UNIVERSITY OF DELAWARE

DOCTOR OF PHILOSOPHY IN BIOINFORMATICS & SYSTEMS BIOLOGY

ACADEMIC PROGRAM APPLICATION

FEBRUARY 7, 2012

TABLE OF CONTENT

PART I UNIVERSITY FACULTY SENATE FORM 5

PART II RESOLUTION STATEMENT 12

PART III GRADUATE CATALOG LISTING 14

BIOINFORMATICS & SYSTEMS BIOLOGY 15

A. PROGRAM OVERVIEW 15

B. REQUIREMENTS FOR ADMISSION 15

C. OVERVIEW OF DEGREE REQUIREMENTS 16

PART IV PROPOSAL 20

I. DESCRIPTION 21

II. RATIONALE AND DEMAND 22
- A. Institutional Factors 23
  - A.1. Compatibility with University Academic Priorities 23
  - A.2. Planning Process 23
  - A.3. Significant Impact on Other University Programs 25
  - A.4. Utilization of Existing Resources 25
- B. Student Demand 26
  - B.1. Enrollment Projections 26
  - B.2. Needs of Student Clienteles 26
- C. Transferability 26
- D. Access to Graduate and Professional Programs 27
- E. Demand and Employment Factors 27
- F. Regional, State and National Factors 27
  - F.1. Comparable Courses of Study in the Region or State 27
  - F.2. External Requirements 28
- G. Other Strengths 28
  - G.1. Special Features 28
  - G.2. Collaborative Arrangements 29

III. ENROLLMENT, ADMISSIONS AND FINANCIAL AID 29
- A. Enrollment 29
- B. Admission Requirements 29
  - B.1. Selection Criteria 29
  - B.2. Change of Classification 31
  - B.3. Application Deadlines 31
- C. Student Expenses and Financial Aid 31
  - C.1. Student Expenses 31
  - C.2. Financial Aid 31

IV. CURRICULUM SPECIFICS 31
A. Institutional Factors 31
B. Curriculum Description 31
B.1. Degree Requirements 31
B.2. Curriculum 33

V. RESOURCES AVAILABLE 35
A. Learning Resources 35
B. Faculty/Administrative Resources 36
C. External Funding 36

VI. RESOURCES REQUIRED 36
A. Learning Resources 36
B. Personnel Resources 37
C. Budgetary Needs 37
C.1. Projected Expenses 37
C.2. Budget Plan 37

VII. IMPLEMENTATION AND EVALUATION 37
A. Implementation Plan 37
B. Assessment Plan 38
B.1. Program Objective 38
B.2. Curricular Map and Learning Outcomes 38
B.3. Assessment plan 40

VIII. APPENDIX I 41
Letters of Approval from Contributing Departments/Units 41

IX. APPENDIX II 42
Letters of Support from Deans of Participating Colleges 42

PART V PROGRAM POLICY STATEMENT 43

I. PROGRAM HISTORY 44
A. Rationale 44
B. Degrees Offered 45

II. ADMISSION 45
A. Admission Requirements 45
B. Application 47
B.1. Application Deadlines 47
B.2. Change of Classification 47
C. Admission Status 47

III. ACADEMIC 48
A. Degree Requirements 48
B. Course Curriculum 49
C. Committees and Director 52

C.1. Graduate Program Committee 52
C.2. Director 52
D. Satisfactory Progress 52
D.1. Faculty Advisor 52
D.2. Academic Load 53
D.3. Transferability 53
D.4. Dissertation 53
D.5. Grade Requirements 54
D.6. Consequences of Unsatisfactory Academic Progress 55
D.7. Standards of Student Conduct 55
D.8. Dismissal 55
D.9. Graduate Student Grievance Procedures 55
D.10. Attendance at Conferences and Professional Meetings 55

IV. FINANCIAL AID 55
A. Financial Awards 56
B. Continuation of Financial Aid 56

X. APPENDIX III 57
Course Descriptions 57

PART I

UNIVERSITY FACULTY SENATE FORM

Doctor of Philosophy in Bioinformatics and Systems Biology

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 Doctoral Program in Bioinformatics an and Systems Biology**
(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 12F
(use format 04F, 05W)

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

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

Proposed name: Doctor of Philosophy in Bioinformatics and Systems Biology
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")

BINF697: Systems Biology I: Experimental Techniques and Bioinformatics Analysis of Omics Data (3) * new course being developed
BINF698: Systems Biology II: Computational Modeling of Processes in Cells and Biological Systems (3) * new course being developed
BINF868: Research * new course listing
BINF964: Pre-Candidacy * new course listing
BINF969: Doctoral Dissertation * new course listing

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 Chemistry & Biochemistry
- Department of Mathematical Sciences
- Department of Physics

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

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

College of Earth, Ocean & Environment
- Marine Biosciences Program

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

The University of Delaware currently offers three graduate degree programs (MS-Master of Science, PSM-Professional Science Master's, and Graduate Certificate) in Bioinformatics and Computational Biology that are housed in Computer and Information Sciences and coordinated by the CBCB. These new degree programs have fostered collaborative research and education activities among many faculty with scientific expertise in bioinformatics and systems biology, who are dispersed throughout several Colleges and Departments across UD. The proposed Ph.D.

program will continue to build upon this foundation and further support cross disciplinary research and education. The rationales for the proposed Ph.D. in Bioinformatics and Systems Biology are:

- Bioinformatics and systems 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 capitalize on existing strengths of the University of Delaware and continue to build on the foundation provided by the current Master's programs in Bioinformatics and Computational Biology;
- An interdisciplinary Ph.D. program in Bioinformatics and Systems Biology will enhance graduate student recruitment and help to attract and retain talented faculty in various areas, including biological sciences, engineering, math and information technology;
- A cross-college Ph.D. program in Bioinformatics and Systems Biology will provide opportunities for interactions among researchers from diverse disciplines;
- The program will provide a foundation for educational funding and training grant opportunities;
- 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*."

