UNIVERSITY OF DELAWARE

MASTER OF SCIENCE IN BIOINFORMATICS & COMPUTATIONAL BIOLOGY

COMPUTATIONAL SCIENCES CONCENTRATION

ACADEMIC PROGRAM APPLICATION

FEBRUARY 18, 2010

PART I

UNIVERSITY FACULTY SENATE FORM

MASTER OF SCIENCE IN BIOINFORMATICS & COMPUTATIONAL BIOLOGY: COMPUTATIONAL SCIENCES CONCENTRATION

Academic Program Approval

This form is a routing document for the approval of new and revised academic programs. Proposing department should complete this form. For more information, call the Faculty Senate Office at 831-2921.

Submitted by: Cathy H. Wu phone number 831-8869

Department: Computer & Information Sciences email address wuc@udel.edu

Action: Request for New Master of Science in Bioinformatics & Computational Biology (BICB-MS), Computational Sciences Concentration (CS)
(Example: add major/minor/concentration, delete major/minor/concentration, revise major/minor/concentration, academic unit name change, request for permanent status, policy change, etc.)

Effective term 10F
(use format 04F, 05W)

Current degree N/A
(Example: BA, BACH, BACJ, HBA, EDD, MA, MBA, etc.)

Proposed change leads to the degree of: MS
(Example: BA, BACH, BACJ, HBA, EDD, MA, MBA, etc.)

Proposed name: Master of Science in Bioinformatics & Computational Biology (BICB-MS), Computational Sciences Concentration (CS)
Proposed new name for revised or new major / minor / concentration / academic unit (if applicable)

Revising or Deleting:

Undergraduate major / Concentration:_____
(Example: Applied Music – Instrumental degree BMAS)

Undergraduate minor:_____
(Example: African Studies, Business Administration, English, Leadership, etc.)

Graduate Program Policy statement change:_____
(**Must attach** your Graduate Program Policy Statement)

Graduate Program of Study:_____
(Example: Animal Science: MS Animal Science: PHD Economics: MA Economics: PHD)

Graduate minor / concentration:_____

Note: all graduate studies proposals must include an electronic copy of the Graduate Program Policy Document, highlighting the changes made to the original policy document.

List new courses required for the new or revised curriculum. How do they support the overall program objectives of the major/minor/concentrations)?
(Be aware that approval of the curriculum is dependent upon these courses successfully passing through the Course Challenge list. If there are no new courses enter "None")

CISC636: Bioinformatics (3) * submitted for re-title from "Introduction to Bioinformatics"
PLSC636: Plant Genes and Genomes (3) * submitted for re-title from "Advanced Plant Genetics"
MATH660: Introduction to Systems Biology (3) * adapted from MATH460
STAT613: Multivariate Statistical Methods with Biology Applications (3) * new course being developed
BINF869: Master's Thesis * new course listing
BINF865: Seminar * new course listing
STAT670: Introduction to Statistical Analysis I (3) * new course being developed
STAT671: Introduction to Statistical Analysis II (3) * new course being developed

Explain, when appropriate, how this new/revised curriculum supports the 10 goals of undergraduate education: http://www.ugs.udel.edu/gened/

N/A

Identify other units affected by the proposed changes:
(Attach permission from the affected units. If no other unit is affected, enter "None")

College of Arts & Sciences:
- Department of Biological Sciences
- Department of Mathematical Sciences

College of Agriculture & Natural Resources
- Department of Plant & Soil Sciences
- Department of Food & Resource Economics
- Department of Animal & Food Sciences

College of Engineering
- Department of Electrical & Computer Engineering
- Department of Chemical Engineering

College of Earth, Ocean & Environment
- Marine Biosciences Program

Alfred Lerner College of Business & Economics
- Department of Business Administration

College of Education & Public Policy
- School of Urban Affairs & Public Policy

Describe the rationale for the proposed program change(s):
(Explain your reasons for creating, revising, or deleting the curriculum or program.)

The Master of Science in Bioinformatics & Computational Biology (BICB-MS) will provide an interdisciplinary program to foster research collaborations across Colleges, and will support the future development of a PhD degree program in Bioinformatics & Computational Systems Biology. The thesis-based BICB-MS degree will prepare students for advanced research. The

Computational Sciences Concentration (CS) will allow students with strong quantitative sciences background to gain solid knowledge and research experience in developing computational methods and bioinformatics tools and databases for the study of biological systems. The graduates may pursue further study towards a PhD or other professional degree, or a research career in academia, industry, or government agencies.

Program Requirements:

(Show the new or revised curriculum as it should appear in the Course Catalog. If this is a revision, be sure to indicate the changes being made to the current curriculum and **include a side-by-side comparison** of the credit distribution before and after the proposed change.)

BICB-MS Computational Sciences Concentration (CS) – Degree Requirement	
33 Credit Hours Total	
Bioinformatics & Computational Biology Core – Computational Sciences	15 Credits
Ethics Core	3 Credits
Electives – Computational Sciences	6 Credits
Thesis	6 Credits
Seminar	3 Credits (1 Credit/Semester, P/F)

BICB-MS Computational Sciences Concentration (CS) – Course Curriculum	
Bioinformatics & Computational Biology Core – Computational Sciences (15)	
Bioinformatics (3)	CISC636: Bioinformatics (3) *
Introduction to Discipline (3) [select one]	ELEG671: Introduction to Biomedical Engineering (3)
	BISC602: Molecular Biology of Animal Cells (3)
	BISC612: Advanced Cell Biology (3)
	BISC654: Biochemical Genetics (3)
	PLSC636: Plant Genes and Genomes (3) *
	ANFS670: Principles of Molecular Genetics (3)
	MAST616: Methods in Molecular Biology (3)
Systems Biology (3)	MATH660: Introduction to Systems Biology (3) *
Database (3)	CISC637: Database Systems (3)
Biostatistics (3) [select one]	STAT613: Multivariate Statistical Methods with Biology Applications (3) *
	STAT656: Biostatistics (3)
Ethics Core (3)	
Ethics (3) [select one]	BISC631: Practice of Science (3)
	UAPP648: Environmental Ethics (3)
	UAPP650: Values Ethics and Leadership (3)
	BUAD840: Ethical Issues in Global Business Environments (3)
Electives – Computational Sciences (6)	
Electives (6) [select two]	CISC841: Algorithms in Bioinformatics (3)
	CISC621: Algorithm Design and Analysis (3)
	CISC640: Computer Graphics (3)
	CISC642: Introduction to Computer Vision (3)
	CISC650: Computer Networks (3)
	CISC675: Object Oriented Software Engineering (3)
	CISC681: Artificial Intelligence (3)

	CISC683: Introduction to Data mining (3)
	CISC882: Natural Language Processing (3)
	CISC886: Multi-Agent Systems (3)
	CISC887: Internet Information Gathering (3)
	CISC888: Machine Learning (3)
	MATH607: Survey of Scientific Computing (3)
	MATH611: Introduction to Numerical Analysis and Scientific Computing (3)
	STAT670: Introduction to Statistical Analysis I (3) *
	STAT671: Introduction to Statistical Analysis II (3) *
	STAT608: Statistical Research Methods (3)
	STAT615: Design and Analysis of Experiments (3)
	STAT619: Time Series Analysis (3)
	STAT621: Survival analysis (3)
	STAT674: Applied Data Base Management (3)
	ELEG633: Image Processing (3)
	ELEG652: Principles of Parallel Computer Architectures (3)
	ELEG655: High-Performance Computing with Commodity Hardware (3)
	ELEG679: Introduction to Medical Imaging Systems (3)
	ELEG680: Immunology for Engineers (3)
	CHEG620: Biochemical Engineering (3)
	CHEG621: Metabolic Engineering (3)
Thesis (6)	
Thesis (6)	BINF869: Master's Thesis (1-6) *
Seminar (3)	
Seminar [3 semesters]	BINF865: Seminar (1) *

ROUTING AND AUTHORIZATION

(Please do not remove supporting documentation.)

Department Chairperson _____ Date _____

Dean of College _____ Date _____

Chairperson, College Curriculum Committee _____ Date _____

Chairperson, Senate Com. on UG or GR Studies _____ Date _____

Chairperson, Senate Coordinating Com. _____ Date _____

Secretary, Faculty Senate _____ Date _____

Date of Senate Resolution _____ Date to be Effective _____

Registrar _____ Program Code _____ Date _____

Vice Provost for Academic Affairs & International Programs _____ Date _____

Provost _____ Date _____

Board of Trustee Notification _____ Date _____

Revised 10/23/2007 /khs

APPENDIX - COURSE DESCRIPTIONS

BIOINFORMATICS & COMPUTATIONAL BIOLOGY CORE – COMPUTATIONAL SCIENCES

- **Bioinformatics**

  CISC636: Bioinformatics (3)
  - Introduction to concepts, methodologies, and tools in bioinformatics. Abstraction of biological problems for computational solutions. Genome sequencing and assembly, bio-sequence comparison and database search, dynamics programming, hidden Markov models, and phylogenetic trees. PREREQ: CISC220 or permission of instructor. TERM: Fall Semester

- **Introduction to Discipline**

  ELEG671: Introduction to Biomedical Engineering (3)
  - Mathematical methods in Human Physiology. Introduction to human physiology from a systems perspective, covering all hierarchical levels including molecular, biochemical, cellular, tissue, organ, and integrated systems. Dynamic modeling of physiologic systems including homeostatic control systems, endocrine regulatory systems, immune response dynamics, mutation, selection and evolution. Mathematical methods covered include linear and nonlinear ordinary differential equations, Lyapunov stability analysis, mass action kinetics, Hamming spaces, reaction-diffusion equations, and numerical simulation. TERM: Fall Semester.

  BISC602: Molecular Biology of Animal Cells (3)
  - Examination of eucaryotic genes, synthesis and processing of messenger RNA and control of protein synthesis with emphasis on regulation of normal cellular growth and differentiation and the process of cancer cell transformation. Emphasis on recombinant DNA technology, monoclonal antibody production and tissue culture. PREREQ: BISC401 and BISC403. Requires permission from the instructor. TERM: Fall Semester

  BISC612: Advanced Cell Biology (3)
  - Four major sections: (1) cell structure/function; (2) signaling mechanisms and cell fate; (3) protein biosynthesis and trafficking and (4) integrative cell biology. Requires interpreting and evaluating data from primary scientific literature. Meets literature requirement for biology majors.

  BISC654: Biochemical Genetics (3)
  - Covers the use of genetic model organisms to answer biological questions, including mapping and cloning of human disease genes and the creation of animal models for human genetic diseases. There is an emphasis on examples from the recent scientific literature and building scientific writing skills. PREREQ: BISC403 and BISC401; or permission of instructor

  PLSC636: Plant Genes and Genomes (3)
  - Advanced survey of molecular genetics in higher plants, including molecular methods of plant biotechnology. Topics include genome composition and evolution, transposable elements and retrotransposons, DNA methylation and

epigenetics, small RNAs, quantitative traits, chromosome structure and gene expression. PREREQ: PLSC300 and PLSC306.

ANFS670: Principles of Molecular Genetics (3)

- Fundamentals of nucleic acid biochemistry (replication, repair, and recombination) and bacterial genetics provide the background needed for detailed study of selected topics in animal and plant molecular biology. PREREQ: ANFS300 or permission of instructor.

MAST616: Methods in Molecular Biology (3)

- Conceptual experience in molecular biological techniques with an emphasis on their application to marine related problems. Topics include: nucleic acid extractions, cloning, gene amplification and characterization, and expression methodologies. PREREQ: MAST634

- **Systems Biology**

MATH660: Introduction to Systems Biology (3)

- Systems biology approach, mathematical modeling of biological systems; examples from biomedical and agricultural research areas, biotechnology, industrial processes, and others. Differential equations, stochastic, feedback and control, or network models are discussed. Hands-on work via PBL modules. PREREQ: CHEM527, MATH535 and one of BISC302, 305, 306, 401 or 403.

- **Database**

CISC637: Database Systems (3)

- Physical and logical organization of databases. Data retrieval languages, relational database languages, security and integrity, concurrency, distributed databases. PREREQ: CISC220 and CISC304 or equivalent. TERM: Fall Semester

- **Biostatistics**

STAT613: Multivariate Statistical Methods with Biology Applications (3)

- Emphasis on applying multivariate statistical methods in biology. Principal component, factor analysis, discriminant analysis, cluster analysis, and canonical correlation methods are applied for data sets in biology.

STAT656: Biostatistics (3)

- An introduction to statistics focused toward applications in biological, medical and other life sciences. Topics include graphical and numerical techniques, random variables and their distribution, estimation and inference. PREREQ: MATH201

ETHICS CORE

BIOL631: Practice of Science (3)

- Uses historical, philosophical, and sociological perspectives to better understand the nature of modern science and its practice. Examines "science misconduct," and satisfies the NIH mandate requiring graduate training in "the responsible conduct of research."

UAPP648: Environmental Ethics (3)

- Ethical problems associated with environmental protection, local, national, and international. Relations to social and political movements. Seminar format.

UAPP650: Values Ethics and Leadership (3)

- Looks at the "ends" served by leaders in various contexts (including government, nonprofits, business, and media) and the ethical standards by which the leaders' actions are judged. Examines cases of unethical conduct as well as cases of exemplary conduct.

BUAD840: Ethical Issues in Global Business Environments (3)

- Topics include ethics in organizations, and problems and challenges dealing with external environment demands including global issues.

BIOINFORMATICS & COMPUTATIONAL BIOLOGY SEMINAR/THESIS

BINF865: Seminar (1)

- Lectures and discussions by guest speakers, faculty, and students on specialized topics and cutting-edge developments in bioinformatics and computational biology.

