction to Physical Implementation of Databases. 1 Hour.**
Semester course; 1 lecture hour. 1 credit. Prerequisite: permission of instructor. Basic searching and sorting algorithm design, and advanced data structures including hashing and B-trees.

**BNFO 505. Essentials of Statistics in Bioinformatics. 2 Hours.**
Semester course; 2 lecture hours. 2 credits. Prerequisites: Statistics and permission of instructor. An intensive course designed for graduate students in either the biology/genomics or the computational science tracks of the bioinformatics program, aimed at providing the background in statistical concepts necessary for them to participate in graduate-level courses involving statistics. The course will focus on areas of particular interest in bioinformatics, including probability, combinatorics and linear models.

**BNFO 507. Essentials of Molecular Biology in Bioinformatics. 2 Hours.**
Semester course; 2 lecture hours. 2 credits. Prerequisites: Cell biology and permission of instructor; Pre- or corequisite: Organic chemistry or permission of instructor. An intensive course designed for graduate students in either the quantitative/statistics or the computational science tracks of the bioinformatics program, aimed at providing the background in molecular biology necessary for them to participate in graduate-level courses involving molecular biology. The course will focus on areas of particular interest in bioinformatics, including DNA, RNA and protein synthesis, gene structure, function and regulation, protein structure, activity and regulation, and the tools by which formation in these areas has been discovered.

**BNFO 508. Introduction to Bioinformatics Research. 2 Hours.**
Semester course; lectures and 3 laboratory hours. 2 credits. Prerequisites: graduate status and permission of instructor. Introduction to all active research programs in bioinformatics. Presentations of research programs by investigators and rotation of students through track-appropriate faculty labs to gain direct exposure to individual research projects. Graded as S/U/F. Required of all first-year students pursuing the thesis option (M.S.).

**BNFO 514. Modeling Biocomplexity. 3 Hours.**
Semester course; 2.5 lecture and .5 laboratory hours. 3 credits. Prerequisite: one year of calculus. Introduction to the modeling and simulation of the behavior of complex biological systems, including models in both continuous and discrete time. Numerical methods using mathematica, analytical methods using calculus and laboratory experiments using computer interfaces will be used to study population dynamics and the behavior of physiological systems exhibiting such properties as oscillations and chaotic biological dynamics. Crosslisted as: PHYS 514.

**BNFO 530. Bioinformatics and Genomics in Drug Research. 3 Hours.**
Semester course; 3 lecture hours. 3 credits. Covers the basic elements of cellular pathways and drug interactions, and how modern genomics comes into play. Presents bioinformatics principles being used every day in data-intensive fields of research. Introductory and concept-oriented, the course will prepare students for grasping how bioinformatics is being used in many areas of biomedical sciences. Geared toward students coming from a variety of backgrounds in biology, biochemistry and chemistry. While many of the analytical approaches are statistical in nature, there is no requirement for a background in statistics or mathematics. Each student will have the opportunity to design a small project applying bioinformatics concepts. Crosslisted as: MEDC 530.

**BNFO 531. Quantitative Methods in Bioinformatics. 3 Hours.**
Semester course; 3 lecture hours. 3 credits. Enrollment is restricted to students with graduate status or permission of instructor. Students will be introduced to quantitative methods including probability and statistical theory in order to recognize and interpret the underlying mathematics behind common bioinformatic analyses. Students will learn to apply these bioinformatic data analysis principles using packages and tools in the R software environment. Topics covered include regression, differential expression, t-SNE and principal component analyses.

**BNFO 540. Fundamentals of Molecular Genetics. 3 Hours.**
Semester course; 3 lecture hours. 3 credits. Prerequisite: BIOL 310 or consent of instructor. The basic principles and methodologies of molecular biology and genetics are applied to genome organization, replication, expression, regulation, mutation and reorganization. Emphasis will be placed on a broad introduction to and integration of important topics in prokaryotic and eukaryotic systems. Crosslisted as: BIOL 540.

**BNFO 541. Laboratory in Molecular Genetics. 2 Hours.**
Semester course; 1 lecture and 4 laboratory hours. 2 credits. Pre- or corequisite: BIOL 540 or equivalent. Experiments are designed to apply advanced techniques and concepts of molecular biology and genetics using prokaryotic and eukaryotic systems. Emphasis will be placed on experimental design, integrating results throughout the semester, making use of relevant published literature, scientific writing and providing hands-on experience with advanced equipment and methodologies. Crosslisted as: BIOL 541.

**BNFO 591. Special Topics in Bioinformatics. 1-4 Hours.**
Semester course; 1-4 lecture hours. 1-4 credits. May be repeated for a maximum total of eight credits, with the provision that no more than eight combined credits of BNFO 591 and BNFO 593 can apply toward graduation. Adviser's approval is required for counting each special topics course toward meeting specific requirements of the master's program. 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.

**BNFO 592. Independent Study. 1-9 Hours.**
Semester course; 1-9 independent study hours. 1-9 credits. Determination of the amount of credit and permission of instructor, adviser and curriculum committee must be obtained prior to registration for this course. Designed to provide an opportunity for independent study at an introductory graduate level in a bioinformatics-related area of interest and significance to the student outside what is available through the courses and other options in the Bioinformatics Program. Graded as satisfactory/unsatisfactory.

**BNFO 593. Special Topics in Bioinformatics. 1-4 Hours.**
Semester course; 1-4 lecture hours. 1-4 credits. May be repeated for a maximum total of eight credits, with the provision that no more than eight combined credits of BNFO 591 and BNFO 593 can apply toward graduation. An advanced, 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. or M.S. programs. Graded as satisfactory/unsatisfactory.

