

GRADUATE CATALOG LISTING

BIOINFORMATICS & COMPUTATIONAL BIOLOGY

Telephone: (302) 831-0161

<http://bioinformatics.udel.edu/Education>

Faculty Listing: <http://bioinformatics.udel.edu/Education/faculty>

A. PROGRAM OVERVIEW

Bioinformatics & Computational Biology is an emerging field where biological and computational disciplines converge. The field encompasses the development and application of computational tools and techniques for the collection, analysis, management, and visualization of biological data, as well as modeling and simulation methods for the study of biological systems. Essential to the 21st century life sciences research and key to our understanding of complex biological systems, Bioinformatics & Computational Biology is impacting the science and technology of fields ranging from agricultural, energy and environmental sciences to pharmaceutical and medical sciences.

The Master's program in Bioinformatics & Computational Biology is administered through the Department of Computer & Information Sciences and coordinated by the Center for Bioinformatics & Computational Biology. The scientific curriculum is supported with the research strength, education resources and bioinformatics infrastructure from ten participating Departments across the Colleges of Arts & Sciences, Engineering, Agriculture & Natural Resources, and Earth, Ocean & Environment, as well as the Delaware Biotechnology Institute.

The Master's program offers three degrees—Master of Science in Bioinformatics & Computational Biology (BICB-MS), Professional Science Master's in Bioinformatics (BINF-PSM), and Graduate Certificate in Bioinformatics (BINF-CERT), each with two concentrations—Computational Sciences Concentration and Life Sciences Concentration. The Computational Sciences Concentration provides knowledge and experience in developing computational methods and bioinformatics tools and databases for modern biological studies, biotechnology or medicine. The Life Sciences Concentration provides knowledge and experience in applying bioinformatics methods, tools and databases as an integral approach to life science research, modern biotechnology or medicine.

Graduates of the Master's program will play a key role in multi- and interdisciplinary teams, bridging life sciences and computational sciences. The thesis-based MS degree will prepare students for advanced research in bioinformatics and computational biology. The scientific curriculum, along with "Plus" component for professional skills and the immersive internship will prepare PSM graduates for a professional career in industry or government. The Certificate will provide bioinformatics core competency as a stepping stone for a professional career.

B. REQUIREMENTS FOR ADMISSION

Admission to the graduate program is competitive. Those who meet stated requirements are not guaranteed admission, nor are those who fail to meet all of those requirements necessarily precluded from admission if they offer other appropriate strengths.

The following are the admission requirements to the Master's program in Bioinformatics & Computational Biology that apply to all three degrees (BICB-MS, BINF-PSM and BINF-CERT):

- A bachelor's degree at an accredited four-year college or university with a minimum grade average of 3.0 on a 4.0 system;
- Applicants may have undergraduate degrees from biological, computational, or other disciplines. However, applicants are expected to have scholarly competence in mathematics, computer science and/or biology;
- The following GRE scores are competitive: Quantitative: 650, Verbal + Quantitative: 1200. No GRE subject test is required;
- International student applicants must demonstrate a satisfactory level of proficiency in the English language if English is not the first language. The University requires an official paper-based TOEFL score of at least 550, at least 213 on the computer-based TOEFL, or at least 79 on the Internet-based TOEFL. TOEFL scores more than two years old cannot be considered official;
- Three letters of recommendation are required. At least one letter must be from professors, other letters can be from employers or others who have had a supervisory relationship with the applicant and are able to assess the applicant's potential for success in graduate studies; and
- Applications must also include a resume outlining work and academic experience, as well as an application essay consisting of the answers to the following questions:
 1. What educational background and scientific research or employment experience prepare you for this bioinformatics degree program?
 2. What are your long-term professional objectives?
 3. What specific attributes of the bioinformatics program make you feel that this degree is appropriate to help you achieve your professional objectives?