BINF869: Master's Thesis (1-6)

- Independent, supervised research leading to the Master's Thesis on specialized topics in bioinformatics and computational biology ranging from computational genomics and structural bioinformatics to systems biology and high performance biomedical computing. The research may involve the development of computational methods and bioinformatics tools and databases for the study of biological systems, or the application of bioinformatics methods, tools and databases as an integral approach to life science research.

ELECTIVES – COMPUTATIONAL SCIENCES

CISC841: Algorithms in Bioinformatics (3)

- Advanced topics in current bioinformatics research, such as hidden Markov models, kernel based methods, and bayesian based analysis with applications to functional annotation, structural prediction, and biological networks inferences. PREREQ: CISC436 or CISC636 or permission of instructor.

CISC621: Algorithm Design and Analysis (3)

- Emphasis on developing expertise in the design and analysis of algorithms. Equal importance given to techniques and specific algorithms. Particular topics include advanced data structures, graph algorithms, disjoint set manipulation, sorting and selection, amortized analysis, NP-completeness, and matrix and polynomial multiplication. PREREQ: Undergraduate algorithms and discrete math courses. TERM: Fall Semester

CISC640: Computer Graphics (3)

- Computer graphics technology, two- and three-dimensional systems, graphics software systems, modeling and object hierarchy, and animation. PREREQ: CISC220 or equivalent. COREQ: CISC320 recommended. TERM: Fall Semester

CISC642: Introduction to Computer Vision (3)

- An introduction to the analysis of images and video to recognize, reconstruct, model, and otherwise infer static and dynamic properties of objects in the three-dimensional world. Geometry of image formation; image processing such as smoothing, edge and feature detection, color, and texture; segmentation; shape

representation including deformable templates; stereo vision; motion estimation and tracking; techniques for 3-D reconstruction; image registration methods. PREREQ: CISC220 equivalent

CISC650: Computer Networks (3)

- Foundation principles, architectures, and techniques employed in computer and communication networks. Focuses on mechanisms used in TCP/IP protocol suite. Topics include connection management, end-to-end reliable data transfer, sliding window protocols, quality of service, flow control, congestion control, routing, LANs, framing, error control, analog versus digital transmission, packet versus circuit switching, multiplexing. PREREQ: CISC360, CISC361 or CISC663

CISC675: Object Oriented Software Engineering (3)

- Understand and apply a complete modern software engineering process. Topics include requirements analysis, specification, design, implementation, verification, and project management. Real-life team projects cover all aspects of software development lifecycle, from requirements to acceptance testing. Use of formal methods in the specification, design, and verification of software will be explored.

CISC681: Artificial Intelligence (3)

- Programming techniques for problems not amenable to algorithmic solutions. Problem formulation, search strategies, state spaces, applications of logic, knowledge representation, planning and application areas. PREREQ: CISC220 and CISC304 or equivalent. TERM: Fall Semester

CISC683: Introduction to Data mining (3)

- Concepts, techniques, and algorithms for mining large data sets to discover structural patterns that can be used to make subsequent predictions. Emphasis on practical approaches and empirical evaluation. Use of a workbench of data mining tools, such as the Weka toolkit.

CISC882: Natural Language Processing (3)

- Introduction to computational models of syntax, semantics and pragmatics for natural language understanding. Emphasis on design of English interfaces to data bases and ill-formed input. PREREQ: CISC681. TERM: Fall Semester

CISC886: Multi-Agent Systems (3)

- Introduction to the field of Multi-Agent Systems, examining issues that arise when groups of self-interested or cooperating autonomous agents interact to solve shared problems. Issues include reasoning about the knowledge and beliefs of other agents, communication and negotiation, computational organization, coordination and control. PREREQ: CISC681 or equivalent

CISC887: Internet Information Gathering (3)

- Approaches to information gathering, filtering, and integration including work in the heterogeneous database, information retrieval and agent-oriented communities. Text indexing, vector-based and probabilistic retrieval, semantic web technologies, wrappers and mediators, query planning and optimization, collaborative filtering, information agents, applications. PREREQ: CISC681 or equivalent

CISC888: Machine Learning (3)

- Concepts and algorithms underlying computer programs that learn from data to solve a task will be discussed. A range of modern machine learning algorithms will be covered.

MATH607: Survey of Scientific Computing (3)

- Numerical solution of linear systems; interpolation; differentiation and quadrature; transforms/FFT; nonlinear equations; initial value problems; boundary value problems; Monte Carlo methods; finite difference methods for partial differential equations. Additional topics at the discretion of the instructor. PREREQ: Linear algebra, differential equations, multivariable calculus. TERM: Fall Semester

MATH611: Introduction to Numerical Analysis and Scientific Computing (3)

- Introduction to numerical computing, analysis and solution of systems of linear equations, linear least-squares, eigenvalue problems, methods for unconstrained optimization, solution of systems of nonlinear equations. Experience with standard computer packages, code development and simulations of applied problems. PREREQ: Linear algebra and multivariate calculus. TERM: Fall Semester

STAT670: Introduction to Statistical Analysis I (3)

- Basic probability; continuous, discrete and joint distributions; distribution of functions of random variables; order statistics; expected value and central limit theorem.

STAT671: Introduction to Statistical Analysis II (3)

- Distributions of common statistics, sampling techniques, estimation, confidence intervals, hypotheses testing and selected topics.

STAT608: Statistical Research Methods (3)

- Experimental design and plot plans, collection, analysis and presentation of data in agricultural and biological research. TERM: Fall Semester

STAT615: Design and Analysis of Experiments (3)

- Fundamental principles of design, randomized designs, Latin squares, sources of error, components of error. Factorial designs, response surfaces, models for design. PREREQ: STAT371. TERM: Fall Semester

STAT619: Time Series Analysis (3)

- Fundamental topics in time series analysis - features the Box and Jenkins techniques of fitting time series data. Includes an introduction to appropriate statistical packages.

STAT621: Survival Analysis (3)

- Statistical techniques used in the analysis of censored data including the Kaplan-Meier estimator, the analysis of one, two and K sample problems, and regression analysis based on the Cox proportional hazards model. RESTRICTIONS: Requires permission of instructor.

STAT674: Applied Data Base Management (3)

- Provides an in-depth understanding of using computers to manage data using programs such as SAS and Microsoft/Access. RESTRICTIONS: Requires permission of instructor. TERM: Fall Semester

ELEG633: Image Processing (3)

- Review of concepts of linear systems and spectral analysis, human visual response, scanning and display of images, Fourier optics, image enhancement and feature extraction, design of digital filters for image processing, 2D fast Fourier transform algorithms and computed tomography. RESTRICTIONS: Requires permission of instructor. TERM: Spring Semester (may not be offered every year)

ELEG652: Principles of Parallel Computer Architectures (3)

- Provides an introduction to the principles of parallel computer architecture. Begins at a level that assumes experience in introductory undergraduate courses such as digital system design, computer architecture, and microprocessor based systems. TERM: Spring Semester

ELEG655: High-Performance Computing with Commodity Hardware (3)

- New commodity computing devices, e.g., GPUs, bring the originally elite high performance computing into the reach of general public. Principles of program optimization, GPU and IBM Cell architecture, along with concepts and techniques for optimizing general purpose computing on the new hardware. TERM: Fall Semester

ELEG679: Introduction to Medical Imaging Systems (3)

- Physics, instrumentation, system design, and image reconstruction algorithms will be covered for the following modalities: radiography, x-ray computed tomography (CT), single photon emission computed tomography (SPECT), positron emission tomography (PET), magnetic resonance imaging (MRI), and real-time ultrasound. RESTRICTIONS: Requires permission of instructor. TERM: Spring Semester

ELEG680: Immunology for Engineers (3)

- Human adaptive immune response to viruses, both cellular and humoral. Generation of the immune response cells and response to types of immunogen as well as basic nonlinear differential model analysis, basic mathematical models of their interactions and implications of these models for the treatment of disease. Access significant amount of current literature. No prior knowledge of biology required. RESTRICTIONS: Requires permission of instructor. TERM: Spring Semester (may not be offered every year)

CHEG620: Biochemical Engineering (3)

- Application of chemical engineering principles to analyze different molecular engineering approaches, evaluate bioreactors and product recovery processes, analyze cellular engineering approaches and critically evaluate primary bioengineering data from literature and laboratory experiments. PREREQ: MATH243 and CHEM527 or CHEM641 and CHEM642. TERM: Fall Semester

CHEG621: Metabolic Engineering (3)

- Focuses on design and control of cellular metabolism and includes analysis of metabolic function using systems engineering and molecular biology tools. Goals are to learn computational approaches for analyzing metabolic behavior, and experimental techniques to measure cellular components, metabolites, proteins and nucleic acids. PREREQ: CHEM527 or CHEM641; MATH305.

PART II

RESOLUTION STATEMENT

PROVISIONAL APPROVAL OF NEW PROGRAM -- RESOLUTION

MASTER OF SCIENCE IN
BIOINFORMATICS & COMPUTATIONAL BIOLOGY
COMPUTATIONAL SCIENCES CONCENTRATION

WHEREAS, the proposed *Master of Science in Bioinformatics and Computational Biology* provides a new graduate course of study in an emerging scientific discipline essential to the 21st century life sciences research and key to our understanding of complex biological systems, impacting the science and technology of fields ranging from agricultural, energy and environmental sciences to pharmaceutical and medical sciences, and

WHEREAS, the proposed *Computational Sciences Concentration* will allow students with strong quantitative sciences background to gain solid knowledge and research experience in developing computational methods and bioinformatics tools and databases for the study of biological systems, and will prepare them for advanced research in bioinformatics and computational biology, playing a key role in multi- and interdisciplinary research teams, and

WHEREAS, the proposed program builds upon the research strength, education resources and bioinformatics infrastructure from Departments across the Colleges of Arts & Sciences, Engineering, Agriculture & Natural Resources, Earth, Ocean & Environment, Business & Economics, and Education & Public Policy, as well as from the Delaware Biotechnology Institute and the newly established Center for Bioinformatics & Computational Biology, and

WHEREAS, the proposed program contributes to the scholarly and educational missions of the University—to disseminate scientific, humanistic, and social knowledge for the benefit of the larger society and to produce graduates who are prepared to contribute to a global society, addressing the critical needs of the state, nation and global community, and

WHEREAS, the proposed program fosters multi- and interdisciplinary research and educational collaboration across campus, providing a critical component to University's strategic priorities in energy, environment, and life and health sciences, and serving as a pillar of UD's *Path to Prominence*, be it therefore

RESOLVED, that the Faculty Senate approves provisionally, for five years, the establishment of a new program leading to the *Master of Science degree in Bioinformatics and Computational Biology*, effective June 1, 2010.

RESOLVED, that the Faculty Senate approves provisionally, for five years, the establishment of a new program entitled *Master of Science in Bioinformatics and Computational Biology (BICB-MS), Computational Sciences Concentration (CS)*, effective June 1, 2010.

PART III

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 of Science 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 Computational Sciences Concentration provides knowledge and experience in developing computational methods and bioinformatics tools and databases for modern biological studies, biotechnology or medicine.

Graduates of the Master of Science 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.

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 of Science program in Bioinformatics & Computational Biology:

- 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. DEGREE REQUIREMENTS

The Master of Science program in Bioinformatics & Computational Biology has the following curriculum requirements:

- Science Core in Bioinformatics & Computational Biology (15)
- Ethics Core (3)
- Science Electives in Bioinformatics & Computational Biology (6)
- Thesis (6)
- Seminar (3)

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.

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 660 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

E. Seminar in Bioinformatics & Computational Biology (3 credits)
Seminar (3 Semesters)
BINF 865 Seminar ……..……..……...….... 1

PART IV

PROPOSAL

I. DESCRIPTION

The completion of the human genome sequence marked the beginning of a new era of biological research. Scientists have begun to systematically tackle gene functions and other complex regulatory processes by studying organisms at the global scales. Advances in high-throughput biotechnologies and large-scale bioscience have further enabled modeling and simulation over a multitude of length, time and biological scales from biomolecules, cells, tissues and organs to organisms and population. With the enormous volume of data being produced, biology is becoming an increasingly quantitative science. Computational approaches, in combination with experimental methods, have become essential for generating novel hypotheses, deriving new scientific knowledge, and driving discovery and innovation.

Bioinformatics & Computational Biology is an emerging field where biological and computational disciplines converge. According to the National Institutes of Health, the working definitions of Bioinformatics and Computational Biology are as follows:

- *Bioinformatics*: Research, development, or application of computational tools and approaches for expanding the use of biological, medical, behavioral or health data, including those to acquire, store, organize, archive, analyze, or visualize such data.
- *Computational Biology*: The development and application of data-analytical and theoretical methods, mathematical modeling and computational simulation techniques to the study of biological, behavioral, and social systems.

Fundamental to the modern day biological studies and key to the basic understanding of complex biological systems, Bioinformatics & Computational Biology is impacting the science and technology of fields ranging from agricultural and environmental sciences to pharmaceutical and medical sciences. The research requires close collaboration among multi-disciplinary teams of researchers in quantitative sciences, life sciences, and their interfaces.

The Master of Science program in Bioinformatics & Computational Biology aims to train the next-generation of researchers and professionals who will play a key role in multi- and interdisciplinary teams, bridging life sciences and computational sciences. The program will be administered through its academic home, the Department of Computer & Information Sciences, and will be coordinated by the newly established Center for Bioinformatics & Computational Biology. The scientific curriculum will build upon the research and educational strength from departments across the Colleges of Arts & Sciences, Engineering, Agriculture & Natural Resources, and Earth, Ocean & Environment. The Master's program will provide a solid foundation for the future development of a PhD degree program in Bioinformatics & Computational Systems Biology. The program will be synergistic to the existing degree programs, providing a critical component to University's strategic priorities in energy, environment, and life and health sciences, and serving as a pillar of UD's *Path to Prominence*.