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.)

PhD Program Course Requirements Summary

Degree Requirements (36 - 45 Credits)	
Core and Elective Courses (15 - 24 Credits)	
Bioinformatics and Systems Biology Core	9 Credits
Prerequisites (if required)	3-9 Credits
Electives	6 Credits
Seminar and Research (21 Credits)	
Seminar	6 Credits
Research	6 Credits
Doctoral Dissertation	9 Credits

Course Curriculum (36 -45 credits)		
Core (9)		
Bioinformatics (3) [select one]		ANFS644: Bioinformatics (3)
		CISC636: Bioinformatics (3)
Systems Biology (6)		BINF697/MAST698/ANFS667: Systems Biology I: Experimental Techniques and Bioinformatics Analysis of Omics Data (3)*
		BINF698/MATH660: Systems Biology II: Computational Modeling of Processes in Cells and Biological Systems (3)* [Or Systems Biology recommended elective upon approval**]
Prerequisites – if required (3-9)		
Introduction to Discipline (3) [select one]		BISC654 Biochemical Genetics (3)
		MAST697: Bioinformatics Programming for Biologists (3)
		PLSC636: Plant Genes and Genomes (3)
Database (3)		CISC637: Database Systems (3)
Biostatistics (3) [select one]		STAT613: Multivariate Statistical Methods with Biology Applications (3)
		STAT656: Biostatistics (3)
Electives (6)		
Recommended Electives	Bioinformatics	CISC841: Algorithms in Bioinformatics (3)
		CISC/BINF849: Computational Biomedicine (3)
	Systems Biology	CHEG621: Metabolic Engineering (3)
		CISC/BINF889: Modeling and Simulation of Biological Systems (3)
		ELEG671: Mathematical Physiology (3)
	Research Writing	EGGG867: Writing Academic Research in Engineering and Science (3)
		MAST607: Writing Papers in the Marine Sciences
ANFS670: Principles of Molecular Genetics (3)		
ANFS/PLSC671: Paradigms in Cell Signaling (3)		
BINF601: Protein Modifications: a Proteomics and Bioinformatics Approach (3)*		
BISC600: Biotechnology and Molecular Medicine (3)		
BISC602: Molecular Biology of Animal Cells (3)		
BISC612: Advanced Cell Biology (3)		
BISC615: Vertebrate Developmental Biology (3)		
BISC631: Practice of Science (3)		
BISC641: Microbial Ecology (3)		
BISC645: Bacterial Evolution (3)		
BISC656: Evolutionary Genetics (3)		
BISC665: Advanced Molecular Biology & Genetics (3)		
BISC671: Cellular and Molecular Immunology (3)		
BISC679: Virology (3)		
BISC682: Bacterial Pathogens: Molecular Mechanisms (3)		
BISC693: Human Genetics (3)		
BUAD840: Ethical Issues in Global Business Environments (3)		
CHEG620: Biochemical Engineering (3)		

CHEM624: Principles of Mass Spectrometry (3)
CHEM645: Protein Structure and Function (3)
CHEM646: DNA-Protein Interactions (3)
CHEM649: Molecular Biophysics (3)
CISC621: Algorithm Design and Analysis (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)
CPEG/ELEG657: Search and Data Mining (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)
MAST616: Methods in Molecular Biology (3)
MAST618: Marine Microbial Ecology (3)
MAST623: Physiology of Marine Organisms (3)
MAST625: Microbial Physiology and Diversity (3)
MAST634: Marine Molecular Sciences (3)
MATH607: Survey of Scientific Computing (3)
MATH611: Introduction to Numerical Analysis and Scientific Computing (3)
STAT608: Statistical Research Methods (3)
STAT615: Design and Analysis of Experiments (3)
STAT619: Time Series Analysis (3)
STAT670: Introduction to Statistical Analysis I (3)
STAT671: Introduction to Statistical Analysis II (3)
UAPP648: Environmental Ethics (3)
UAPP650: Values Ethics and Leadership (3)
Seminar (6)
BINF865: Seminar (1)***
Research (6)
BINF868: Research (1-5) - Until Successful Completion of preliminary exam****
BINF964: Pre-Candidacy (1-5) - Until Successful Completion of candidacy exam****
Doctoral Dissertation (9)
BINF969: Doctoral Dissertation****

* new course being developed, submitted for permanent status

** Substitution requires permission of dissertation committee and Graduate Program Director.

*** must enroll in every semester for the first three years and present one seminar in the second and third years

**** new course listing

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

PART II

RESOLUTION STATEMENT

PROVISIONAL APPROVAL OF NEW PROGRAMS -- RESOLUTION

DOCTOR OF PHILOSOPHY IN BIOINFORMATICS & SYSTEMS BIOLOGY

WHEREAS, the proposed *Doctor of Philosophy in Bioinformatics and Systems 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 program builds upon the research strength, education resources and bioinformatics infrastructure from Departments across the Colleges of Arts & Sciences, Engineering, Agriculture & Natural Resources, and Earth, Ocean & Environment, as well as from the Delaware Biotechnology Institute and the 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 *Doctor of Philosophy in Bioinformatics and Systems Biology*, effective June 1, 2012.

PART III

GRADUATE CATALOG LISTING

BIOINFORMATICS & SYSTEMS BIOLOGY

Telephone: (302) 831-0161
http://bioinformatics.udel.edu/Education

A. PROGRAM OVERVIEW

Bioinformatics and Systems Biology is an emerging and rapidly expanding field where biological, computational, and quantitative 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. Fundamental to modern day biological studies and key to the basic understanding of complex biological systems, bioinformatics & systems 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 and life sciences, and their interfaces.