C. OVERVIEW OF DEGREE REQUIREMENTS

The Table below summarizes the degrees offered in the Master's program in Bioinformatics & Computational Biology and their curriculum requirements:

- Science Core in Bioinformatics & Computational Biology
 - Computational Sciences (CS)
 - Life Science (LS)
- Ethics Core
- Science Electives in Bioinformatics & Computational Biology
 - Computational Sciences (CS)
 - Life Science (LS)
- Thesis/Seminar/Internship in Bioinformatics & Computational Biology
- Professional Science Master's Plus Courses
 - Business/Industry Track (BI)
 - Government/Non-Profit Track (GN)

Curriculum/Credits	Degrees Offered*					
	BICB-MS (CS)	BICB-MS (LSC)	BINF-PSM (CS1)	BINF-PSM (LSC1)	BINF-CERT (CS2)	BINF-CERT (LSC2)
Science Core-CS	15		15		15	
Science Core-LS		15		15		15
Ethics Core	3	3	3	3		
Science Electives-CS	6		6			
Science Electives-LS		6		6		
Thesis	6	6				
Seminar	3	3				
Internship			6	6		
PSM Plus – BI or GN			12	12		
Total Credits	33	33	42	42	15	15

BICB-MS (CS): Master of Science in Bioinformatics & Computational Biology, Computational Sciences Concentration
 BICB-MS (LSC): Master of Science in Bioinformatics & Computational Biology, Life Sciences Concentration
 BINF-PSM (CS1): Professional Science Master's in Bioinformatics, Computational Sciences Concentration
 BINF-PSM (LSC1): Professional Science Master's in Bioinformatics, Life Sciences Concentration
 BINF-CERT (CS2): Graduate Certificate in Bioinformatics, Computational Sciences Concentration
 BINF-CERT (LSC2): Graduate Certificate in Bioinformatics, Life Sciences Concentration

D. REQUIREMENTS FOR MASTER OF SCIENCE IN BIOINFORMATICS & COMPUTATIONAL BIOLOGY (BICB-MS)

The **Master of Sciences in Bioinformatics & Computational Biology** requires 24 credits of graduate-level coursework, 6 credits of thesis and 3 credits of seminar, totaling 33 credits. The 24 credits of coursework must include 15 credits in the Bioinformatics & Computational Biology Core courses and 3 credits in the Ethics Core courses. Attendance in Seminar (BINF865) is required for three semesters for all graduate students.

A Thesis (BINF869) is required for the MS degree. Unless special permission is granted, students need to complete 12 credit hours prior to the start of their thesis. Students, with the assistance of their Faculty Advisor, will prepare and present a research proposal to their Thesis Committee for review and approval of the proposed research project. Following completion of the research outlined in the proposal, the MS degree candidate will prepare a written thesis according to the guidelines set forth by the Office of Graduate and Professional Education. A thesis defense, preceded by a seminar, will be held. The student's Faculty Advisor and Thesis Committee will administer and evaluate the thesis defense.

BICB-MS: COMPUTATIONAL SCIENCES CONCENTRATION

Credit Requirements:

- A. Bioinformatics & Computational Biology Core–Computational Science..... 15 Credits
- B. Ethics Core 3 Credits
- C. Electives–Computational Sciences 6 Credits
- D. Thesis 6 Credits
- E. Seminar 3 Credits

Total number of required credits: 33

A. Bioinformatics & Computational Biology Core–Computational Science (15 credits)

Bioinformatics

CISC636 Bioinformatics 3

Introduction to Discipline (select one)

ELEG 671 Introduction to Biomedical Engineering 3

BISC 602 Molecular Biology of Animal Cells 3

BISC 612 Advanced Cell Biology..... 3

BISC 654 Biochemical Genetics..... 3

PLSC 636 Plant Genes and Genomes..... 3

ANFS 670 Principles of Molecular Genetics..... 3

MAST 616 Methods in Molecular Biology..... 3

Systems Biology

MATH 560 Introduction to Systems Biology..... 3

Database

CISC 637 Database Systems..... 3

Biostatistics (select one)

STAT 613 Multivariate Statistical Methods with Biology Applications..... 3

STAT 656 Biostatistics..... 3

B. Ethics Core (3 credits)

Ethics (select one)

BIOL 631 Practice of Science..... 3

UAPP 648 Environmental Ethics..... 3

UAPP 650 Values Ethics and Leadership..... 3

BUAD 840 Ethical Issues in Global Business Environments..... 3

C. Electives–Computational Sciences (6 credits)

Electives (select two)