II. RATIONALE AND DEMAND

The University of Delaware currently does not offer a specialized graduate degree in Bioinformatics & Computational Biology, although related courses have been taught in several

departments for a number of years. We propose to develop a Master's program in Bioinformatics & Computational Biology. The rationales are:

- Bioinformatics & Computational Biology is essential to 21st century life science research in academia and industry;
- The program will build upon the research strength and bioinformatics infrastructure at the Delaware Biotechnology Institute and from departments across the Colleges of Arts & Sciences, Engineering, Agriculture & Natural Resources, and Earth, Ocean & Environment;
- The program will offer graduate education in a discipline essential for UD as a major research university, providing a critical component to University's strategic priorities in energy, environment, and life and health sciences. Indeed the program aligns with the University strategic plan to "*engage closely with the critical issues of our day, to increase the global impact of the University, and to raise its prominence in the world*."

The Master of Science in Bioinformatics & Computational Biology (BICB-MS) will provide an interdisciplinary program to foster research collaborations across Colleges, and will support the future development of a PhD degree program in Bioinformatics & Computational Systems Biology. The thesis-based BICB-MS degree will prepare students for advanced research. The Computational Sciences Concentration (CS) will allow students with strong quantitative sciences background to gain solid knowledge and research experience in developing computational methods and bioinformatics tools and databases for the study of biological systems. The graduates may pursue further study towards a PhD or other professional degree, or a research career in academia, industry, or government agencies.

A. INSTITUTIONAL FACTORS

A.1. COMPATIBILITY WITH UNIVERSITY ACADEMIC PRIORITIES

A strong educational program in Bioinformatics & Computational Biology will contribute to the scholarly and educational missions of the University—to *disseminate scientific, humanistic, and social knowledge for the benefit of the larger society* and to produce graduates who *are prepared to contribute to a global society*, addressing *the critical needs of the state, nation and global community*.

A.2. PLANNING PROCESS

The planning process started in Spring 2009 after the recruitment of Dr. Cathy H. Wu, Edward G. Jefferson Chair of Bioinformatics & Computational Biology, who was charged to take the responsibility and leadership for establishing the *Center for Bioinformatics & Computational Biology* at the University of Delaware and the development of new graduate programs in Bioinformatics & Computational Biology.

A Bioinformatics Steering Committee was established in June 2009 to guide the development of the Master's program in Bioinformatics & Computational Biology. The committee consists of faculty members from ten Departments across four Colleges participating in this degree program,

with expertise in areas ranging from genomics and systems biology to biostatistics and high performance computing (Table 1). The committee meets monthly throughout the entire planning process to discuss all aspects of the program development.

Table 1. Bioinformatics Steering Committee

Member	College	Department	Expertise
Wu, Cathy (Chair)	Arts & Sciences	Computer & Information Sciences	Bioinformatics and Computational Biology
Antoniewicz, Maciek	Engineering	Chemical Engineering	Metabolic Engineering, Systems Biology
Bahnson, Brian	Arts & Sciences	Chemistry & Biochemistry	Structure Biology, Molecular Modeling
Duncan, Melinda	Arts & Sciences	Biological Sciences	Biotechnology PSM, Developmental Biology
Hanson, Thomas	Earth, Ocean & Environment	Marine Biosciences	Microbial Genomics
Lee, Kelvin	Engineering	Chemical Engineering	Systems Biology, Proteomics
Liao, Li	Arts & Sciences	Computer & Information Sciences	Bioinformatics and Computational Biology
Marsh, Adam	Earth, Ocean & Environment	Marine Biosciences	Environmental Bioinformatics
Meyers, Blake	Agriculture & Natural Resources	Plant & Soil Sciences	Plant Genomics, Bioinformatics
Rejto, Lidia	Agriculture & Natural Resources	Food & Resource Economics	Biostatistics
Schleiniger, Gilberto	Arts & Sciences	Mathematical Sciences	Quantitative Biology BS Major, Mathematical Biology
Schmidt, Carl	Agriculture & Natural Resources	Animal & Food Sciences	Avian Genomics
Taufer, Michaela	Arts & Sciences	Computer & Information Sciences	Grid Computing, Cloud Computing
Wommack, Eric	Agriculture & Natural Resources	Plant & Soil Sciences	Viral Genomics
Zurakowski, Ryan	Engineering	Electrical & Computer Engineering	Biomedical Engineering

The Bioinformatics Graduate Committee was established in August 2009 to be responsible for the admission, advising, and progress assessment of the students in the Master's program in Bioinformatics & Computational Biology. The committee consists of at least two representative faculty members from each participating College in this degree program (Table 2).

Table 2. Bioinformatics Graduate Committee

Member	College	Department
Wu, Cathy (Chair)	Arts & Sciences	Computer & Information Sciences/

		Biological Science
Hanson, Thomas	Earth, Ocean & Environment	Marine Biosciences
Lee, Kelvin	Engineering	Chemical Engineering
Liao, Li	Arts & Sciences	Computer & Information Sciences
Papoutsakis, Eleftherios	Engineering	Chemical Engineering
Patel, Sandeep	Arts & Sciences	Chemistry & Biochemistry
Rejto, Lidia	Agriculture & Natural Resources	Food & Resource Economics
Schleiniger, Gilberto	Arts & Sciences	Mathematical Sciences
Schmidt, Carl	Agriculture & Natural Resources	Animal & Food Sciences
Wommack, Eric	Agriculture & Natural Resources/ Earth, Ocean & Environment	Plant and Soil Sciences/ Marine Biosciences

A.3. SIGNIFICANT IMPACT ON OTHER UNIVERSITY PROGRAMS

The positive impact of the proposed Master's program in Bioinformatics & Computational Biology on University research and educational programs is multi-fold:

- It will offer graduate education in a discipline essential for University of Delaware as a major research university. According to the listing at the International Society for Computational Biology web site (http://www.iscb.org/iscb-degree-certificate-programs), there are presently 180 bioinformatics-related degree programs worldwide, almost 100 in the United States alone;
- It will provide courses that can be used as electives in current graduate and undergraduate degree programs, and used for the development of new minors, concentrations, or degree programs, thus, complementing, not competing with already existing degree programs;
- It will create a context for faculty from the various participating disciplines across-campus to articulate the interface of their research and foster research collaborations;
- It will produce graduate students with knowledge and professional expertise in bioinformatics and computational biology, who can play a key role in multi- and interdisciplinary teams;
- The educational program, coupling with collaborative interdisciplinary research, will provide a solid foundation for University of Delaware to compete for training grants (such as NSF's IGERT-Integrative Graduate Education and Research Traineeship Program and NIH's Institutional Research Training Grants) and research grants (such as NIH's CTSA-Clinical and Translational Science Award);
- The educational program will provide a solid foundation for the future development of a PhD degree program in Bioinformatics & Computational Systems Biology (planned for Fall 2012 start).

A.4. UTILIZATION OF EXISTING RESOURCES

With strong computational and engineering programs and full biological disciplines from health sciences to agriculture and marine studies, as well as state-of-the-art facilities for bioinformatics at the Delaware Biotechnology Institute, the University of Delaware provides a rich environment for educational programs in Bioinformatics & Computational Biology. The proposed curricula

fully leverage the course offerings from the following departments/units across Colleges. The letters of approval from contributing department/units are attached in Appendix I.

B. STUDENT DEMAND

According to many accredited scientific and industry reviews, bioinformatics and computational biology may well be the single fastest-growing specialty in the life sciences. A recent report estimates the current global bioinformatics market at about $1.4 billion, and is projecting an average annual growth rate of 15.8 per cent to reach nearly $3 billion by 2010, reflecting bioinformatics' explosive growth.

B.1. ENROLLMENT PROJECTIONS

We project that we will have a steady increase in new students entering the Master of Science program in Bioinformatics & Computational Biology each year and reach 10 new students in the steady state (covering both Computational Sciences Concentration and Life Sciences Concentration). The projection is based on a M.S. Bioinformatics Track program established by Wu at Georgetown University, where enrollment has increased steadily each semester since its launching in Fall 2009. Based on the enrollment of similar programs, we project that 80% of BICB-MS student will be full-time.

Full-time student is expected to complete the BICB-MS program (33 credits) in two years. The program may be completed over a longer time frame for part-time students.

B.2. NEEDS OF STUDENT CLIENTELES

The Master of Science in Bioinformatics & Computational Biology degree will prepare students for advanced research. The Computational Sciences Concentration will allow students with strong quantitative sciences background to gain solid knowledge and research experience in developing computational methods and bioinformatics tools and databases for the study of biological systems. The graduates may pursue further study towards a PhD or other professional degree, or a research career in academia, industry, or government agencies.

C. TRANSFERABILITY

Prior to admission to the Master of Science program in Bioinformatics & Computational Biology, a prospective student from another institution can be approved by the Graduate Committee to take up to 9 graduate credits that, if/when admitted to the degree program, would be applied to that degree. Graduate courses counted toward a degree received elsewhere may not be transferred into a degree at the University of Delaware. Once the student has successfully completed 9 approved graduate UD credits and been admitted to the degree program, then a maximum of 9 graduate credits can be transferred into the Master's program from another institution with the approval of the Graduate Committee.

Students who complete graduate credits with the classification of CEND (Continuing Education Non-degree) at the University of Delaware may use a maximum of 9 graduate credits earned

with this classification toward their graduate degree. Students matriculated in other graduate degree programs upon admission to the Master's program in Bioinformatics & Computational Biology may transfer their graduate credits provided that: (i) the course was at the 600-800 level, (ii) the course was taken within the time limit appropriate for the degree, and (iii) the course was approved by the Graduate Committee and in accordance with the student's plan of study.

D. ACCESS TO GRADUATE AND PROFESSIONAL PROGRAMS

The graduates of the Master's program in Bioinformatics & Computational Biology will have different career paths. Some will decide to pursue a PhD in the participating departments. Other students, especially those who have already been employed in industry or government may consider the program as a terminal degree.

E. DEMAND AND EMPLOYMENT FACTORS

The demand and growth of bioinformatics and computational biology as a research field and in the global industry have been discussed above (sections I and II.B).

F. REGIONAL, STATE AND NATIONAL FACTORS

According to the listing at the International Society for Computational Biology web site, there are presently 180 bioinformatics-related degree programs worldwide, almost 100 in the United States alone.

F.1. COMPARABLE COURSES OF STUDY IN THE REGION OR STATE

No other university in the State of Delaware offers a Master's program in Bioinformatics & Computational Biology. In the Delaware Valley region, there are only two graduate degree programs in Bioinformatics & Computational Biology, an interdisciplinary Ph.D. program in Genomics and Computational Biology at the University of Pennsylvania, and a Master's (non-thesis M.S.) in Bioinformatics at the University of the Sciences in Philadelphia.

We believe that the UD Master o Science program in Bioinformatics & Computational Biology will emerge as a highly competitive educational opportunity based on: (i) a strong scientific core curriculum and comprehensive list of elective courses with many subfields in Computational Sciences, (ii) proximity to major biotech and pharmaceutical industry and active participation of regional industry partners, (iii) rich opportunities for thesis research projects, and (iv) the competitive total cost of the degree program.

F.2. EXTERNAL REQUIREMENTS

We note that there are no formal guidelines for a Master of Science program in Bioinformatics & Computational Biology, nor are there accreditation standards. The proposed curriculum was designed based on a careful study of bioinformatics and computational biology curricula offered by other institutions. We have closely examined offered programs at selected, prominent

research universities, conducted a series of talks with the local industry partners, and recognized the needs from both the student and employer perspectives. The proposed curriculum compiles the information gathered from these resources into one carefully tailored program.

G. OTHER STRENGTHS

G.1. SPECIAL FEATURES

A special feature of the proposed program is the close collaboration among participating Departments across Colleges. These departments are working together to develop and offer courses for this new Master of Science program in Bioinformatics & Computational Biology. Going forward, this collaboration will continue in the form of the Bioinformatics Steering Committee and the Bioinformatics Graduate Committee.

Another feature of the program is its coordination through the Center for Bioinformatics & Computational Biology, which provides extensive bioinformatics resources and capabilities at the BioIT Center at the Delaware Biotechnology Institute (DBI) and the Protein Information Resource (PIR). The BioIT Center provides both computing infrastructure and cyber-knowledgeable personnel with significant hardware, software and professional support for computational and data management needs. The computing infrastructure includes a High-Performance Compute Cluster, a Database Server Cluster, and an immersive 3-D Visualization Studio. The PIR is a public bioinformatics resource that provides integrated databases and analytical tools to support genomics, proteomics and systems biology research. The PIR web sites are freely accessible by researchers worldwide with over 4 million hits per month from over 100,000 unique sites, while the FTP sites serve over 1 terabyte of data download monthly.

G.2. COLLABORATIVE ARRANGEMENTS

No collaborative arrangement is required.

III. ENROLLMENT, ADMISSIONS AND FINANCIAL AID

A. ENROLLMENT

There is no need to limit enrollment due to resources. Enrollment is estimated at 20 new students per academic year in the steady state. Based on the entrance requirements and specified prerequisites, students may enroll in the Master of Science program with a regular status or provisional status:

- **Regular status** is offered to students who meet all of the established entrance requirements, who have a record of high scholarship in their fields of specialization, and who have the ability, interest, and maturity necessary for successful study at the graduate level in a degree program.

- **Provisional status** is offered to students who are seeking admission to the degree program but lack one or more of the specified prerequisites. All provisional requirements must be met within the deadline given before regular status can be granted. Students admitted with provisional status are generally not eligible for assistantships or fellowships. Students who file an application during the final year of undergraduate or current graduate work and are unable to supply complete official transcripts showing the conferral of the degree will be admitted pending conferral of the degree if their records are otherwise satisfactory and complete. For students lacking appropriate preparatory course work, additional courses applicable to certain areas of study may be required prior to admission or students may be admitted with the provision that completion of certain area content courses be completed concurrent with the courses in the degree program.