The Ph.D. in Bioinformatics and Systems Biology is offered as a university-wide interdisciplinary graduate program with scientific curriculum that builds upon the research and educational strength from departments across the Colleges of Engineering (CoE), Arts & Sciences (CAS), Agriculture & Natural Resources (CANR), and Earth, Ocean & Environment (CEOE). The Center for Bioinformatics and Computational Biology (CBCB) administers the Ph.D. program in Bioinformatics and Systems Biology and coordinates with the individual Departments involved in the program.

The Ph.D. in Bioinformatics and Systems 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. Students will receive training in experimental, computational and mathematical disciplines through their coursework and research. Students who complete this degree will be able to generate and analyze experimental data for biomedical research as well as develop physical or computational models of the molecular components that drive the behavior of the biological system.

B. REQUIREMENTS FOR ADMISSION

The following are the admission requirements to the Ph.D. program in Bioinformatics and Systems Biology:

- A completed University of Delaware Graduate Studies application. Students may apply to the program prior to arranging a primary faculty advisor; however, all students in the program will need the agreement of a Program Faculty member to serve as the primary faculty advisor before admission into the program;
- 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;
- Official, up-to-date transcripts of all undergraduate and graduate programs;

- 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 if taken prior to August 1, 2011 or Quantitative: 151, Verbal + Quantitative: 307 if taken after August 1, 2011. 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. International applicants must have an official TOEFL score of at least 250 on computer-based or 100 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 7.5 overall with no individual sub-score below 6.0.
- Three letters of recommendation are required. At least one letter must be from a professor, 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 degree program?
    2. What are your long-term professional objectives?
    3. What specific attributes of the program make you feel that this degree is appropriate to help you achieve your professional objectives?

Applicants must, at the time of admission, have a Primary Faculty Advisor who has agreed to direct and advise a program of study. The Graduate Program Committee must approve all advisor selections. It is the expectation of the Committee that graduate advisors will have active research programs with funding at a level sufficient to support graduate student training.

Applicants will typically have an M.S. degree in related field. Direct admission to the Ph.D. program immediately after a B.S. degree will only be considered for exceptionally qualified candidates, as determined by the Graduate Program Committee. However, these candidates will have to complete an additional nine credit hours to fulfill course requirements associated with the Bioinformatics and Computational Biology M.S. curriculum.

C. OVERVIEW OF DEGREE REQUIREMENTS

Students must complete a minimum of 15 hours of coursework, plus 6 credit hours of seminar, 6 credit hours of research and 9 credit hours of doctoral dissertation. Students who are admitted directly after a B.S degree will be required to fulfill the Bioinformatics and Computational Biology M.S. core curriculum by completing an additional 9 credit hours as prerequisites (for a total of 24 coursework credits) in the following areas: Database Systems, Statistics, and Introduction to Discipline. In addition, if students entering the program with an M.S. degree are lacking equivalent prerequisites, they also will be required to complete courses in these three areas; however, these courses may fulfill the elective requirement in the Ph.D. program, if

approved in the program of study. Students must maintain a 3.0 cumulative GPA and courses with a grade of C or below will not be counted towards the degree.

PHD IN BIOINFORMATICS & SYSTEMS BIOLOGY

Credit Requirements:

A. Bioinformatics & Systems Biology Core……..……..... 9 Credits
B.Prerequisites……..……3-9 Credits
C. Electives...……...…….....……....6 Credits
D. Seminar ……..3 Credits
E. Research…..…… 6 Credits
F. Doctoral Dissertation.……..3 Credits
Total number of required credits: 36-45

A. Bioinformatics & Systems Biology Core (9 credits)

Bioinformatics (select one)
CISC636 Bioinformatics ……..... 3
ANFS644 Bioinformatics ……..... 3
Systems Biology
BINF697/MAST698/ANFS667: Systems Biology I: Experimental Techniques and Bioinformatics Analysis of Omics Data (3)……..…….. 3
BINF698/MATH660: Systems Biology II: Computational Modeling of Processes in Cells and Biological Systems*……...……..3
* Or Systems Biology recommended elective upon approval by dissertation committee and Graduate Program Director

B. Prerequisites – if required (3-9 credits)*

Introduction to Discipline (select one)
BISC 654 Biochemical Genetics……..…..… 3
MAST 697 Bioinformatics Programming for Biologists ……..……. 3
PLSC 636 Plant Genes and Genomes……..…….. 3
Database
CISC 637 Database Systems……..…..… 3
Biostatistics (select one)
STAT 613 Multivariate Statistical Methods with Biology Applications…….……..…..… 3
STAT 656 Biostatistics……..…..… 3
*****Necessary for students lacking equivalent courses

C. Electives (6 credits)

RECOMMENDED
Bioinformatics
CISC841: Algorithms in Bioinformatics ……..…….. 3
CISC/BINF849: Computational Biomedicine: Principles of Molecular Genetics ……. 3
Systems Biology
CHEG621: Metabolic Engineering ……...……..3
CISC/BINF889: Modeling and Simulation of Biological Systems ……..... 3
ELEG671: Mathematical Physiology...…..…….. 3
Research Writing

EGGG867: Writing Academic Research in Engineering and Science ……..……..3
MAST607: Writing Papers in the Marine Sciences ……... 3