**BNFO 600. Basic Scripting Languages. 3 Hours.**
Semester course; 3 lecture hours. 3 credits. Basics of programming in Python or other appropriate scripting language.

**BNFO 601. Integrated Bioinformatics. 4 Hours.**
Semester course; 3 lecture and 3 laboratory hours. 4 credits. Enrollment requires permission of instructor. Presents major concepts in bioinformatics through a series of real-life problems to be solved by students. Problems addressed will include but not be limited to issues in genomic analysis, statistical analysis and modeling of complex biological phenomena. Emphasis will be placed on attaining a deep understanding of a few widely used tools of bioinformatics. Crosslisted as: BIOL 601.

**BNFO 620. Bioinformatics Practicum. 3 Hours.**
Semester course; 3 lecture hours. 3 credits. BNFO 601/BIOL 601 or permission of instructor. Practical application of bioinformatics to genomic, proteomic and pharmacogenomic analyses. Students will work in small groups to plan, develop and execute a project designed to solve practical challenges in the realm of bioinformatics. Proficiency in various aspects of bioinformatics will be developed.

**BNFO 621. Business and Entrepreneurship Essentials for Life Scientists. 3 Hours.**
Semester course; 3 lecture hours. 3 credits. Consists of presentations on the core concepts of business, including intellectual property, patents and patent law, entrepreneurship, launching a "start up," raising capital, financial management, marketing, managerial accounting, planning, and project management. Course includes lectures and discussions on core concepts of business and their real-world application. Students will develop a business plan and/or a plan to manage a research project. Business case studies and team projects with presentations are required. Focus is on the biotechnology and pharmaceutical industries.

**BNFO 637. Networks Biology. 3 Hours.**
Semester course; 2.5 lecture hours. 3 credits. Prerequisite: prior course work in cell biology or molecular biology, or permission of instructor. Covers in detail networks as a basic tool for the systems biology approach to biology and medicine, particularly on the molecular level. Qualitative and quantitative aspects of biological systems and processes will be identified and analyzed. The course focuses on the biochemical networks formed in the cell from genes, proteins and metabolites. Network structure and dynamics will be characterized proceeding from graph theory and other mathematical methods. Essential part of the course is the practical work with basic software for building, manipulation and analysis of biological networks, as well as for identifying structural motifs and modules, and comparative network organisms (human, drosphila, yeast, C. elegans).

**BNFO 650. Sequence Analysis in Biological Systems. 3 Hours.**
Semester course; 1 lecture and 2 laboratory hours. 3 credits. Prerequisite: BNFO 601/BIOL 601 or permission of instructor. This course will treat the computational theory behind algorithms that are used for nucleic acid and protein sequence analysis. Students will be exposed to the theory and methodology of computational biology that has led to the development of current sequence analysis software. The objective of the course is to provide students with a basic knowledge of how current software tools have been developed and how they function, which will permit them to then apply this knowledge to the development of new algorithms and technology.

**BNFO 653. Advanced Molecular Genetics: Bioinformatics. 3 Hours.**
Semester course; 3 lecture hours. 3 credits. Prerequisites: Cell/molecular biology or permission of instructor. An advanced course on contemporary bioinformatics. Topics covered include the principles and practice of DNA, RNA and protein sequence analysis, computational chemistry and molecular modeling, expression array analysis and pharmacogenomics. The course includes lectures, reading, computer lab, homework problem sets and projects.

**BNFO 690. Seminars in Bioinformatics. 1 Hour.**
Semester course; 1 lecture hour. 1 credit. Presentation and discussion of research topics of current interest in the field of bioinformatics. Graded as satisfactory/unsatisfactory.

**BNFO 691. Special Topics in Bioinformatics. 1-4 Hours.**
Semester course; 1-4 lecture hours. 1-4 credits. May be repeated for a maximum total of eight credits, with the provision that no more than eight combined credits of BNFO 691 and BNFO 693 can apply toward graduation. Adviser's approval is required for counting each special topics course toward meeting specific requirements of the master's program. An advanced, 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.

**BNFO 692. Independent Study. 1-9 Hours.**
Semester course; variable hours. Variable credit. Determination of the amount of credit and permission of the instructor, adviser and curriculum committee must be obtained prior to registration for this course. A course designed to provide an opportunity for independent study in a bioinformatics-related area of interest and significance to the student outside what is available through the courses and other options in the Bioinformatics Program.

**BNFO 693. Special Topics in Bioinformatics. 1-4 Hours.**
Semester course; 1-4 lecture hours. 1-4 credits. May be repeated for a maximum total of eight credits, with the provision that no more than eight combined credits of BNFO 691 and BNFO 693 can apply toward graduation. Adviser's approval is required for counting each special topics course toward meeting specific requirements of the master's program. An advanced, 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. Graded as satisfactory/unsatisfactory.

**BNFO 697. Directed Research in Bioinformatics. 1-9 Hours.**
Semester course; variable hours. 1-9 credits. May be repeated for credit. Directed research leading to the M.S. degree in bioinformatics. Graded as S/U/F.

**BNFO 700. Externship in Bioinformatics. 1,2 Hour.**
Semester course; variable hours. 1 or 2 credits. Prerequisites: BNFO 601/BIOL 601 and BNFO 620, or permission of instructor. Typically off-campus planned experiences for advanced graduate students designed to extend professional competencies, carried out in a professional setting under supervision of an approved professional. Externship activities monitored and evaluated by university faculty. Plan of experience designed by extern and external adviser with prior approval of department. An externship class will meet weekly using online technology to accommodate students doing out-of-town summer externships. Each externship will be a defined project leading to a required final report or product and offering real potential benefits to the sponsoring company/lab. Subsequent to the externship, a presentation to program faculty and students is required.