B. ADMISSION REQUIREMENTS

B.1. SELECTION CRITERIA

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 of Science program in Bioinformatics & Computational Biology:

- 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 TOEFL score of at least 550 on paper-based, 213 on computer-based, or 79 on Internet-based tests. TOEFL scores more than two years old cannot be considered official. Alternatively, IELTS can be accepted in place of the TOEFL. The minimum IELTS score is 6.5 overall with no individual sub-score below 6.0.
- 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?

B.2. CHANGE OF CLASSIFICATION

Students currently matriculated in other graduate degree programs should complete a "Change of Classification Form" to seek approval to enter the Master of Science program in Bioinformatics & Computational Biology. The Bioinformatics Graduate Committee will evaluate each "Change of Classification" request on a case-by-case basis and determine whether the student is required to submit a completed admission application form to the Office of Graduate and Professional Education and follow the same procedures for admission as other applicants.

B.3. APPLICATION DEADLINES

Admission decisions are made on a rolling basis as and when applications are complete. The application deadlines are:

- Fall Semester: July 1st (regular application); March 1st (financial aid)
- Spring Semester: December 1st (regular application); October 1st (financial aid)

C. STUDENT EXPENSES AND FINANCIAL AID

C.1. STUDENT EXPENSES

The Master's program in Bioinformatics & Computational Biology does not require student expenses beyond the traditional book and supplies, except for the availability of a personal computer or laptop.

C.2. FINANCIAL AID

Admission to the Master of Science program in Bioinformatics & Computational Biology does not automatically entitle an applicant to financial aid. Students may seek financial aid opportunities, such as fellowships or scholarships from sources within the University and from private and federal agencies. Interested students should check the Office of Graduate Studies for the most current opportunities.

Financial aid is awarded on a competitive basis from the pool of admitted applicants. The University of Delaware's policies apply to all forms of financial aid. Please refer to the University Policies for Graduate Student Assistantships and Fellowships.

Students in the BICB-MS program may apply for the Graduate Assistantships:

- **Research Assistantships (RAs)** are generally funded by research grants and contracts provided by external funding agencies. Students may be supported as an RA through their Faculty Advisor's research funds after their first year. A research assistantship provides full tuition and a stipend. The RA's advisor is responsible for defining the student's responsibilities and for evaluating the student's performance. The amount of service or

research may vary from week to week but the average is usually expected to be 20 hours per week.

- **Teaching Assistantships (TAs)** are offered for graduate students to perform teaching and other instructional activities. The amount of service may vary from week to week but the average is usually expected to be 20 hours per week. A teaching assistantship provides full tuition and a stipend. In accordance with University of Delaware regulations, foreign students must achieve a TOEFL score of at least 600 (paper-based), 250 (computer-based) or 100 (Internet-based), or an IELTS score of at least 7.5 in order to qualify for teaching assistantships.

IV. CURRICULUM SPECIFICS

A. INSTITUTIONAL FACTORS

Students who successfully complete the program will be awarded the following degree: Master of Science in Bioinformatics & Computational Biology (BICB-MS).

B. CURRICULUM DESCRIPTION

B.1. DEGREE REQUIREMENTS

BICB-MS Computational Sciences Concentration (CS) – Degree Requirement	
33 Credit Hours Total	
Bioinformatics & Computational Biology Core – Computational Sciences	15 Credits
Ethics Core	3 Credits
Electives – Computational Sciences	6 Credits
Thesis	6 Credits
Seminar	3 Credits (1 Credit/Semester, P/F)

B.2. CURRICULUM

The tables below list the course curriculum for the major components of the Master of Science program in Bioinformatics & Computational Biology. New or revised courses required for the curriculum are marked. All of these courses have been submitted to the Course Challenge list and will be effective for the Fall 2010 term.

Bioinformatics & Computational Biology Core – Computational Sciences (15)	
Bioinformatics (3)	CISC636: Bioinformatics (3) *
Introduction to Discipline (3) [select one]	ELEG671: Introduction to Biomedical Engineering (3)
	BISC602: Molecular Biology of Animal Cells (3)
	BISC612: Advanced Cell Biology (3)
	BISC654: Biochemical Genetics (3)

	PLSC636: Plant Genes and Genomes (3) *
	ANFS670: Principles of Molecular Genetics (3)
	MAST616: Methods in Molecular Biology (3)
Systems Biology (3)	MATH660: Introduction to Systems Biology (3) *
Database (3)	CISC637: Database Systems (3)
Biostatistics (3) [select one]	STAT613: Multivariate Statistical Methods with Biology Applications (3) *
	STAT656: Biostatistics (3)

CISC636: Bioinformatics (3) * submitted for re-title from "Introduction to Bioinformatics"
PLSC636: Plant Genes and Genomes (3) * submitted for re-title from "Advanced Plant Genetics"
MATH660: Introduction to Systems Biology (3) * adapted from MATH460
STAT613: Multivariate Statistical Methods with Biology Applications (3) * new course being developed

Ethics Core (3)	
Ethics (3) [select one]	BISC631: Practice of Science (3)
	UAPP648: Environmental Ethics (3)
	UAPP650: Values Ethics and Leadership (3)
	BUAD840: Ethical Issues in Global Business Environments (3)

Seminar (3)	
Seminar [3 semesters]	BINF865: Seminar (1) *
Thesis (6)	
Thesis (6)	BINF869: Master's Thesis (1-6) *

BINF865: Seminar * new course listing
BINF869: Master's Thesis * new course listing

Electives – Computational Sciences (6)	
Electives (6) [select two]	CISC841: Algorithms in Bioinformatics (3)
	CISC621: Algorithm Design and Analysis (3)
	CISC640: Computer Graphics (3)
	CISC642: Introduction to Computer Vision (3)
	CISC650: Computer Networks (3)
	CISC675: Object Oriented Software Engineering (3)
	CISC681: Artificial Intelligence (3)
	CISC683: Introduction to Data mining (3)
	CISC882: Natural Language Processing (3)
	CISC886: Multi-Agent Systems (3)
	CISC887: Internet Information Gathering (3)
	CISC888: Machine Learning (3)
	MATH607: Survey of Scientific Computing (3)
	MATH611: Introduction to Numerical Analysis and Scientific Computing (3)
	STAT670: Introduction to Statistical Analysis I (3) *
	STAT671: Introduction to Statistical Analysis II (3) *
	STAT608: Statistical Research Methods (3)
	STAT615: Design and Analysis of Experiments (3)
	STAT619: Time Series Analysis (3)
	STAT621: Survival analysis (3)
	STAT674: Applied Data Base Management (3)

	ELEG633: Image Processing (3)
	ELEG652: Principles of Parallel Computer Architectures (3)
	ELEG655: High-Performance Computing with Commodity Hardware (3)
	ELEG679: Introduction to Medical Imaging Systems (3)
	ELEG680: Immunology for Engineers (3)
	CHEG620: Biochemical Engineering (3)
	CHEG621: Metabolic Engineering (3)

STAT670: Introduction to Statistical Analysis I (3) * new course being developed
STAT671: Introduction to Statistical Analysis II (3) * new course being developed

V. RESOURCES AVAILABLE

A. LEARNING RESOURCES

There are no special Learning Resources required to support this degree program. No new library or technology resources will be required for this Master of Science program in Bioinformatics & Computational Biology, as it will extend from the previous courses in the participating departments and build upon the bioinformatics infrastructure at the Delaware Biotechnology Institute. The library's current holdings and subscriptions have covered major bioinformatics journals (many are open-access) and are sufficient as instructional materials.

B. FACULTY/ADMINISTRATIVE RESOURCES

Faculty resources will be available to the Master of Science program in Bioinformatics & Computational Biology for course offerings from the participating departments. Faculty members may serve as course directors, course instructors, and/or research mentors. The research mentors will also serve as the Faculty Advisor who will be the primary contact for students and will develop a course of study with the student before the beginning of the second semester.

All the courses in the curriculum will be offered every year, except for a few elective courses, which may be offered every other year. The total enrollment each year from the Master of Science program is projected at 10 students in the steady state. The demand from Bioinformatics & Computational Biology students can be absorbed by most existing classes. In a few cases, especially for the Core courses (such as CISC637 Database Systems), additional sections may be needed.

Additional faculty and administrative resources will be available from the Center for Bioinformatics & Computational Biology. These include: (i) four tenure-track faculty positions for faculty recruitment in critical areas of bioinformatics research and education–a search is currently underway for one position in the College of Arts & Sciences, (ii) an Administrative Assistant for administrative assistance for three years, and (iii) bioinformatics research faculty and scientific staff at the BioIT Center and PIR at Delaware Biotechnology Institute.

C. External Funding

Unidel Foundation funds have been requested to support a Scientific Coordinator position for three years at the Center for Bioinformatics & Computational Biology. The Coordinator will be recruited at the rank of Research Assistant Professor to assist the Center Director in managing and coordinating activities in all three areas of research, education and core. If funded, the Coordinator will provide day-to-day management of the Master's program in Bioinformatics & Computational Biology and assist with student recruitment, admission, advising, progress assessment, and career planning. In addition, funds were requested to support Center activities including seminar series, training workshops and research symposiums. This will provide support for the Bioinformatics Seminar course (BINF865) and for an annual Research Day at the University of Delaware where MS students will present posters and showcase their thesis.

VI. Resources Required

A. Learning Resources

Students in the program will utilize standard University computing systems. No new learning resources are required.

B. Personnel Resources

No additional personnel resources will be requested beyond the faculty and administrative resources described in Section V.

C. Budgetary Needs

C.1. Projected Expenses

The projected expenses for the Master of Science program in Bioinformatics & Computational Biology include personnel costs for program administration, course instruction, mentoring and student scholarships, as well as costs for advertisement, materials and supplies and for hosting program activities.

	% Effort/Costs	Initial Funding
Personnel Expenses		
Program Administration		
Faculty Director	3.3%	Arts & Sciences (CBCB)
Program Coordinator (Research Faculty)	10.0%	Unidel (CBCB)
Administrative Assistant	6.7%	Arts & Sciences (CBCB)
Administration Personnel Total	0.2 FTE	
Course Instruction, Mentoring, Fellowships		
Additional Sections of Existing Courses	12.5%/course	Participating Departments/Colleges

New Course Development	12.5%/course	Participating Departments/Colleges
Student Scholarships	50% tuition	Participating Departments/Colleges
Operational Expenses		
Web Design and Maintenance	$1,700	Arts & Sciences (CBCB)
Brochures and Advertisement	$6,700	Arts & Sciences (CBCB)
Materials and Supplies	$3,300	Arts & Sciences (CBCB)
Bioinformatics Seminars and Research Day	$3,300	Unidel (CBCB)
Operational Expenses Total	$15,000	

* Covers both Computational Sciences Concentration and Life Sciences Concentration.

The initial funding for the administration personnel costs is available from the College of Arts & Sciences (and from the Unidel Foundation if funded) through the Center for Bioinformatics & Computational Biology (CBCB). The costs for course instruction by tenure-track faculty represent redirections of effort, as their salaries are already being paid by the respective Departments/Colleges. There may be needs to establish S-Contracts for part-time instructors to offer new sections of existing courses or to develop new courses in the future, especially for researchers or professionals from the collaborating companies and institutions who may provide industry perspectives and real-world problem-based learning.

The Bioinformatics Steering Committee further recommends that financial assistance be sought from Deans of the participating Colleges to provide tuition scholarships to outstanding students in the initial period of the Master's program to increase the prestige of the program,

Other operational expenses for the Master of Science program include recurring annual costs for recruitment and marketing, materials and supplies, and educational program activities. The latter will include honorarium and travel supports for invited speakers participating in the Bioinformatics Seminar course and the Research Day, as well as costs for hosting the Research Day events and student poster presentations.

C.2. BUDGET PLAN

The tuition income constitutes the major income for the Master of Science program in Bioinformatics & Computational Biology. Based on the assumption that we will have a steady increase in new enrollment of full-time student equivalents (FTEs) from three students in year one to 10 students in year four when it reaches a steady state, the program is likely to have a net income starting the third year. The table below provides the projection of the number of new admits each year and the total number of students of the two-year program.

Student Enrollment (New/Total FTEs)	Y01	Y02	Y03	Y04	Y05
Master of Science (MS)	3/3	5/8	7/12	10/17	10/20

* Covers both Computational Sciences Concentration and Life Sciences Concentration.

A budget plan should be in place and agreed upon among the Deans of the participating Colleges to cover the costs of launching the program initially, to incentivize faculty members to participate and contribute to this educational program, and to share the profit generated by the success of the program.

The proposed Master of Science program in Bioinformatics & Computational Biology is fully endorsed by the Deans of the following participating Colleges. Their letters of support are attached in Appendix II.

College of Arts & Sciences:
College of Agriculture & Natural Resources
College of Engineering
College of Earth, Ocean & Environment

VII. IMPLEMENTATION AND EVALUATION

A. IMPLEMENTATION PLAN

The Master's program in Bioinformatics & Computational Biology is planned for an official start in the Fall semester of 2010. The Bioinformatics Graduate Committee will establish policies of their operation and for the program, and coordinate with the home department and other participating departments about course offerings.

Simultaneously with this proposal, Faculty Senate approval will be sought for new or revised courses required for the curriculum, as submitted to the Course Challenge list.

B. ASSESSMENT PLAN

B.1. PROGRAM OBJECTIVE

The Master's program in Bioinformatics & Computational Biology aims to train the next-generation of researchers and professionals who will play a key role in multi- and interdisciplinary teams, bridging life sciences and computational sciences. The *Master of Science degree* will prepare students for advanced research in bioinformatics and computational biology.