OTHER ELECTIVE OPTIONS
ANFS670: Principles of Molecular Genetics ……..3
ANFS/PLSC671: Paradigms in Cell Signaling……..…….... 3
BINF601: Protein Modifications: a Proteomics and Bioinformatics Approach...…..……...3
BISC600: Biotechnology and Molecular Medicine..…….……..…3
BISC602: Molecular Biology of Animal Cells ..…….……3
BISC612: Advanced Cell Biology ……..……...…..……3
BISC615 Vertebrate Developmental Biology ……...…..…….……3
BISC631: Practice of Science ……...…… 3
BISC641: Microbial Ecology ……..……...…..…… 3
BISC645: Bacterial Evolution ……..……..…… 3
BISC656: Evolutionary Genetics ……...…..……3
BISC665: Advanced Molecular Biology & Genetics ……..3
BISC671: Cellular and Molecular Immunology ……...…..…… 3
BISC679: Virology ……...…… 3
BISC682: Bacterial Pathogens: Molecular Mechanisms ……...…..……3
BISC693: Human Genetics ……..…… 3
BUAD840: Ethical Issues in Global Business Environments …… 3
CHEG620: Biochemical Engineering ……...…..…… 3
CHEM624: Principles of Mass Spectrometry...…… 3
CHEM645: Protein Structure and Function……...…..…… 3
CHEM646: DNA-Protein Interactions…. …… 3
CHEM649: Molecular Biophysics.……...…..…… 3
CISC621: Algorithm Design and Analysis…… 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
CPEG/ELEG657: Search and Data Mining ……..……..……...…..……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
MAST616: Methods in Molecular Biology ……...……..…3
MAST618: Marine Microbial Ecology ……..……...…..……3
MAST623: Physiology of Marine Organisms ……..……... 3
MAST625: Microbial Physiology and Diversity...……...…..……..3
MAST634: Marine Molecular Sciences …… 3
MATH 607 Survey of Scientific Computing ……...…..…… 3
MATH 611 Introduction to Numerical Analysis and Scientific Computing ……..……3
STAT 608 Statistical Research Methods ……...…..……... 3

STAT 615 Design and Analysis of Experiments ……..…..……3
STAT 619 Time Series Analysis ……...……..… 3
STAT 670 Introduction to Statistical Analysis I ……...…..…….3
STAT 671 Introduction to Statistical Analysis II ……..……...…..…….. 3
STAT 621 Survival Analysis ……..……...…..……3
STAT 674 Applied Data Base Management……..…….. 3
UAPP648: Environmental Ethics ……..……...…..……. 3
UAPP650: Values Ethics and Leadership …….……. 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. Seminar (3 credits)
Seminar (3 Semesters)
BINF 865 Seminar ……..……..……...….... 1

E. Research (6 credits)
BINF868: Research (1-5) - Until Successful Completion of preliminary exam …….....… 1-6
BINF964: Pre-Candidacy (1-5) - Until Successful Completion of candidacy exam...…….....… 1-6

F. Doctoral Dissertation (9 credits)
BINF969: Doctoral Dissertation ……..…….....… 1-6

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 scale. 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 and Systems Biology is an emerging and rapidly expanding field where biological, computational, and quantitative disciplines converge. According to the National Institutes of Health, the working definitions of bioinformatics and systems 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.
- *Systems Biology*: A discipline at the intersection of biology, mathematics, engineering and the physical sciences that integrates experimental and computational approaches to study and understand biological processes in cells, tissues and organisms.

Fundamental to modern day biological studies and key to the basic understanding of complex biological systems, bioinformatics & systems 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 and life sciences, and their interfaces.

We propose to offer a *Ph.D. in Bioinformatics and Systems Biology* 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 Ph.D. program will build upon the successful foundation of the newly established (Fall 2010) Master's degree programs in Bioinformatics and Computational Biology and further strengthen bioinformatics and systems biology research at the University of Delaware.

A unique feature of this program is that students will receive training in experimental, computational and mathematical disciplines through their coursework and research, in contrast to other graduate programs with solely experimental or solely computational focus. Students who complete this degree will be able to generate and analyze experimental data for biomedical research as well as develop physical or computational models of the molecular components that drive the behavior of the biological system.

Due to the interdisciplinary nature of bioinformatics and systems biology, experts in these fields within the University of Delaware are housed in many Colleges and Departments on campus and may be in one of several engineering, math or life sciences disciplines. Therefore, the Ph.D. in

Bioinformatics and Systems Biology will be offered as a university-wide interdisciplinary graduate program that will attract students to many Departments across Colleges. The students will identify a Primary Faculty Advisor who will be responsible for defining the student's responsibilities and for evaluating the student's performance. The students will be housed in the Department associated with their Primary Advisor and the degree will be awarded by the College of residence.

The Center for Bioinformatics and Computational Biology (CBCB) will administer the Ph.D. program in Bioinformatics and Systems Biology and will coordinate with the individual Departments involved in the program. While this will be an interdisciplinary degree program offered to students within various Departments, students will be required to meet program specific requirements to be awarded the degree in Bioinformatics and Systems Biology.

The scientific curriculum will build upon the research and educational strength from departments across the Colleges of Engineering (CoE), Arts & Sciences (CAS), Agriculture & Natural Resources (CANR), and Earth, Ocean & Environment (CEOE), as well as the curriculum from the existing Master's program in Bioinformatics and Computational Biology. In addition, this new Ph.D. 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 offers three graduate degree programs (MS-Master of Science, PSM-Professional Science Master's, and Graduate Certificate) in Bioinformatics and Computational Biology that are housed in Computer and Information Sciences and coordinated by the CBCB. These new degree programs have fostered collaborative research and education activities among many faculty with scientific expertise in bioinformatics and systems biology, who are dispersed throughout several Colleges and Departments across UD. The proposed Ph.D. program will continue to build upon this foundation and further support cross disciplinary research and education. The rationales for the proposed Ph.D. in Bioinformatics and Systems Biology are:

- Bioinformatics and systems 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 capitalize on existing strengths of the University of Delaware and cfontinue to build on the foundation provided by the current Master's programs in Bioinformatics and Computational Biology;
- An interdisciplinary Ph.D. program in Bioinformatics and Systems Biology will enhance graduate student recruitment and help to attract and retain talented faculty in various areas, including biological sciences, engineering, math and information technology;

- A cross-college Ph.D. program in Bioinformatics and Systems Biology will provide opportunities for interactions among researchers from diverse disciplines;
- The program will provide a foundation for educational funding and training grant opportunities;
- 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*."