CISC 841 Algorithms in Bioinformatics 3

CISC 621 Algorithm Design and Analysis 3

CISC 640 Computer Graphics 3

CISC 642 Introduction to Computer Vision 3

CISC 650 Computer Networks 3

CISC 675 Object Oriented Software Engineering 3

CISC 681 Artificial Intelligence 3

CISC 683 Introduction to Data mining 3

CISC 882 Natural Language Processing 3

CISC 886 Multi-Agent Systems 3

CISC 887 Internet Information Gathering 3

CISC 888 Machine Learning 3

MATH 607 Survey of Scientific Computing 3

MATH 611 Introduction to Numerical Analysis and Scientific Computing 3

STAT 670 Introduction to Statistical Analysis I 3

STAT 671 Introduction to Statistical Analysis II 3

STAT 608 Statistical Research Methods 3

STAT 615 Design and Analysis of Experiments	3
STAT 619 Time Series Analysis	3
STAT 621 Survival Analysis	3
STAT 674 Applied Data Base Management.....	3
ELEG 633 Image Processing	3
ELEG 652 Principles of Parallel Computer Architectures	3
ELEG 655 High-Performance Computing with Commodity Hardware	3
ELEG 679 Introduction to Medical Imaging Systems	3
ELEG 680 Immunology for Engineers	3
CHEG 620 Biochemical Engineering	3
CHEG 621 Metabolic Engineering	3

D. Thesis (6 credits)

BINF 869 Master's Thesis.....	1-6
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E. Seminar in Bioinformatics & Computational Biology (3 credits)

Seminar (3 Semesters)

BINF 865 Seminar	1
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BICB-MS: LIFE SCIENCES CONCENTRATION

Credit Requirements:

A. Bioinformatics & Computational Biology Core–Life Science.....	15 Credits
B. Ethics Core	3 Credits
C. Electives–Life Sciences	6 Credits
D. Thesis	6 Credits
E. Seminar	3 Credits

Total number of required credits: 33

A. Bioinformatics & Computational Biology Core–Life Science (15 credits)

Bioinformatics

ANFS 644 Bioinformatics	3
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Introduction to Discipline

MAST 697 Bioinformatics Programming for Biologists	3
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Systems Biology

MAST 698 Environmental and Systems Bioinformatics	3
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Database

CISC 637 Database Systems.....	3
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Biostatistics (select one)

STAT 613 Multivariate Statistical Methods with Biology Applications.....	3
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STAT 656 Biostatistics.....	3
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B. Ethics Core (3 credits)

Ethics (select one)

BIOL 631 Practice of Science.....	3
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UAPP 648 Environmental Ethics.....	3
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UAPP 650 Values Ethics and Leadership.....	3
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BUAD 840 Ethical Issues in Global Business Environments.....	3
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C. Electives–Life Sciences (6 credits)

Electives (select two)

BISC 600 Biotechnology and Molecular Medicine	3
BISC 602 Molecular Biology of Animal Cells	3
BISC 605 Advanced mammalian physiology	3
BISC 612 Advanced Cell Biology	3
BISC 615 Vertebrate Developmental Biology.....	3
BICS 625 Cancer Biology	3
BISC 641 Microbial Ecology	3
BISC 645 Bacterial Evolution	3
BISC 654 Biochemical Genetics	3
BISC 656 Evolutionary Genetics	3
BISC 665 Advanced Molecular Biology & Genetics	3
BISC 671 Cellular and Molecular Immunology	3
BISC 675 Cardiovascular Physiology	3
BISC 679 Virology	3
BISC 682 Bacterial Pathogens Molecular Mechanisms	3
BISC 693 Human Genetics	3
STAT 670 Introduction to Statistical Analysis I	3
STAT 671 Introduction to Statistical Analysis II	3
CHEM 624 Principles of Mass Spectrometry	3
CHEM 641 Biochemistry	3
CHEM 645 Protein Structure and Function	3
CHEM 646 DNA-Protein Interactions	3
CHEM 649 Molecular Biophysics	3
ANFS 670 Principles of Molecular Genetics	3
MAST 616 Methods in Molecular Biology	3
MAST 618 Marine Microbial Ecology	3
MAST 623 Physiology of Marine Organisms	3
MAST 625 Microbial Physiology and Diversity	3
MAST 634 Marine Molecular Sciences	3
PLSC 636 Plant Genes and Genomes	3
PLSC 644 Physiology of Plant Stress	3
PLSC 667 Analytical Plant Genetics	3
HESC 602 Data Analysis and Interpretation in Health Sciences	3
HESC 654 Medical Physiology	3
PHYT 606 Research.....	3
PHYT 623 Clinical Neuroscience.....	4
PHYT 633 Applied Physiology II	3