B.2. CURRICULAR MAP AND LEARNING OUTCOMES

The Master of Science program has four major curriculum components:

1. Science Core in Bioinformatics & Computational Biology
2. Ethics Core
3. Science Electives in Bioinformatics & Computational Biology
4. Seminar/Thesis in Bioinformatics & Computational Biology

The curricular map indicates the following learning outcomes addressed in the curriculum:

1. Core competency in bioinformatics & computational biology
2. Knowledge of scientific/business ethics
3. Advanced knowledge of bioinformatics & computational biology and related disciplines
4. Independent mentored research experience in bioinformatics & computational biology
5. Working experience of bioinformatics in industry and business

6. Competence in scientific communication
7. Experience working with interdisciplinary teams, bridging life sciences and computational sciences

	Learning Outcomes						
Curriculum	Core competency in Bioinformatics	Knowledge of ethics	Advanced knowledge of bioinformatics & related disciplines	Independent research experience	Working experience of bioinformatics in industry	Competence in scientific communication	Experience working with interdisciplinary teams
Science Core	x						
Ethics Core		x					
Science Electives			x				
Seminar			x			x	
Thesis			x	x		x	x

B.3. ASSESSMENT PLAN

Objectives	**Strategic Activities**	**Measures**	**Short-term Outcomes**	**Long-term Impact**
Train students in the science disciplines pertinent to bioinformatics & computational biology	Recruit excellent applicant and matriculate students with credentials similar to those in UD graduate programs	Number and demographic data of student applicants and matriculated students	Retention and time to degree statistics	Students gain employment in bioinformatics related fields
	Course work covering the disciplines related to bioinformatics & computational biology (Science Core and Electives)	Faculty evaluation of student progress in course work; Survey of faculty advisors; Surveys of graduate students in the program and post-	Course work helped students secure initial employment; Students and graduates report applying knowledge from	Graduates enjoy long term success in academic or professional careers

		graduation	courses to work settings	
Provide training in science-related ethics	Course work addressing these issues	Surveys of students focusing on their experiences in these classes; Surveys of graduates to determine the utility of these classes to their career; Faculty evaluation of student progress in course work	Students and graduates report applying knowledge from courses to work settings	Graduates enjoy long term success in professional careers
Provide experiential training in academia or industry research to prepare students for the expectations of the workplace	Mentored research or development projects (Thesis); Lectures and discussions on specialized topics and cutting-edge developments (Seminar)	Surveys of students focusing on their experiences in their thesis; Surveys of graduates to determine the utility of their experiential training to their career; Faculty advisor evaluation of both the project and the written reports and presentation; Interviews and surveys of faculty advisors	Experiential training prepares students for the workplace and helps them secure their first post-graduation position	Graduates enjoy long term success in academic or professional careers

Program improvement will be an ongoing process. The results of the assessment measures will be shared with the Bioinformatics Steering Committee and the Bioinformatics Graduate Committee. The curriculum will be modified as necessary to achieve the goal of producing graduates who apply the knowledge, skills and abilities gained from the Master of Science program in Bioinformatics & Computational Biology to their career.

PART V

PROGRAM POLICY STATEMENT

I. PROGRAM HISTORY

A. RATIONALE

The completion of the human genome sequence marked the beginning of a new era of biological research. Scientists have begun to systematically tackle gene functions and other complex regulatory processes by studying organisms at the global scales. Advances in high-throughput biotechnologies and large-scale bioscience have further enabled modeling and simulation over a multitude of length, time and biological scales from biomolecules, cells, tissues and organs to organisms and population. With the enormous volume of data being produced, biology is becoming an increasingly quantitative science. Computational approaches, in combination with experimental methods, have become essential for generating novel hypotheses, deriving new scientific knowledge, and driving discovery and innovation.

Bioinformatics & Computational Biology is an emerging field where biological and computational disciplines converge. According to the National Institutes of Health, the working definitions of Bioinformatics and Computational Biology are as follows:

- *Bioinformatics*: Research, development, or application of computational tools and approaches for expanding the use of biological, medical, behavioral or health data, including those to acquire, store, organize, archive, analyze, or visualize such data.
- *Computational Biology*: The development and application of data-analytical and theoretical methods, mathematical modeling and computational simulation techniques to the study of biological, behavioral, and social systems.

Fundamental to the modern day biological studies and key to the basic understanding of complex biological systems, Bioinformatics & Computational Biology is impacting the science and technology of fields ranging from agricultural and environmental sciences to pharmaceutical and medical sciences. The research requires close collaboration among multi-disciplinary teams of researchers in quantitative sciences, life sciences, and their interfaces.

According to many accredited scientific and industry reviews, bioinformatics and computational biology may well be the single fastest-growing specialty in the life sciences. The University of Delaware currently does not offer a specialized graduate degree in Bioinformatics & Computational Biology, although related courses have been taught in several departments for a number of years. The Master's program in Bioinformatics & Computational Biology will offer graduate education in a discipline essential for UD as a major research university. According to the International Society for Computational Biology, there are presently 180 bioinformatics-related degree programs worldwide, almost 100 in the United States alone.

The Master of Science program in Bioinformatics & Computational Biology will train the next-generation of researchers and professionals who will play a key role in multi- and interdisciplinary teams, bridging life sciences and computational sciences. The program will be administered through its academic home, the Department of Computer & Information Sciences, and will be coordinated by the newly established Center for Bioinformatics & Computational Biology. The scientific curriculum will build upon the research and educational strength from departments across the Colleges of Arts & Sciences, Engineering, Agriculture & Natural

Resources, and Earth, Ocean & Environment. The Master's program will provide a solid foundation for the future development of a PhD degree program in Bioinformatics and Computational Systems Biology. The program will be synergistic to the existing degree programs, providing a critical component to University's strategic priorities in Energy and Environment studies and Translational Medicine, and serving as a pillar of UD's *Path to Prominence*.

B. DEGREES OFFERED

The program will offer the degree *Master of Science in Bioinformatics & Computational Biology (BICB-MS)* with a *Computational Sciences Concentration (CS).*

The Master of Science in Bioinformatics & Computational Biology (BICB-MS) will offer graduate education in a discipline essential for UD as a major research university. The BICB-MS will provide an interdisciplinary program to foster educational and research collaborations across Colleges, increasing UD's competitiveness in interdisciplinary training programs such as NSF's IGERT (Integrative Graduate Education and Research Traineeship Program) and research initiatives such as NIH's CTSA (Clinical and Translational Science Award). The BICB-MS will provide a solid foundation for the future development of a PhD degree program in Bioinformatics and Computational Systems Biology.

The thesis-based BICB-MS degree will prepare students for advanced research. The Computational Sciences Concentration (CS) will allow students with strong quantitative sciences background to gain knowledge and research experience in developing computational methods and bioinformatics tools and databases for the study of biological systems. The BICB-MS graduates will have solid knowledge and research experience to pursue further study towards a PhD or other professional degree such as MD, MBA or law, or a research career in academia, industry, or government agencies.

II. ADMISSION

A. ADMISSION REQUIREMENTS

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 of Science program in Bioinformatics & Computational Biology:

- 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?

B. APPLICATION

Application to the Master's program in Bioinformatics & Computational Biology will be submitted using the on-line graduate admission application that includes transcripts from all previous college or university study, letters of recommendation, resume, application essay, and official GRE and TOEFL scores (if applicable). If any part of an application is missing, evaluation of the application cannot begin. The applicant will apply to the Department of Computer & Information Sciences.

B.1. APPLICATION DEADLINES

Admission decisions are made on a rolling basis as and when applications are complete. Decisions on financial aid awards are usually made in March-May for the Fall Semester, and in November-December for the Spring Semester. The central graduate admissions office continues to process applications and transcripts throughout the year and follows the stated two (2) week processing timeline for all materials received in the office.

The application deadlines are:

- Fall Semester: July 1st (regular application); March 1st (financial aid)
- Spring Semester: December 1st (regular application); October 1st (financial aid)

B.2. CHANGE OF CLASSIFICATION

Students currently matriculated in other graduate degree programs should complete a "Change of Classification" Form to seek approval to enter the Master of Science program in Bioinformatics & Computational Biology. The Bioinformatics Graduate Committee will evaluate each Change of Classification request on a case-by-case basis and determine whether the student is required to

submit a completed admission application form to the Office of Graduate and Professional Education and follow the same procedures for admission as other applicants.

C. ADMISSION STATUS

Students may be admitted into the Master of Science program in Bioinformatics & Computational Biology with regular status or provisional status.

Regular. Regular status is offered to students who meet all of the established entrance requirements, who have a record of high scholarship in their fields of specialization, and who have the ability, interest, and maturity necessary for successful study at the graduate level in a degree program.

Provisional. Provisional status is offered to students who are seeking admission to the degree program but lack one or more of the specified prerequisites. All provisional requirements must be met within the deadline given before regular status can be granted. Students admitted with provisional status are generally not eligible for assistantships or fellowships. Students who file an application during the final year of undergraduate or current graduate work and are unable to supply complete official transcripts showing the conferral of the degree will be admitted pending conferral of the degree if their records are otherwise satisfactory and complete. For students lacking appropriate preparatory course work, additional courses applicable to certain areas of study may be required prior to admission or students may be admitted with the provision that completion of certain area content courses be completed concurrent with the courses in the degree program.

III. ACADEMIC

A. DEGREE REQUIREMENTS

BICB-MS Computational Sciences Concentration (CS) – Degree Requirement	
33 Credit Hours Total	
Bioinformatics & Computational Biology Core – Computational Sciences	15 Credits
Ethics Core	3 Credits
Electives – Computational Sciences	6 Credits
Thesis	6 Credits
Seminar	3 Credits (1 Credit/Semester, P/F)

B. COURSE CURRICULUM

The tables below list the course curriculum for the major components of the Master of Science program in Bioinformatics & Computational Biology. New or revised courses required for the curriculum are marked. All of these courses have been submitted to the Course Challenge list and will be effective for the Fall 2010 term.

1. BIOINFORMATICS SCIENCE CORE – COMPUTATIONAL SCIENCES

Bioinformatics & Computational Biology Core – Computational Sciences (15)	
Bioinformatics (3)	CISC636: Bioinformatics (3) *
Introduction to Discipline (3) [select one]	ELEG671: Introduction to Biomedical Engineering (3)
	BISC602: Molecular Biology of Animal Cells (3)
	BISC612: Advanced Cell Biology (3)
	BISC654: Biochemical Genetics (3)
	PLSC636: Plant Genes and Genomes (3) *
	ANFS670: Principles of Molecular Genetics (3)
	MAST616: Methods in Molecular Biology (3)
Systems Biology (3)	MATH660: Introduction to Systems Biology (3) *
Database (3)	CISC637: Database Systems (3)
Biostatistics (3) [select one]	STAT613: Multivariate Statistical Methods with Biology Applications (3) *
	STAT656: Biostatistics (3)

CISC636: Bioinformatics (3) * submitted for re-title from "Introduction to Bioinformatics"
PLSC636: Plant Genes and Genomes (3) * submitted for re-title from "Advanced Plant Genetics"
MATH660: Introduction to Systems Biology (3) * adapted from MATH460
STAT613: Multivariate Statistical Methods with Biology Applications (3) * new course being developed

2. ETHICS CORE

Ethics Core (3)	
Ethics (3) [select one]	BISC631: Practice of Science (3)
	UAPP648: Environmental Ethics (3)
	UAPP650: Values Ethics and Leadership (3)
	BUAD840: Ethical Issues in Global Business Environments (3)

3. BIOINFORMATICS & COMPUTATIONAL BIOLOGY SEMINAR/THESIS

Seminar (3)	
Seminar [3 semesters]	BINF865: Seminar (1) *
Thesis (6)	
Thesis (6)	BINF869: Master's Thesis (1-6) *

BINF865: Seminar * new course listing
BINF869: Master's Thesis * new course listing

4. ELECTIVES – COMPUTATIONAL SCIENCES

Electives – Computational Sciences (6)	
Electives (6) [select two]	CISC841: Algorithms in Bioinformatics (3)
	CISC621: Algorithm Design and Analysis (3)
	CISC640: Computer Graphics (3)
	CISC642: Introduction to Computer Vision (3)
	CISC650: Computer Networks (3)
	CISC675: Object Oriented Software Engineering (3)

	CISC681: Artificial Intelligence (3)
	CISC683: Introduction to Data mining (3)
	CISC882: Natural Language Processing (3)
	CISC886: Multi-Agent Systems (3)
	CISC887: Internet Information Gathering (3)
	CISC888: Machine Learning (3)
	MATH607: Survey of Scientific Computing (3)
	MATH611: Introduction to Numerical Analysis and Scientific Computing (3)
	STAT670: Introduction to Statistical Analysis I (3) *
	STAT671: Introduction to Statistical Analysis II (3) *
	STAT608: Statistical Research Methods (3)
	STAT615: Design and Analysis of Experiments (3)
	STAT619: Time Series Analysis (3)
	STAT621: Survival analysis (3)
	STAT674: Applied Data Base Management (3)
	ELEG633: Image Processing (3)
	ELEG652: Principles of Parallel Computer Architectures (3)
	ELEG655: High-Performance Computing with Commodity Hardware (3)
	ELEG679: Introduction to Medical Imaging Systems (3)
	ELEG680: Immunology for Engineers (3)
	CHEG620: Biochemical Engineering (3)
	CHEG621: Metabolic Engineering (3)

STAT670: Introduction to Statistical Analysis I (3) * new course being developed
STAT671: Introduction to Statistical Analysis II (3) * new course being developed

C. COMMITTEES AND DIRECTOR

The development, administration and progress assessment of the Master of Science program in Bioinformatics & Computational Biology will be guided by the Director and the Bioinformatics Steering Committee and the Bioinformatics Graduate Committee, as outlined below.

C.1. BIOINFORMATICS STEERING COMMITTEE

The Steering Committee will advise the development and progress assessment of the Master of Science program in Bioinformatics & Computational Biology. The committee consists of faculty members from all ten Departments across four Colleges participating in this degree program.