A. INSTITUTIONAL FACTORS

A.1. COMPATIBILITY WITH UNIVERSITY ACADEMIC PRIORITIES

A strong educational program in bioinformatics and systems 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. This included the successful launch of new graduate degrees (Master of Science, Professional Science Master, and Graduate Certificate) in Bioinformatics and Computational Biology in Fall 2010.

A Steering Committee was established in May 2011 to guide the development of the Ph.D. program in Bioinformatics & Systems Biology. The committee consists of faculty members from eleven Departments across four Colleges participating in this degree program, with broad expertise in genomics, proteomics, bioinformatics, quantitative biology and systems biology (Table 1). The committee meets monthly throughout the entire planning process to discuss all aspects of the program development.

Table 1. PhD Steering Committee

Member	College	Department	Expertise
Wu, Cathy (Chair)	Engineering/Arts & Sciences	Computer & Information Sciences/ Biological Sciences	Bioinformatics and Computational Biology
Antoniewicz, Maciek	Engineering	Chemical Engineering	Metabolic Engineering, Systems Biology
Bahnson, Brian	Arts & Sciences	Chemistry & Biochemistry	Structural Enzymology

Boyd, Fidelma	Arts & Sciences	Biological Sciences	Microbial Genomics
Green, Pamela	Agriculture & Natural Resources	Plant & Soil Sciences/ Marine Biosciences	Plant Genomics
Hanson, Thomas	Earth, Ocean & Environment	Marine Biosciences	Microbial Genomics
Lee, Kelvin	Engineering	Chemical Engineering	Systems Biology, Proteomics
Liao, Li	Engineering	Computer & Information Sciences	Bioinformatics and Computational Biology
Lyman, Edward	Arts & Sciences	Physics	Computational Biophysics
Marsh, Adam	Earth, Ocean & Environment	Marine Biosciences	Environmental Bioinformatics
Meyers, Blake	Agriculture & Natural Resources	Plant & Soil Sciences	Plant Genomics, Bioinformatics
Papoutsakis, Eleftherios	Engineering	Chemical Engineering	Systems Biology
Schleiniger, Gilberto	Arts & Sciences	Mathematical Sciences	Quantitative Biology BS Major, Mathematical Biology
Schmidt, Carl	Agriculture & Natural Resources	Animal & Food Sciences	Avian Genomics
Ilvento, Thomas	Agriculture & Natural Resources	Food & Resource Economics	Community Development
Usher, David	Arts & Sciences	Quantitative Biology BS	Quantitative Biology BS Major, Systems Biology
Wommack, Eric	Agriculture & Natural Resources	Plant & Soil Sciences	Viral Genomics
Zurakowski, Ryan	Engineering	Electrical & Computer Engineering	Biomedical Engineering

The Ph.D. steering committee selected a Graduate Program Committee in August 2011 to be responsible for the admission, advising, and progress assessment of the students in the Ph.D. program in Bioinformatics and Systems Biology. The committee consists of at least one representative faculty member from each participating College in this degree program (Table 2).

Table 2. Graduate Program Committee

Member	College	Department
Wu, Cathy (Chair)	Engineering/Arts & Sciences	Computer & Information Sciences/ Biological Science
Green, Pamela	Agriculture & Natural Resources	Plant & Soil Sciences/ Marine Biosciences
Hanson, Thomas	Earth, Ocean & Environment	Marine Biosciences
Boyd, Fidelma	Arts & Sciences	Biological Sciences
Papoutsakis, Eleftherios	Engineering	Chemical Engineering
Braun, Richard	Arts & Sciences	Mathematical Sciences
Schmidt, Carl	Agriculture & Natural Resources	Animal & Food Sciences
Zurakowski, Ryan	Engineering	Electrical & Computer Engineering

A.3. SIGNIFICANT IMPACT ON OTHER UNIVERSITY PROGRAMS

The positive impact of the proposed Ph.D. program in Bioinformatics and Systems 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;
- 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 systems 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 and research grants.

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 CBCB, the University of Delaware provides a rich environment for educational programs in bioinformatics and systems biology. The proposed Ph.D. program in Bioinformatics and Systems Biology will build upon the strength of existing resources.

There are many experts in the field of bioinformatics and systems biology at the University of Delaware, dispersed throughout several Colleges and Departments on campus. The CBCB will identify these researchers and invite them to be Program Faculty, which allows them to function as Primary or Secondary Faculty Advisors, participate on Dissertation Committees and serve on the Graduate Program Committee. Since students will be housed in the Department of their Primary Faculty Advisor, students in this program will contribute towards the statistics of their home Department and College.

The CBCB Director, Dr. Cathy Wu, will serve as the Program Director of this Ph.D. Program for the initial three-year term. The CBCB Education and Outreach Coordinator will provide administrative support to help manage day-to-day program activities.

The Ph.D. program in Bioinformatics and Systems Biology has the support from the Chairs of the eleven contributing Departments across four Colleges—encouraging faculty participation as Program Faculty, Primary or Secondary Faculty Advisor, or member of the Program Committee, as well as offering core courses and/or elective courses in the curriculum. The letters of approval from the Chair of the contributing Department are attached in Appendix I.