D. Thesis (6 credits)

BINF 869 Master's Thesis.....	1-6
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E. Seminar in Bioinformatics & Computational Biology (3 credits)

Seminar (3 Semesters)

BINF 865 Seminar	1
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E. REQUIREMENTS FOR PROFESSIONAL SCIENCE MASTER’S IN BIOINFORMATICS (BINF-PSM)

The **Professional Science Master’s in Bioinformatics** requires 24 credits of graduate-level coursework, 6 credits of internship and 12 credits of PSM PLUS coursework, totaling 42 credits. The 24 credits of coursework must include 15 credits in the Bioinformatics & Computational Biology Core courses and 3 credits in the Ethics Core courses.

An Internship (BINF864) is required for the PSM degree. The internship will be in most cases completed at participating companies/institutions in the BINF-PSM program and be jointly supervised by the Faculty Advisor and a Co-Mentor in the hosting institution. Unless special permission is granted, students need to complete 12 credit hours prior to the start of their internship. The participating mentors will develop with the internship student specific objectives to be met during the internship, and have the internship approved by the Director of the Master’s BINF-PSM program prior to the start of the internship. A final written report and a poster presentation are required to complete the course.

The PSM degree requires at least 12 credits of PLUS coursework in addition to their science core. Whereas students in the PSM program may have professional goals that would lead them into business and industry or to government or non-profit employment, the University of Delaware offers two tracks for the PSM PLUS component. The University recommends the student follow one of the PLUS tracks below, however students may cross over tracks to fit their interest.

BINF-PSM: COMPUTATIONAL SCIENCES CONCENTRATION

Credit Requirements:

A. Bioinformatics & Computational Biology Core–Computational Science.....	15 Credits
B. Ethics Core	3 Credits
C. Electives–Computational Sciences	6 Credits
D. Internship	6 Credits
E. PSM Plus courses.....	12 Credits

Total number of required credits: 42

A. Bioinformatics & Computational Biology Core–Computational Science (15 credits)

Bioinformatics

CISC636 Bioinformatics

CISC636 Bioinformatics	3
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Introduction to Discipline (select one)

ELEG 671 Introduction to Biomedical Engineering

ELEG 671 Introduction to Biomedical Engineering	3
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BISC 602 Molecular Biology of Animal Cells

BISC 602 Molecular Biology of Animal Cells	3
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BISC 612 Advanced Cell Biology.....

BISC 612 Advanced Cell Biology.....	3
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BISC 654 Biochemical Genetics.....

BISC 654 Biochemical Genetics.....	3
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PLSC 636 Plant Genes and Genomes.....

PLSC 636 Plant Genes and Genomes.....	3
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ANFS 670 Principles of Molecular Genetics.....

ANFS 670 Principles of Molecular Genetics.....	3
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MAST 616 Methods in Molecular Biology.....

MAST 616 Methods in Molecular Biology.....	3
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Systems Biology

MATH 560 Introduction to Systems Biology.....	3
<i>Database</i>	
CISC 637 Database Systems.....	3
<i>Biostatistics (select one)</i>	
STAT 613 Multivariate Statistical Methods with Biology Applications.....	3
STAT 656 Biostatistics.....	3
B. Ethics Core (3 credits)	
<i>Ethics (select one)</i>	
BIOL 631 Practice of Science.....	3
UAPP 648 Environmental Ethics.....	3
UAPP 650 Values Ethics and Leadership.....	3
BUAD 840 Ethical Issues in Global Business Environments.....	3
C. Electives–Computational Sciences (6 credits)	
<i>Electives (select two)</i>	
CISC 841 Algorithms in Bioinformatics	3
CISC 621 Algorithm Design and Analysis	3
CISC 640 Computer Graphics	3
CISC 642 Introduction to Computer Vision	3
CISC 650 Computer Networks	3
CISC 675 Object Oriented Software Engineering	3
CISC 681 Artificial Intelligence	3
CISC 683 Introduction to Data mining	3
CISC 882 Natural Language Processing	3
CISC 886 Multi-Agent Systems	3
CISC 887 Internet Information Gathering	3
CISC 888 Machine Learning	3
MATH 607 Survey of Scientific Computing	3
MATH 611 Introduction to Numerical Analysis and Scientific Computing	3
STAT 670 Introduction to Statistical Analysis I	3
STAT 671 Introduction to Statistical Analysis II	3
STAT 608 Statistical Research Methods	3
STAT 615 Design and Analysis of Experiments	3
STAT 619 Time Series Analysis	3
STAT 621 Survival Analysis	3
STAT 674 Applied Data Base Management.....	3
ELEG 633 Image Processing	3
ELEG 652 Principles of Parallel Computer Architectures	3
ELEG 655 High-Performance Computing with Commodity Hardware	3
ELEG 679 Introduction to Medical Imaging Systems	3
ELEG 680 Immunology for Engineers	3
CHEG 620 Biochemical Engineering	3
CHEG 621 Metabolic Engineering	3
D. Internship (6 credits)	
BINF 864 Internship.....	1-6