Member	College	Department	Expertise
Wu, Cathy (Chair)	Arts & Science	Computer & Information Sciences	Bioinformatics, Cyberinfrastrcture
Antoniewicz, Maciek	Engineering	Chemical Engineering	Metabolic Engineering, Systems Biology
Bahnson, Brian	Arts & Science	Chemistry & Biochemistry	Structure Biology, Molecular Modeling
Duncan, Melinda	Arts & Science	Biological Sciences	Biotechnology PSM, Developmental Biology
Hanson, Thomas	Earth, Ocean &	Marine Biosciences	Microbial Genomics

	Environment		
Lee, Kelvin	Engineering	Chemical Engineering	Systems Biology, Proteomics
Liao, Li	Arts & Science	Computer & Information Sciences	Bioinformatics and Computational Biology
Marsh, Adam	Earth, Ocean & Environment	Marine Biosciences	Environmental Bioinformatics
Meyers, Blake	Agriculture & Natural Resources	Plant & Soil Sciences	Plant Genomics, Bioinformatics
Rejto, Lidia	Agriculture & Natural Resources	Food & Resource Economics	Biostatistics
Schleiniger, Gilberto	Arts & Science	Mathematical Sciences	Quantitative Biology BS Major, Mathematical Biology
Schmidt, Carl	Agriculture & Natural Resources	Animal & Food Sciences	Avian Genomics
Taufer, Michaela	Arts & Science	Computer & Information Sciences	Grid Computing, Cloud Computing
Wommack, Eric	Agriculture & Natural Resources	Plant & Soil Sciences	Viral Genomics
Zurakowski, Ryan	Engineering	Electrical & Computer Engineering	Biomedical Engineering

C.2. BIOINFORMATICS GRADUATE COMMITTEE

The Graduate Committee will be responsible for admission, advising, and progress assessment of the students in the Master of Science program in Bioinformatics & Computational Biology, working closely with the students' Faculty Advisors. The committee consists of at least two representative faculty members from each participating College in this degree program.

Member	College	Department
Wu, Cathy (Chair)	Arts & Sciences	Computer & Information Sciences/ Biological Science
Hanson, Thomas	Earth, Ocean & Environment	Marine Biosciences
Lee, Kelvin	Engineering	Chemical Engineering
Liao, Li	Arts & Sciences	Computer & Information Sciences
Papoutsakis, Eleftherios	Engineering	Chemical Engineering
Patel, Sandeep	Arts & Sciences	Chemistry & Biochemistry
Rejto, Lidia	Agriculture & Natural Resources	Food & Resource Economics
Schleiniger, Gilberto	Arts & Sciences	Mathematical Sciences
Schmidt, Carl	Agriculture & Natural Resources	Animal & Food Sciences
Wommack, Eric	Agriculture & Natural Resources/ Earth, Ocean & Environment	Plant and Soil Sciences/ Marine Biosciences

C.3. DIRECTOR

The Director of the Master of Science program in Bioinformatics & Computational Biology will be responsible for the overall implementation, quality and progress of the degree program, advised by the Steering Committee and the Industry Advisory Board. The Director will also be the Chair of the Bioinformatics Graduate Committee. We propose that the Director of the Master of Science program in Bioinformatics & Computational Biology be a rotating position. Because of a significant amount of time and effort spent in starting up the program, we propose that the Director be located in Computer & Information Sciences for the first two years to get things started. Then, the position will rotate for a three-year term. The Director may appoint a Coordinator to provide day-to-day program management and assist with student recruitment, admission, advising, progress assessment, and career planning.

D. SATISFACTORY PROGRESS

D.1. FACULTY ADVISOR

Students are required to choose an appropriate Faculty Advisor from a list of faculty members participating in the degree program or have an appropriate Faculty Advisor appointed by the Director of the Master of Science program in Bioinformatics & Computational Biology. The participating faculty members are faculty approved by the Bioinformatics Steering Committee to advise students and/or serve as research mentors or co-mentors. The list of participating faculty, along with their departments and research interests, are available from the Bioinformatics program web site (http://bioinformatics.udel.edu/Education).

The Faculty Advisor will be the primary contact of the student for questions and advice. The student will develop a plan of study for the program with the Faculty Advisor before the beginning of the second semester. The Director of the Master of Science program in Bioinformatics & Computational Biology will verify that the student has completed the requirements for the program and will approve the application for the degree upon successful completion of the requirements.

D.2. ACADEMIC LOAD

Full-time student is expected to complete the BICB-MS program (33 credits) in two years. The program may be completed over a longer time frame for part-time students.

Students enrolled in at least 9 credit hours or in sustaining credit are considered full-time students. Those enrolled for fewer than 9 credit hours are considered part-time students, although students holding assistantships are considered full-time with six credits. Generally, a maximum load is 12 graduate credit hours; however, additional credit hours may be taken with the approval of the student's adviser and the Office of Graduate and Professional Education. A maximum course load in either summer or winter session is 7 credit hours. Permission must be obtained from the Office of Graduate and Professional Education to carry an overload in any session

D.3. TRANSFERABILITY

Prior to admission to the Master of Science program in Bioinformatics & Computational Biology, a prospective student from another institution can be approved by the Bioinformatics Graduate Committee to take up to 9 graduate credits that, if/when admitted to the degree program, would be applied to that degree. Once the student has successfully completed 9 approved graduate UD credits and been admitted to the degree program, then a maximum of 9 graduate credits, but not the grades or quality points, can be transferred into the Master's program from another institution with the approval of the Graduate Committee.

Students who complete graduate credits with the classification of CEND (Continuing Education Non-degree) at the University of Delaware may use a maximum of 9 graduate credits earned with this classification toward their graduate degree.

All requests for transfer credit should be directed to the academic home department, Department of Computer & Information Sciences, using a "Request for Transfer of Graduate Credit" Form. Transfer credits will be accepted provided that such credits: (i) were earned with a grade of no less than B-, (ii) are approved by the Bioinformatics Graduate Committee, (iii) are in accord with the Program Policy Statement of the Master's program in Bioinformatics & Computational Biology, (iv) are not older than five years, (v) are graduate level courses, and (vi) were completed at an accredited college or university. Graduate courses counted toward a degree received elsewhere may not be transferred into a degree at UD. Credits from institutions outside of the United States are generally not transferable to UD.

D.4. MASTER'S THESIS

The master's thesis of the BICB-MS program will be in most cases completed at the University of Delaware supervised by the Thesis Faculty Advisor. Unless special permission is granted, students need to complete 12 credit hours prior to the start of their thesis. Each student working on a master's thesis, with the advice of the Thesis Faculty Advisor, needs to establish a Thesis Committee. The Committee should consist of 3 at least three faculty members, the composition of which should be approved by the Bioinformatics Graduate Committee. The Committee Chair should be the Thesis Faculty Advisor and a participating faculty member in the degree program. At least one other member should be a participating faculty member in the program.

Students, with the assistance of their Thesis 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. Upon completion of the master's thesis, a final oral examination must be passed, consisting of a seminar and a defense of the master's thesis. The final oral examination will be directed and evaluated by the student's Thesis Committee.

D.5. GRADE REQUIREMENTS

Only graduate courses completed with a grade of B or higher count towards the requirements of Bioinformatics Master's program. Students receiving a B- or lower in a required core course are subject to dismissal from the program. However, they may file an appeal to the Bioinformatics

Graduate Committee for approval to retake the course and remain in the program if the appeal is approved. Students must obtain at least a 3.0 cumulative grade point average in the courses in the curriculum to receive the degree.

D.6. Consequences of Unsatisfactory Academic Progress

The Bioinformatics Graduate Committee will meet at least once each semester to evaluate each student's progress. If a student is failing to make satisfactory progress towards a degree, the committee will recommend suitable action to the Director of the Master's program in Bioinformatics & Computational Biology. Possible actions include (but are not limited to): (i) requirement for additional courses, (ii) suspension of financial support, and (iii) recommendation for dismissal.

D.7. Standards of Student Conduct

All graduate students are subject to University of Delaware regulations regarding academic honesty. Violations of the UD regulations regarding academic honesty or other forms of gross misconduct may result in immediate dismissal from the Program.

D.8. Dismissal

The procedures for dismissal as detailed in the University Catalog will be followed. Briefly, the Graduate Committee will report its recommendation and reason for dismissal to the Director of the Bioinformatics Master's program. The Director will make a recommendation to the Office of Graduate Studies, who will decide whether to dismiss the student. The student may appeal this decision to the Office of Graduate Studies, following the procedure given in the University Catalog.

D.9. Graduate Student Grievance Procedures

Students who feel that they have been graded inappropriately or receive what they perceive as an unfair evaluation by a faculty member may file grievances in accordance with University of Delaware policies. Students are encouraged to contact the Director of the Bioinformatics Master's program prior to filing a formal grievance in an effort to resolve the situation informally.

D.10. Attendance at Conferences and Professional Meetings

The Bioinformatics Master's program encourages students to attend conferences and professional meetings. They provide opportunities to meet future employers and colleagues, and can offer specialized training beyond course work.

IV. Financial Aid

A. Financial Awards

Admission to the Master of Science program in Bioinformatics & Computational Biology does not automatically entitle an applicant to financial aid. Students may seek financial aid opportunities, such as fellowships or scholarships from sources within the University and from private and federal agencies. Interested students should check the Office of Graduate Studies for the most current opportunities.

Financial aid is awarded on a competitive basis from the pool of admitted applicants. The University of Delaware's policies apply to all forms of financial aid. Please refer to the University Policies for Graduate Student Assistantships and Fellowships.

Students in the BICB-MS program may apply for the Graduate Assistantships:

- **Research Assistantships (RAs)** are generally funded by research grants and contracts provided by external funding agencies. Students may be supported as an RA through their Faculty Advisor's research funds after their first year. A research assistantship provides full tuition and a stipend. The RA's advisor is responsible for defining the student's responsibilities and for evaluating the student's performance. The amount of service or research may vary from week to week but the average is usually expected to be 20 hours per week.
- **Teaching Assistantships (TAs)** are offered for graduate students to perform teaching and other instructional activities. The amount of service may vary from week to week but the average is usually expected to be 20 hours per week. A teaching assistantship provides full tuition and a stipend. In accordance with University of Delaware regulations, foreign students must achieve a TOEFL score of at least 600 (paper-based), 250 (computer-based), or 100 (Internet-based) in order to qualify for teaching assistantships.

B. CONTINUATION OF FINANCIAL AID

Students who are awarded financial aid must maintain satisfactory academic progress with satisfactory performance of assistantship duties (when applicable). Satisfactory academic progress includes registering for a minimum of 9 graduate-level credits each Fall and Spring semester, and maintaining a minimum 3.0 GPA.

The RA's responsibilities and performance standards will be established by the Faculty Advisor. In the event of an unsatisfactory performance by an RA, the advisor will notify the student and the Graduate Committee at least four weeks prior to terminating the assistantship.

The TA's responsibilities and performance standards will be established by the Director of the course in which the student teaches. In the event of an unsatisfactory performance by a TA, the Course Director will notify the student and the Graduate Committee of the academic department offering the course. The Committee may recommend termination of the assistantship to the Department Chair.

APPENDIX I

LETTERS OF APPROVAL FROM CONTRIBUTING DEPARTMENTS/UNITS

College of Arts & Sciences

1. Dr. David Saunders, Chair, Department of Computer & Information Sciences [Academic Home Department]
2. Dr. Randall Duncan, Chair, Department of Biological Sciences
3. Dr. Peter Monk, Chair, Department of Mathematical Sciences
4. Dr. Klaus Theopold, Chair, Department of Chemistry & Biochemistry

College of Agriculture & Natural Resources

5. Dr. Jack Gelb Jr., Chair, Department of Animal & Food Sciences
6. Dr. Thomas Ilvento, Chair, Department of Food & Resource Economics
7. Dr. Blake Meyers, Interim Chair, Department of Plant & Soil Sciences

College of Engineering

8. Dr. Kenneth Barner, Chair, Department of Electrical & Computer Engineering
9. Dr. Norman Wagner, Chair, Department of Chemical Engineering

College of Earth, Ocean & Environment

10. Dr. Charles Epifanio, Director, School of Marine Science and Policy

College of Health Sciences

11. Dr. Susan Hall, Chair, Department of Health, Nutrition & Exercise Sciences
12. Dr. Stuart Binder-Macleod, Chair, Department of Physical Therapy

Alfred Lerner College of Business & Economics

13. Dr. Rick Andrews, Chair, Department of Business Administration
14. Dr. Guido Geerts, Chair, Department of Accounting & management Information Systems

College of Education & Public Policy

15. Dr. Maria Aristigueta, Director, School of Urban Affairs & Public Policy

Office of the Vice Provost for Graduate & Professional Education

16. Dr. John Sawyer, Associate Provost for Professional Education

APPENDIX II

LETTERS OF SUPPORT FROM DEANS OF PARTICIPATING COLLEGES

1. Dr. George H. Watson, Interim Dean, College of Arts & Sciences
2. Dr. Robin W. Morgan, Dean, College of Agriculture & Natural Resources
3. Dr. Michael J. Chajes, Dean, College of Engineering
4. Dr. Nancy M. Targett, Dean, College of Earth, Ocean & Environment

Department of Computer and Information Sciences
University of Delaware
103 Smith Hall
Newark, DE 19716
(302) 831-6238
saunders@cis.udel.edu

October 15, 2009

Cathy H. Wu, Ph.D.
Edward G. Jefferson Professor of Bioinformatics & Computational Biology
Department of Computer & Information Sciences
Delaware Biotechnology Institute
University of Delaware
15 Innovation Way, Suite 205
Newark, DE 19711

Dear Cathy,

The Department of Computer and Information Sciences is pleased to support core and elective courses for the proposed Professional Science Masters in Bioinformatics (BINF-PSM) and Masters of Science in Bioinformatics and Computational Biology (BICB-MS) degree programs and for the Graduate Certificate in Bioinformatics (BINF-CERT).