College of Arts & Sciences:
- Department of Biological Sciences
- Department of Chemistry & Biochemistry
- Department of Mathematical Sciences
- Department of Physics and Astronomy

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 Computer & Information Sciences
- Department of Electrical & Computer Engineering
- Department of Chemical Engineering

College of Earth, Ocean & Environment
- Marine Biosciences Program

B. STUDENT DEMAND

B.1. ENROLLMENT PROJECTIONS

We project that we will have a steady increase in new students entering the Ph.D. program and will reach 5 new students per year in the steady state. The student enrollment will primarily be capped by the number of graduate assistantships to be offered by participating Departments and Program Faculty, and scholarships that may be offered through grants and other sources of funding.

B.2. NEEDS OF STUDENT CLIENTELES

The Ph.D. program in Bioinformatics and Systems Biology will support students from different educational backgrounds and with different career aspirations. The students may come from various backgrounds, including life sciences, computational sciences, and engineering. The program offers both academic rigor, as well as flexibility, to meet the needs and interests of students and their primary faculty advisors. Upon completion of the graduate program, students will have a firm grasp of both the computational and life science aspects of bioinformatics and systems biology.

C. TRANSFERABILITY

Previous graduate level courses (a maximum of 9 credit hours) will be considered towards the completion of the Ph.D. requirements, subject to approval by the Graduate Program Committee. 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 Graduate Program Committee, (iii) are in accord with the Program Policy Statement of the Ph.D. program in Bioinformatics & Systems 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.

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.

D. Access to Graduate and Professional Programs

The graduates of the Ph.D. program in Bioinformatics and Systems Biology will have different career paths and students will complete the program prepared to pursue careers for research, education, or development in academia, business, industry, government agencies, or non-profit organizations.

E. Demand and Employment Factors

According to many accredited scientific and industry reviews, bioinformatics 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 it is projected to reach nearly $8.3 billion by 2014, reflecting bioinformatics' explosive growth.

Modern life science research is becoming increasingly dependent on quantitative sciences and this fundamental shift is requiring a new workforce of adequately trained scientists. Graduates of this Ph.D. program will learn how to apply computational and theoretical methods to biological problems, which will make them extremely competitive in the job market. Our close collaboration with regional Biosciences industry will provide opportunities for industry internship, career advising, as well as employment opportunities.

F. Regional, State and National Factors

According to the listing at the International Society for Computational Biology web site, there are presently over 50 bioinformatics-related Ph.D. programs worldwide, with over 40 in the United States alone. However, there are less than 20 Systems Biology Ph.D. programs in the United States and they are typically offered by top tiered research universities, such as Harvard University, UC San Diego, Stanford, Cornell, and MIT. Systems biology is an emerging discipline with tremendous room for growth. The University of Delaware is positioned to become a pioneer in this developing field by becoming part of the small but growing number of academic institutions that offer a Ph.D. program in Systems Biology.

F.1. Comparable Courses of Study in the Region or State

No other academic institution in the State of Delaware offers a Ph.D. program in Bioinformatics and Systems Biology, nor any related field. In the Delaware Valley region, there are only two graduate degree programs in Bioinformatics and 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.

This Ph.D. program in Bioinformatics and Systems Biology will emerge as a highly competitive educational opportunity based on: (i) a strong interdisciplinary curriculum (ii) proximity to major biotech and pharmaceutical industries, and (iii) rich opportunities for dissertation research projects.

F.2. External Requirements

There are no formal guidelines for a Ph.D. program in Bioinformatics and Systems Biology, nor are there accreditation standards. The proposed curriculum was designed based on a careful study of bioinformatics and systems biology related curricula offered by other institutions. We have closely examined offered programs at selected, prominent research universities, 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 have been successfully working together to develop and offer courses for the newly established Master's program in Bioinformatics and Computational Biology. This collaboration has continued to develop additional integrative courses for the Ph.D. in Bioinformatics and Systems Biology. In addition, faculty members from the various Departments are members of the Steering Committee and the Program Committee.

The University of Delaware has several faculty members with expertise in systems biology, included two new faculty members recruited from a recent bioinformatics cluster faculty search. Therefore, the University is in a remarkable and unique position to offer a robust program in systems biology.

Another feature of the program is its coordination through the Center for Bioinformatics and Computational Biology (CBCB), which provides extensive bioinformatics resources and capabilities at the Delaware Biotechnology Institute (DBI) and the Protein Information Resource (PIR). The CBCB 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 30 million hits per month from over 100,000 unique sites.

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 other than the availability of assistantships and/or scholarships. Enrollment is estimated at 5 new students per academic year in the steady state. Based on the entrance requirements and specified prerequisites, students may enroll in the 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 Ph.D. program in Bioinformatics and Systems Biology:

- A completed University of Delaware Graduate Studies application. Students may apply to the program prior to arranging a primary faculty advisor; however, all students in the program will need the agreement of a Program Faculty member to serve as the primary faculty advisor before admission into the program;
- 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;
- Official, up-to-date transcripts of all undergraduate and graduate programs;

- 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 if taken prior to August 1, 2011 or Quantitative: 151, Verbal + Quantitative: 307 if taken after August 1, 2011. 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. International applicants must have an official TOEFL score of at least 250 on computer-based or 100 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 7.5 overall with no individual sub-score below 6.0.
- Three letters of recommendation are required. At least one letter must be from a professor, 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 degree program?
    2. What are your long-term professional objectives?
    3. What specific attributes of the program make you feel that this degree is appropriate to help you achieve your professional objectives?