E. PSM Plus courses (12 credits)

Business/Industry Track

Survey of Business

BUAD 500 Survey of Business 3

Leadership and Organization

BUAD 870 Understanding People in Organizations 3

Project Management, Operations or Entrepreneurship (select one)

BUAD 831 Operations Management and Management Science 3

BUAD 835 Managing New Product Development Projects 3

BUAD 871 Managing for Creativity and Innovation 3

ENTR 860 High Technology Entrepreneurship 3

MISY 840 Project Management and Costing 3

Intellectual Property

CHEG 595 Intellectual Property for Engineers and Scientists 3

Or Government/Non-Profit Track

Survey of Public Administration

UAPP 803 Seminar in Public Administration 3

Leadership and Organization (select one)

UAPP 835 Organization and Management in Public and Nonprofit Sectors 3

UAPP 604 Leadership in Organizations 3

Managerial Decision Making or Financial Management (select one)

UAPP 819 Management Decision Making in Public & Nonprofit Sectors 3

UAPP 833 Financial Management in Public & Nonprofit Sectors 3

UAPP 827 Program and Project Analysis 3

UAPP 829 Taxation and Fiscal Policies 3

Legal and Regulatory Affairs

UAPP 646 Administrative Law and Policy 3

BINF-PSM: LIFE SCIENCES CONCENTRATION

Credit Requirements:

A. Bioinformatics & Computational Biology Core–Life Science.....15 Credits

B. Ethics Core 3 Credits

C. Electives–Life Sciences 6 Credits

D. Internship 6 Credits

E. PSM Plus courses.....12 Credits

Total number of required credits: 42

A. Bioinformatics & Computational Biology Core–Life Science (15 credits)

Bioinformatics

ANFS 644 Bioinformatics3

Introduction to Discipline

MAST 697 Bioinformatics Programming for Biologists 3

Systems Biology

MAST 698 Environmental and Systems Bioinformatics 3

Database

CISC 637 Database Systems..... 3

Biostatistics (select one)

STAT 613 Multivariate Statistical Methods with Biology Applications..... 3

STAT 656 Biostatistics..... 3

B. Ethics Core (3 credits)

Ethics (select one)

BIOL 631 Practice of Science..... 3

UAPP 648 Environmental Ethics..... 3

UAPP 650 Values Ethics and Leadership..... 3

BUAD 840 Ethical Issues in Global Business Environments..... 3

C. Electives–Life Sciences (6 credits)

Electives (select two)