In particular, as we have discussed, we will work together to ensure that the courses CISC636 Bioinformatics and CISC637 Database Systems will be taught in such a way (1) to be accessible to students of varied degrees of preparation in computation and biology and (2) to continue to provide rigorous training in these subjects for CIS graduate students and BINF/BICB students alike.

The elective CISC6xx courses listed are normally taught every year, some of them every semester. Likewise the CISC8xx course electives usually are offered each year, though occasionally they appear 3 or 4 semesters apart. Courses do sometimes fill to capacity, but I anticipate that our schedule of offerings and the number of seats available will provide a rich set of options for students in this program without difficulty.

The Department of Computer and Information Sciences is pleased to contribute to the education of students in this important area. These programs will be a benefit to the University of Delaware and to our society.

Sincerely,

B. David Saunders

UNIVERSITY OF DELAWARE

DEPARTMENT OF BIOLOGY
OFFICE OF THE CHAIR

University of Delaware
Newark, Delaware 19716-2590
Ph: 302/831-6977
Fax: 302/831-2281

Randall L. Duncan, Ph.D.
Professor and Chairman
Department of Biological Sciences
118C Wolf Hall
Telephone (302) 831-6977
Fax No. (302) 831-1033
E-mail: rlduncan@udel.edu

October 12, 2009

Cathy H. Wu, Ph.D.
Edward. G. Jefferson Chair
Professor, Computer & Information Sciences and
Professor, Biological Sciences
Delaware Biotechnology Institute
15 Innovation Way, Suite 205
University of Delaware
Newark, DE 19711

Dear Cathy,

We shall be happy to make available seats in graduate courses in Biological Sciences, which will serve as electives in your proposed Masters of Science degree in Bioinformatics. As a proviso, I cannot guarantee the availability of space for all comers at all times since some of the listed courses often reach their enrollment limits. However, several courses on the list seldom reach enrollment limits and we are willing to consider increasing the available sections for the most popular graduate classes in the future if there is sufficient demand.

Please let me know if you require anything else in this regard. We wish you much success with this new initiative.

Best regards,

Professor and Chair

UNIVERSITY OF DELAWARE

DEPARTMENT OF BIOLOGY
OFFICE OF THE CHAIR

University of Delaware
Newark, Delaware 19716-2590
Ph: 302/831-6977
Fax: 302/831-2281

Randall L. Duncan, Ph.D.
Professor and Chairman
Department of Biological Sciences
118C Wolf Hall
Telephone (302) 831-6977
Fax No. (302) 831-1033
E-mail: rlduncan@udel.edu

October 13, 2009

Cathy H. Wu, Ph.D.
Edward. G. Jefferson Chair
Professor, Computer & Information Sciences and
Professor, Biological Sciences
Delaware Biotechnology Institute
15 Innovation Way, Suite 205
University of Delaware
Newark, DE 19711

Dear Cathy,

We shall be happy to make available seats in graduate courses in Biological Sciences, which will serve as electives in your proposed Professional Science Masters degree in Bioinformatics. As a proviso, I cannot guarantee the availability of space for all comers at all times since some of the listed courses often reach their enrollment limits. However, several courses on the list seldom reach enrollment limits and we are willing to consider increasing the available sections for the most popular graduate classes in the future if there is sufficient demand.

Please let me know if you require anything else in this regard. We wish you much success with this new initiative.

Best regards,

Randall L. Duncan

Professor and Chair

UNIVERSITY OF DELAWARE

DEPARTMENT OF
MATHEMATICAL SCIENCES

501 Ewing Hall
University of Delaware
Newark, Delaware 19716-2553
Ph: 302/831-2653
Fax: 302/831-4511/4456

October 14, 2009

Prof Cathy Wu
Department of Computer and Information Sciences
University of Delaware
Newark, DE 19716

Dear Dr. Wu,

The Department of Mathematical Sciences is pleased to support core and elective courses for the Professional Science Master's (PSM) and certificate programs in bioinformatics.

The Department has proposed a new course, MATH 560 -- Introduction to Systems Biology, that may serve as a core course, and it offers courses in scientific computation that could serve as electives for the bioinformatics programs, namely MATH 607, MATH 611 and MATH 612. Although MATH 611/612 may be renumbered and revised to include some updating, the new courses would still serve the same purpose.

MATH 560, MATH 607, and MATH 611 are courses scheduled to be offered every fall semester and MATH 612 every spring.

The Department is enthusiastic about the possibility of collaborating with the new bioinformatics programs.

Sincerely,

Peter Monk
Chair and UNIDEL Professor

cc G. Schleiniger

UNIVERSITY OF DELAWARE

DEPARTMENT OF CHEMISTRY
AND BIOCHEMISTRY
OFFICE OF THE CHAIRMAN

102 Brown Laboratory
University of Delaware
Newark, Delaware 19716-2522
Ph: 302/831-1247
Fax: 302/831-6335

September 30, 2009

Cathy H. Wu, Ph.D.
Edward G. Jefferson Professor of Bioinformatics & Computational Biology
Department of Computer & Information Sciences
Delaware Biotechnology Institute
University of Delaware
15 Innovation Way, Suite 205
Newark, DE 19711

Dear Prof. Wu:

The Department of Chemistry & Biochemistry strongly supports enrollment of students in our graduate level courses that are listed as electives for your proposed Professional Science Masters in Bioinformatics (BINF-PSM) and Masters of Science in Bioinformatics and Computational Biology (BICB-MS) degree programs.

The Department has submitted a proposal for the regularization of CHEM 684 titled Biochemistry of Nucleic Acids, which will be offered each spring semester. You may consider adding this course to your list of electives.

Each of the courses that are listed in your BINF-PSM or BICB-MS program under the Life Sciences elective are offered once per year. The courses CHEM 641 (Biochemistry), CHEM 645 (Protein Structure and Function) and CHEM 646 (DNA-Protein Interactions) are offered in the fall semester. The CHEM 641 course has two sections open. The courses CHEM 624 (Principles of Mass Spectrometry) and CHEM 649 (Molecular Biophysics) are offered each spring. These courses typically have room for additional enrollment, and we would welcome BINF-PSM and BICB-MS enrollment to fill open seats in these classes.

The Department of Chemistry & Biochemistry is excited to be a part of this initiative and looks forward to teaching students from these new programs.

With best regards,

Klaus H. Theopold
Professor and Chair

e-mail: theopold@udel.edu

UNIVERSITY OF DELAWARE

COLLEGE OF AGRICULTURE AND NATURAL RESOURSES

DEPARTMENT OF ANIMAL AND FOOD SCIENCES

Townsend Hall
University of Delaware
Newark, Delaware 19716-2150
Ph: 302//831-2524

October 14, 2009

MEMORANDUM

To: Cathy Wu
Ed. G. Jefferson Endowed Professor
Computer & Info Sciences

From: Jack Gelb, Jr., Chair
Animal and Food Sciences

I am providing this letter of support at the request of Dr. Carl Schmidt of our department. I will also copy Dr. Limin Kung, Chair of the ANFS Courses and Curriculum Committee.

The Department of Animal and Food Sciences is pleased to support the core course offerings for the proposed Master's degree program in Bioinformatics and Computational Biology.

Specifically, we are prepared to offer ANFS 644 Bioinformatics-3 hr. At the present time, this course is offered during the fall semester each year. Currently, one section is offered and students enrolled in the Master's degree program in Bioinformatics and Computational Biology may use seats in the existing section. Typical enrollment is approximately ten students, but there is space for twenty in the computer laboratory located in Townsend Hall. If necessary, the course could be offered in a larger computer laboratory on the main campus.

The Department of Animal and Food Sciences will benefit from such a Master's program here at the University of Delaware and we look forward to providing instruction for the enrolled students.

c. Carl Schmidt
Limin Kung

UNIVERSITY OF DELAWARE

COLLEGE OF AGRICULTURE AND NATURAL RESOURCES

STATISTICS PROGRAM

Thomas W. Ilvento
213 Townsend Hall
University of Delaware
Newark, DE 19716-2130
Ph: 302-831-6773
Fax: 302-831-6243
Ilvento@udel.edu

October 13, 2008

Cathy H. Wu, Ph.D.
Edward G. Jefferson Professor of Bioinformatics & Computational Biology
Center for Bioinformatics and Computational Biology (CBCB)

Dear Dr. Wu,

The Department of Food and Resource Economics will support the following courses for inclusion in the Masters in Bioinformatics and the Profession Science Masters in Bioinformatics. By supporting these courses we acknowledge our intent to teach these courses on a regular basis and to admit nonmajors into these course as appropriate.

STAT 608 Statistical Research Methods I
STAT 615 Design and Analysis of Experiments
STAT 619 Time Series Analysis
STAT 621 Survival Analysis
STAT 656 Biostatistics
STAT 674 Applied Data Management

The following courses are under the process for revision or a new course. We expected these to be approved in this fiscal year

STAT 670 Introduction to Statistical Analysis I
STAT 671 Introduction to Statistical Analysis II
STAT 613 Multivariate Statistical Methods with Biological Applications

Please call or e-mail if you have any further questions or need anything else from me.

Sincerely,

Thomas W. Ilvento

Thomas W. Ilvento
Professor and Chair, Department of Food and Resource Economics

DEPARTMENT OF PLANT AND SOIL SCIENCES
OFFICE OF THE CHAIR

University of Delaware
Newark, DE 19717-1303
Ph:302/831-8153
Fax: 302/831-0605
Email: meyers@dbi.udel.edu

September 28, 2009

The Department of Plant & Soil Sciences is pleased to support breadth courses for Professional Science Master's (PSM) degree programs.

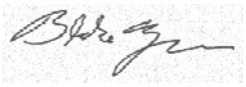
PLSC636: Advanced Plant Genetics is offered during the fall semester. This course is an advanced survey of genetics and genomics in higher plants, including molecular methods of plant biotechnology. Topics include genome composition and evolution, disease resistance, transposable elements and retrotransposons, DNA methylation and epigenetics, quantitative traits, chromosome structure and gene expression. One section of the course is offered each year, and PSM may utilize open seats in existing classes.

PLSC644: Physiology of Plant Stress will be offered during either the fall or spring semester. This course focuses on the response of plants to biotic and abiotic environmental stresses; mineral nutrients, salt, drought, cold, heat, light, pathogens and herbivores at the physiological and molecular levels. At least one section of the course is offered each year, and PSM may utilize open seats in existing classes.

PLSC667: Analytical Plant Genetics will be offered during either the fall or spring semester and is listed as a seminar course only because it is new. It will be taught as a regular course in the coming years.

The Department Plant and Soil Sciences is excited to be a part of this initiative and looks forward to seeing PSM and other students in the classroom.

Sincerely,



Blake Meyers
Professor

UNIVERSITY OF DELAWARE

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

140 Evans Hall
University of Delaware
Newark, Delaware 19716-3130
Ph: 302/831-2405
Fax: 302/831-4316
www.ee.udel.edu

September 28, 2009

Dr. Cathy Wu
Ed. G. Jefferson Endowed Prof., Computer & Info Sciences
Professor, Biological Sciences
103 Smith Hall

Dear Professor Wu:

The Department of Electrical and Computer Engineering is pleased to support core and elective courses for the Bioinformatics and Computational Biology Master of Sciences (MS) and Bioinformatics Professional Science Master's (PSM) degree programs.

ELEG671 (Introduction to Biomedical Engineering) is a core course for the program, and is offered during Fall semesters. One section of the course is offered each year, and the program may utilize open seats in existing classes.

ELEG633 (Image Processing), ELEG652 (Principles of Parallel Computer Architectures), ELEG655 (High-Performance Computing with Commodity Hardware), ELEG679 (Introduction to Medical Imaging Systems) and ELEG680 (Immunology for Engineers) are elective options for both programs; demand for these courses can be spread to use seats in available sections. ELEG 652, ELEG655, and ELEG679 are offered regularly, while ELEG633 and ELEG680 are offered less frequently (every other year as demand permits).

The Department of Electrical and Computer Engineering is excited to be a part of this initiative and looks forward to seeing MS and PSM students in the classroom.

Regards,

Kenneth Barner
Professor and Chair

UNIVERSITY OF DELAWARE

DEPARTMENT OF
CHEMICAL ENGINEERING
OFFICE OF THE CHAIRMAN

University of Delaware
Newark, Delaware 19716-3110
Ph: 302/831-8079 or 831-8155
Fax: 302/831-8201

October 14, 2009

To Whom It May Concern:

The Department of Chemical Engineering is pleased to support elective courses for the Professional Science Master's (PSM) degree programs in Bioinformatics and Computational Biology.

CHEG620 (Biochemical Engineering, 3 credits) is offered every year during the Spring semester. PSM students may utilize open seats in the class.

CHEG621 (Metabolic Engineering, 3 credits) is offered every year during the Spring semester. The course is available to PSM and other graduate/undergraduate students.

The Department of Chemical Engineering is excited to be a part of this initiative and looks forward to seeing PSM and other students in the classroom.

Sincerely,

Norman J. Wagner
Alvin B. and Julia O. Stiles Professor and Department Chairperson

UNIVERSITY OF DELAWARE

COLLEGE OF EARTH, OCEAN, AND ENVIRONMENT

SCHOOL OF MARINE SCIENCE AND POLICY
INTERIM DIRECTOR

University of Delaware
Hugh R. Sharp Campus
700 Pilottown Road
Lewes, DE 19958-1298 U.S.A
Ph: 302/645-4263
Fax: 302/645-4213
E-Mail: epi@udel.edu
URL: www.ceoe.udel.edu

October 12, 2009

Prof. Cathy Wu
Jefferson Chair in Bioinformatics
Director, Center for Bioinformatics and Computational Biology Department of Computer and Information Sciences

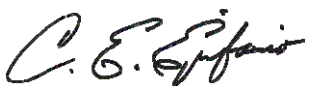
Dear Professor Wu:

The School of Marine Science and Policy is pleased to support core courses for the Professional Science Master's (PSM) and Master of Science degree programs and Graduate Certificate program in Bioinformatics and Computational Biology.