Applicants must, at the time of admission, have a Primary Faculty Advisor who has agreed to direct and advise a program of study. Once the Graduate Program Committee has determined that the applicant meets all admission requirements, the application will be circulated to the Program Faculty in an effort to identify any faculty that may be interested in serving as the student's Primary Faculty advisor. The student is also encouraged to directly contact any Program Faculty whose research is of interest to them. The Graduate Program Committee must approve all advisor selections. It is the expectation of the Committee that graduate advisors will have active research programs with funding at a level sufficient to support graduate student training. If a student's advisor is unable or unwilling to continue as advisor, it is the student's responsibility to identify a faculty member willing to be the new advisor. If a student is unable to identify a new Primary Faculty Advisor, the Graduate Program Committee will review the situation and may recommend to the Program Director that the student be dismissed from the program for failing to make satisfactory academic progress.

Applicants will typically have an M.S. degree in related field. Direct admission to the Ph.D. program immediately after a B.S. degree will only be considered for exceptionally qualified candidates, as determined by the Graduate Program Committee. However, these candidates will have to complete an additional nine credit hours to fulfill course requirements associated with the Bioinformatics and Computational Biology M.S. curriculum.

B.2. Change of Classification

Students currently matriculating in other graduate degree programs should complete a "Change of Classification Form" to seek approval to enter the Ph.D. program in Bioinformatics and Systems Biology. The Program 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. Complete applications received by February 15th for Fall admission and August 15th for Spring admission will have the best opportunity for admission. If space remains, we will continue to review complete applications received prior to April 15th for Fall admission and October 15th for Spring admission.

C. Student Expenses and Financial Aid

C.1. Student Expenses

The Ph.D. in Bioinformatics and Systems Biology does not require student expenses beyond the traditional fees, except for the availability of a personal computer or laptop.

C.2. Financial Aid

Financial assistance 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.

IV. Curriculum Specifics

A. Institutional Factors

Students who successfully complete the Ph.D. program in Bioinformatics and Systems Biology will be awarded the degree by the home College of the student's primary faculty advisor.

B. Curriculum Description

B.1. Degree Requirements

The student needs to establish a Dissertation Committee within the first year of study. The Committee should consist of at least four faculty members, including the primary faculty advisor, a secondary faculty advisor (in a complementary field to the primary advisor), a second faculty from the home Department, and one CBCB affiliate faculty outside the Departments of the primary and secondary advisors.

The development of a program of study will be the joint responsibility of the student in consultation with the primary advisor and it must be approved by the two faculty advisors (primary and secondary) and the Program Director by the end of the first year.

Students must complete a minimum of 15 hours of coursework, plus 6 credit hours of seminar, 6 credit hours of research and 9 credit hours of doctoral dissertation (summarized in Table 3). Students who are admitted directly after a B.S. degree will be required to fulfill the Bioinformatics and Computational Biology M.S. core curriculum by completing an additional 9 credit hours as prerequisites (for a total of 24 coursework credits) in the following areas: Database Systems, Statistics, and Introduction to Discipline. In addition, if students entering the program with an M.S. degree are lacking equivalent prerequisites, they also will be required to complete courses in these three areas; however, these courses may fulfill the elective requirement in the Ph.D. program, if approved in the program of study. Students must maintain a 3.0 cumulative GPA and courses with a grade of C or below will not be counted towards the degree.

Table 3. PhD Program Course Requirements Summary

Degree Requirements (36 - 45 Credits)	
Core and Elective Courses (15 - 24 Credits)	
Bioinformatics and Systems Biology Core	9 Credits
Electives	6 Credits
Prerequisites – if required	3-9 Credits
Seminar and Research (21 Credits)	
Seminar	6 Credits
Research	6 Credits
Doctoral Dissertation	9 Credits

The **preliminary examination** should be taken before the end of the fourth semester and will consist of a written exam in subjects based on the Bioinformatics and Systems Biology core. The student's primary advisor will chair the exam and the content will be determined by the Dissertation Committee. Each member of the Dissertation Committee will provide a single grade (pass, conditional pass or fail) and the final grades will be submitted to the Program Committee for final grade determination. A conditional pass may be appropriate if the committee felt that the student did not have an adequate background or understanding in one or more specific areas. The dissertation committee will communicate the conditional pass to the student and must provide the student with specific requirements and guidelines for completing the conditional pass. The student must inform the Dissertation Committee, the Graduate Program Director and Program Committee when these conditions have been completed. The Dissertation committee will then meet with the student to ensure all recommendations have been completed and whether a re-examination is necessary. If required, the re-examination will be done using the same format and prior to the beginning of the next academic semester. If the student still does not perform satisfactorily on this re-examination, he/she will then be recommended to the Graduate affairs committee for dismissal from the graduate program. Finally, the examining committee may find that a candidate lacks the skills or motivation to successfully complete a graduate program and

may then decide on failure without the possibility of reexamination and will recommend dismissal from the Ph.D. program.

The **candidacy examination** must be completed by the end of the third year. It requires a formal, detailed proposal be submitted to the Dissertation Committee and an oral defense of the student's proposed research project. Upon the recommendation of the Dissertation Committee, the student may be admitted to candidacy for the Ph.D. degree. The stipulations for admission to doctoral candidacy are that the student has (i) completed one academic years of full-time graduate study in residence at the University of Delaware, (ii) completed all required courses with the exception of BINF865 and BINF969, (iii) passed the preliminary exams, (iv) demonstrated the ability to perform research, and (5) had a research project accepted by the Dissertation Committee.

Students who need to complete prerequisite courses may request a deadline extension for the preliminary and subsequently the candidacy examination. Requests must be submitted to the Graduate Program Committee prior to the start of the third semester.