BISC 600 Biotechnology and Molecular Medicine3

BISC 602 Molecular Biology of Animal Cells 3

BISC 605 Advanced mammalian physiology 3

BISC 612 Advanced Cell Biology 3

BISC 615 Vertebrate Developmental Biology..... 3

BISC 625 Cancer Biology 3

BISC 641 Microbial Ecology 3

BISC 645 Bacterial Evolution 3

BISC 654 Biochemical Genetics 3

BISC 656 Evolutionary Genetics 3

BISC 665 Advanced Molecular Biology & Genetics 3

BISC 671 Cellular and Molecular Immunology 3

BISC 675 Cardiovascular Physiology 3

BISC 679 Virology 3

BISC 682 Bacterial Pathogens Molecular Mechanisms 3

BISC 693 Human Genetics 3

STAT 670 Introduction to Statistical Analysis I 3

STAT 671 Introduction to Statistical Analysis II 3

CHEM 624 Principles of Mass Spectrometry 3

CHEM 641 Biochemistry 3

CHEM 645 Protein Structure and Function 3

CHEM 646 DNA-Protein Interactions 3

CHEM 649 Molecular Biophysics 3

ANFS 670 Principles of Molecular Genetics 3

MAST 616 Methods in Molecular Biology 3

MAST 618 Marine Microbial Ecology 3

MAST 623 Physiology of Marine Organisms 3

MAST 625 Microbial Physiology and Diversity 3

MAST 634 Marine Molecular Sciences 3

PLSC 636 Plant Genes and Genomes 3

PLSC 644 Physiology of Plant Stress 3

PLSC 667 Analytical Plant Genetics 3

HESC 602 Data Analysis and Interpretation in Health Sciences 3

HESC 654 Medical Physiology	3
PHYT 606 Research.....	3
PHYT 623 Clinical Neuroscience.....	4
PHYT 633 Applied Physiology II	3

D. Internship (6 credits)

BINF 864 Internship.....	1-6
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E. PSM Plus courses (12 credits)

Business/Industry Track

Survey of Business

BUAD 500 Survey of Business	3
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Leadership and Organization

BUAD 870 Understanding People in Organizations	3
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Project Management, Operations or Entrepreneurship (select one)

BUAD 831 Operations Management and Management Science	3
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BUAD 835 Managing New Product Development Projects	3
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BUAD 871 Managing for Creativity and Innovation	3
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ENTR 860 High Technology Entrepreneurship	3
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MISY 840 Project Management and Costing	3
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Intellectual Property

CHEG 595 Intellectual Property for Engineers and Scientists	3
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Or Government/Non-Profit Track

Survey of Public Administration

UAPP 803 Seminar in Public Administration	3
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Leadership and Organization (select one)

UAPP 835 Organization and Management in Public and Nonprofit Sectors	3
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UAPP 604 Leadership in Organizations	3
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Managerial Decision Making or Financial Management (select one)

UAPP 819 Management Decision Making in Public & Nonprofit Sectors	3
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UAPP 833 Financial Management in Public & Nonprofit Sectors	3
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UAPP 827 Program and Project Analysis	3
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UAPP 829 Taxation and Fiscal Policies	3
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Legal and Regulatory Affairs

UAPP 646 Administrative Law and Policy	3
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F. REQUIREMENTS FOR GRADUATE CERTIFICATE IN BIOINFORMATICS (BINF-CERT)

The **Graduate Certificate in Bioinformatics** requires 15 credits in the Bioinformatics & Computational Biology Core courses to achieve core competency in Bioinformatics.

BINF-CERT: COMPUTATIONAL SCIENCES CONCENTRATION

Credit Requirements:

Bioinformatics & Computational Biology Core–Computational Science..... 15 Credits
Total number of required credits: 15

Bioinformatics & Computational Biology Core–Computational Science (15 credits)

Bioinformatics

CISC636 Bioinformatics 3

Introduction to Discipline (select one)

ELEG 671 Introduction to Biomedical Engineering 3

BISC 602 Molecular Biology of Animal Cells 3

BISC 612 Advanced Cell Biology..... 3

BISC 654 Biochemical Genetics..... 3

PLSC 636 Plant Genes and Genomes..... 3

ANFS 670 Principles of Molecular Genetics..... 3

MAST 616 Methods in Molecular Biology..... 3

Systems Biology

MATH 560 Introduction to Systems Biology..... 3

Database

CISC 637 Database Systems..... 3

Biostatistics (select one)

STAT 613 Multivariate Statistical Methods with Biology Applications..... 3

STAT 656 Biostatistics..... 3

BINF-CERT: LIFE SCIENCES CONCENTRATION

Credit Requirements:

Bioinformatics & Computational Biology Core–Life Science.....15 Credits

Total number of required credits: 15

Bioinformatics & Computational Biology Core–Life Science (15 credits)

Bioinformatics

ANFS 644 Bioinformatics3

Introduction to Discipline

MAST 697 Bioinformatics Programming for Biologists 3

Systems Biology

MAST 698 Environmental and Systems Bioinformatics 3

Database

CISC 637 Database Systems..... 3

Biostatistics (select one)

STAT 613 Multivariate Statistical Methods with Biology Applications..... 3

STAT 656 Biostatistics..... 3