Prof. Adam Marsh, within the Marine Biosciences Program, has submitted two course proposals that will provide part of the core curriculum for the Life Sciences concentrations within each of these programs. These are MAST697: Bioinformatics Programming for Biologists and MAST698: Environmental and Systems Bioinformatics. MAST697 will serve as an entry point for biologists who have used bioinformatics tools that are seeking to acquire skills to customize these tools, collect them into pipelines and develop their own tools by developing basic proficiency in PERL, R, and Python languages that are commonly applied in bioinformatics. MAST698 will serve as an overview of bioinformatic analyses for "-omics" data: genomics, transcriptomics, and proteomics. The course will focus on the analysis of real world data sets so that students are exposed to realistic challenges in analyzing the staggering amounts of data produced by these techniques. Prof. Thomas Hanson will co-teach MAST698 with Prof. Marsh.

The School of Marine Science and Policy strongly supports this initiative. We expect that the courses above will be subscribed by not only Bioinformatics and Computational Biology students, but will also attract students from SMSP, particularly the Marine Biosciences Program, and other life science programs where students need to apply these techniques to their own research questions.

Sincerely,



Charles E. Epifanio, Director
School of Marine Science and Policy

UNIVERSITY OF DELAWARE

COLLEGE OF HEALTH SCIENCES

DEPARTMENT OF HEALTH, NUTRITION, AND EXERCISE SCIENCES

Carpenter Sports Building
University of Delaware
Newark, Delaware 19716-3750
Ph: 302/831-2265
Fax: 302/831-4261

October 16, 2009

Cathy H. Wu, Ph.D.
Edward G. Jefferson Professor of Bioinformatics & Computational Biology
Department of Computer & Information Sciences
Delaware Biotechnology Institute
University of Delaware
15 Innovation Way, Suite 205
Newark, DE 19711

Dear Professor Wu,

The Department of Health, Nutrition, and Exercise Sciences is pleased to support your proposal for the Masters Program in Bioinformatics and Computational Biology. Specifically, we will allow students in the program enrollments in elective courses HESC602, Data Analysis and Interpretation in Health Sciences, and HESC654, Medical Physiology. We wish you success with the program.

Sincerely,

Susan J. Hall

Susan J. Hall
Professor and Department Chair

PHYSICAL THERAPY

301 McKinly Laboratory
University of Delaware
Newark, Delaware 19716-2591
Ph: 302/831-8046
Fax: 302/831-4234

October 13, 2009

Cathy H. Wu, Ph.D.
Edward G. Jefferson Professor of Bioinformatics & Computational Biology
Department of Computer & Information Sciences
Delaware Biotechnology Institute
University of Delaware
15 Innovation Way, Suite 205
Newark, DE 19711

Dear Prof. Wu:

Welcome to the University of Delaware. The Department of Physical Therapy is very pleased to support your efforts in the development a new Master's program for in Bioinformatics and would welcome students from the program to take appropriate elective courses within the Department. As we discussed, we believe appropriate courses would include: PHYT633 -Applied Physiology II, PHYT623 – Clinical Neuroscience, and PHYT606 – Research.

The Department of Physical Therapy is excited to be a part of this initiative and looks forward to teaching students from this new program.

Sincerely,

Stuart Binder-Macleod

Stuart Binder-Macleod, PT, PhD, FAPTA
Edward L. Ratledge Professor and Chair
Department of Physical Therapy

LERNER COLLEGE OF BUSINESS & ECONOMICS

DEPARTMENT OF BUSINESS ADMINISTRATION

Dr. Rick L. Andrews
Deputy Dean, Lerner College of Business & Economics
Chair, Department of Business Administration
Professor of Marketing
Lerner College of Business & Economics
University of Delaware
Newark, DE 19716

Phone: (302) 831-1190
Fax: (302) 831-4196
Email: andrewsr@udel.edu
website: http://www.buec.udel.edu/andrews/

September 8, 2009

The Department of Business Administration is pleased to support breadth courses for Professional Science Master's (PSM) degree programs.

The Department has submitted a proposal for a new breadth course, BUAD500 (SURVEY OF BUSINESS). Starting Spring 2011, one section of the course will be offered every year. The course will be available to PSM and other graduate students across campus who are not matriculated in graduate programs in the Lerner College of Business & Economics.

BUAD840 (ETHICAL ISSUES IN DOMESTIC AND GLOBAL BUSINESS ENVIRONMENTS) is offered during Fall and Spring semesters. Three or four sections of the course are offered each year, and PSM may utilize open seats in existing classes.

BUAD870 (LEADERSHIP AND ORGANIZATIONAL BEHAVIOR) is offered during Fall and Spring semesters. At least four sections of the course are offered each year, and PSM may utilize open seats in existing classes.

BUAD835 (MANAGING NEW PRODUCT DEVELOPMENT PROJECTS), BUAD831 (OPERATIONS MANAGEMENT AND MANAGEMENT SCIENCE) and BUAD871 (MANAGING FOR CREATIVITY AND INNOVATION) are options among a set of five courses; demand for these courses can be spread to use seats in available sections. BUAD831 and BUAD871 are offered regularly, while BUAD835 will be offered less frequently (not more than once per year and perhaps not every year).

The Department of Business Administration is excited to be a part of this initiative and looks forward to seeing PSM and other students in the classroom.

Regards,

Rick Andrews

Dr. Rick L. Andrews

UNIVERSITY OF DELAWARE

ALFRED LERNER COLLEGE OF BUSINESS AND ECONOMICS

DEPARTMENT OF ACCOUNTING AND MANAGEMENT INFORMATION SYSTEMS

University of Delaware
Newark, Delaware 19716-2715
Ph: 302/831-2961
Fax: 302/831-4676

September 17, 2009

To: Dr. John E. Sawyer, Associate Provost for Professional Education
RE: PSM Degree Programs

Dear Dr. Sawyer,

The Department of Accounting and MIS is pleased to support the following two breadth courses for Professional Science Master's (PSM) degree programs:

- ENTR860 (HIGH TECH ENTERPRENEURSHIP) is offered during Spring semester. One section of the course is offered each year, and PSM may utilize open seats in existing classes.

- MISY840 (PROJECT MANAGEMENT AND COSTING) is offered during Spring semester. One section of the course is offered each year, and PSM may utilize open seats in existing classes.

The Department of Accounting and MIS is excited to be a part of this initiative and looks forward to seeing PSM and other students in the classroom.

Regards,

Dr. Guido L. Geerts
Chair, Department of Accounting and MIS
Lerner College of Business and Economics
Purnell Hall 226
Phone: 302-831-6413
E-mail: geertsg@lerner.udel.edu

UNIVERSITY OF DELAWARE

COLLEGE OF HUMAN SERVICES, EDUCATION & PUBLIC POLICY

SCHOOL OF URBAN AFFAIRS AND PUBLIC POLICY

Graham Hall
University of Delaware
Newark, Delaware 19716-7310
Ph: 302/831-1687
Fax: 302/831-3296
E-mail: SUAPP@UDEL.EDU
Internet: www.udel.edu/suapp

September 30, 2009

John E. Sawyer, Ph.D.
Associate Provost for Professional Education Office of Graduate and Professional Education &
Professor & Director - Organizational Effectiveness, Development, and Change
Department of Business Administration
Alfred Lerner College of Business & Economics
320 Lerner Hall
University of Delaware
Newark, DE 19716

Dear Professor Sawyer:

The faculty of the School of Urban Affairs and Public Policy voted unanimously to enthusiastically support the Professional Science Master's Program (PSM Plus). I have reviewed the proposal and this program requires a selection from the following courses in the Government/Non-Profit track—UAPP 803, UAPP835, UAPP604, UAPP819, UAPP833, UAPP827, UAPP829, UAPP646, UAPP648 and UAPP650. We will make these courses available to the PSM Plus students on semesters in which they offered.

I look forward to working with you on this major and on other collaborations in the future.

Regards,

Maria P. Aristigueta

Maria P. Aristigueta
Professor and Director
School of Urban Affairs and Public Policy

UNIVERSITY OF DELAWARE

OFFICE OF GRADUATE & PROFESSIONAL EDUCATION

ASSOCIATE PROVOST
PROFESSIONAL EDUCATION

University of Delaware
Newark, Delaware 19716-2710
Ph: 302-831-4377
Fax: 302-831-8745
E-mail: sawyerj@udel.edu

October 15, 2009

Cathy H. Wu, Ph.D.
Edward. G. Jefferson Chair
Professor, Computer & Information Sciences and
Professor, Biological Sciences
Delaware Biotechnology Institute
15 Innovation Way, Suite 205
University of Delaware
Newark, DE 19711

Dear Cathy,

We are pleased about the bioinformatics graduate programs you are proposing. The MS, Professional Science Master's (PSM) and Certificate provide an excellent array of options to meet a variety of student situations and motivations. These programs will also meet a critical need of idustry for trained professionals in our region.

I am especially excited about the Professional Science Master's (PSM) option. As you know, growing and enhancing graduate professional education is one of the milestones of the Path to Prominence. I believe that the PSM in Bioinformatics will be a key component of the University's portfolio of graduate professional education options, and fits very well with our industry, health care and government partnerships.

Sincerely,

John E. Sawyer, Ph.D.
Associate Provost for Professional Education

UNIVERSITY OF DELAWARE

COLLEGE OF ARTS AND SCIENCES

OFFICE OF THE DEAN

4 Kent Way
University of Delaware
Newark, Delaware 19716
Ph: 302/831-2793
Fax: 302/831-6398

November 20, 2009

Cathy H. Wu
Edward G. Jefferson Professor of Bioinformatics & Computational Biology
Department of Computer & Information Sciences
Delaware Biotechnology Institute
University of Delaware

Dear Professor Wu,

The College of Arts & Sciences is pleased to support your applications for three new graduate programs, the Master's of Science in Bioinformatics & Computational Biology, the Professional Science Master's in Bioinformatics, and the Graduate Certificate in Bioinformatics , each with two concentrations, in Computational Sciences Concentration and Life Sciences Concentration. Given the current courses that will taken by students in this program, and our plans to hire additional faculty in the areas of Bioinformatics and Computational Biology, we can provide the instructional capacity needed for this program. We have reviewed the business plan for the PSM program and believe that this can be a sustainable program, even with modest enrollments. The other programs do not require additional fixed costs beyond what we are investing in current programs, so that they should also be sustainable even if they generate no new revenue.

Programs such as these will provide important new educational options for students, serve local companies by offering training opportunities for their employees, make the region more attractive to prospective employers and residents, and enhance the prominence of the University. We strongly support this initiative.

Sincerely,

George Watson

George H. Watson
Interim Dean

UNIVERSITY OF DELAWARE

COLLEGE OF AGRICULTURE AND NATURAL RESOURCES

OFFICE OF THE DEAN

Townsend Hall
University of Delaware
Newark, Delaware 19716-2103
Ph: 302/831-2501
Fax: 302/831-6758

November 19, 2009

MEMORANDUM

TO: Dr. Cathy H. Wu
Edward G. Jefferson Chair of Bioinformatics & Computational Biology
Delaware Biotechnology Institute

FROM: Dr. Robin W. Morgan, Dean
College of Agriculture and Natural Resources

RE: **Master's program in Bioinformatics and Computational Biology**

The College of Agriculture and Natural Resources is pleased to support the Master's program in Bioinformatics and Computational Biology. You and your colleagues have assembled an impressive program application, and we enthusiastically endorse it.

The College of Agriculture and Natural Resources has invested in bioinformatics to the best of our ability over the past several years, and we are now excited to see this effort escalate. Our faculty who serve on the Bioinformatics Steering Committee and Graduate Committee will be encouraged to participate fully in these efforts, and we will earnestly make our courses that are core or elective courses in the curriculum available to as many students as possible.

This is a great opportunity for the University of Delaware, we look forward to the collaboration this new program offers in the life sciences, and we applaud the standard it sets for similar efforts in other disciplines.

College of Engineering
102 DuPont Hall
University of Delaware
Newark, Delaware 19716

November 19, 2009

Prof. Cathy Wu
Department of Computer & Information Sciences
University of Delaware
Newark, DE 19716

RE: Proposed Master's Program in Bioinformatics & Computational Biology

Dear Cathy,

I am very pleased to be able to provide the support of the College of Engineering for the proposed Master's degree programs—Master of Science in Bioinformatics & Computational Biology (BICB-MS), Professional Science Master's in Bioinformatics (BINF-PSM), and Graduate Certificate in Bioinformatics (BINF-CERT). You have put together an excellent proposal, and there is no doubt that these programs are of extremely high quality. I thank you for your efforts as these programs will be a great addition to our graduate degree offerings here at UD.

We look forward to supporting your efforts as the programs move forward.

Cordially,

Michael J. Chajes, Dean and Professor

UNIVERSITY OF DELAWARE

COLLEGE OF EARTH, OCEAN, AND ENVIRONMENT

OFFICE OF THE DEAN

111 Robinson Hall
University of Delaware
Newark, DE 19716-3501 U.S.A.
Ph: 302/831-2841
Fax: 302/831-4389
E-Mail: ntargett@udel.edu
URL: www.ceoe.udel.edu

21 November 2009

Professor Cathy Wu
Delaware Biotechnology Institute
University of Delaware
Newark, DE 19716

Dear Cathy,

I am pleased to strongly endorse the M.S. program that you propose in Bioinformatics and Computational Biology. You have put together a compelling rationale and a very thorough case in support of this new degree program. CEOE, through its relevant programs, is very pleased to be a participant.

Sincerely,

Nancy

Nancy M. Targett, Ph.D.
Dean