The **dissertation examination** of the Ph.D. program will involve the approval of the written dissertation and an oral defense of the candidate's dissertation. The written dissertation will be submitted to the Dissertation Committee and the CBCB office at least three weeks in advance of the oral defense date. The oral defense date will be publicly announced at least two weeks prior to the scheduled date. The oral presentation will be open to the public and all members of the Bioinformatics and Systems Biology program. The Dissertation Committee will approve the candidate's dissertation. The student and the primary faculty advisor will be responsible for making all corrections to the dissertation document and for meeting all Graduate School deadlines. A copy (electronic and printed hard copy) of the final completed dissertation should be provided to the CBCB and the degree-granting College.

B.2. CURRICULUM

The table below lists the course curriculum for the Ph.D. in Bioinformatics and Systems 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 2012 term.

Table 4. PhD Program Course Curriculum

Course Curriculum (36 -45 credits)		
Core (9)	Bioinformatics (3) [choose one]	ANFS644: Bioinformatics (3)
		CISC636: Bioinformatics (3)
	Systems Biology (6)	BINF697/MAST698/ANFS667: Systems Biology I: Experimental Techniques and Bioinformatics Analysis of Omics Data (3)*
		BINF698/MATH660: Systems Biology II: Computational Modeling of Processes in Cells and Biological Systems (3)* [Or Systems Biology recommended elective upon approval**]
Electives (6)		Select from Elective list (see Table 5)
Prerequisites	Introduction to	BISC654 Biochemical Genetics (3)

– if required (3-9)	Discipline (3) [choose one]	MAST697: Bioinformatics Programming for Biologists (3)
		PLSC636: Plant Genes and Genomes (3)
	Database (3)	CISC637: Database Systems (3)
	Biostatistics (3)	STAT613: Multivariate Statistical Methods with Biology Applications (3)
		STAT656: Biostatistics (3)
Seminar (6)		BINF865: Seminar (1)***
Research (6)		BINF868: Research (1-5) - Until Successful Completion of preliminary exam****
		BINF964: Pre-Candidacy (1-5) - Until Successful Completion of candidacy exam****
Doctoral Dissertation (9)		BINF969: Doctoral Dissertation****

* new course being developed, submitted for permanent status

** Substitution requires permission of dissertation committee and Graduate Program Director.

*** must enroll in every semester for the first three years and present one seminar in the second and third years

**** new course listing

Table 5. PhD Program Electives

Recommended Electives	
Bioinformatics	CISC841: Algorithms in Bioinformatics (3)
	CISC/BINF849: Computational Biomedicine (3)
Systems Biology	CHEG621: Metabolic Engineering (3)
	CISC/BINF889: Modeling and Simulation of Biological Systems (3)
	ELEG671: Mathematical Physiology (3)
Research Writing	EGGG867: Writing Academic Research in Engineering and Science (3)
	MAST607: Writing Papers in the Marine Sciences
Electives	
ANFS670: Principles of Molecular Genetics (3)	
ANFS/PLSC671: Paradigms in Cell Signaling (3)	
BINF601: Protein Modifications: a Proteomics and Bioinformatics Approach (3)*	
BISC600: Biotechnology and Molecular Medicine (3)	
BISC602: Molecular Biology of Animal Cells (3)	
BISC612: Advanced Cell Biology (3)	
BISC615 Vertebrate Developmental Biology (3)	
BISC631: Practice of Science (3)	
BISC641: Microbial Ecology (3)	
BISC645: Bacterial Evolution (3)	
BISC656: Evolutionary Genetics (3)	
BISC665: Advanced Molecular Biology & Genetics (3)	
BISC671: Cellular and Molecular Immunology (3)	
BISC679: Virology (3)	
BISC682: Bacterial Pathogens: Molecular Mechanisms (3)	
BISC693: Human Genetics (3)	
BUAD840: Ethical Issues in Global Business Environments (3)	
CHEG620: Biochemical Engineering (3)	
CHEM624: Principles of Mass Spectrometry (3)	

CHEM645: Protein Structure and Function (3)
CHEM646: DNA-Protein Interactions (3)
CHEM649: Molecular Biophysics (3)
CISC621: Algorithm Design and Analysis (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)
CPEG/ELEG657: Search and Data Mining (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)
MAST616: Methods in Molecular Biology (3)
MAST618: Marine Microbial Ecology (3)
MAST623: Physiology of Marine Organisms (3)
MAST625: Microbial Physiology and Diversity (3)
MAST634: Marine Molecular Sciences (3)
MATH607: Survey of Scientific Computing (3)
MATH611: Introduction to Numerical Analysis and Scientific Computing (3)
STAT608: Statistical Research Methods (3)
STAT615: Design and Analysis of Experiments (3)
STAT619: Time Series Analysis (3)
STAT670: Introduction to Statistical Analysis I (3)
STAT671: Introduction to Statistical Analysis II (3)
UAPP648: Environmental Ethics (3)
UAPP650: Values Ethics and Leadership (3)

* new course being developed, submitted for permanent status

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 Ph.D. program in Bioinformatics and Systems Biology, as it will extend from the previous courses in the participating Departments and build upon the bioinformatics infrastructure at the CBCB. The library's current holdings and subscriptions have covered major bioinformatics and systems biology journals (many are open-access) and are sufficient as instructional materials.

B. FACULTY/ADMINISTRATIVE RESOURCES

Faculty resources will be available to the Ph.D. program in Bioinformatics and Systems Biology for course offerings from the participating Departments. Faculty members may serve as course directors, course instructors, and/or research mentors (see letters of approval attached in Appendix I). 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.

The total enrollment each year from the Ph.D. program is projected at 5 students in the steady state. The demand from Bioinformatics and Systems Biology students can be absorbed by most existing classes and the newly developed core courses.

Additional faculty and administrative resources will be available from the CBCB, including (i) an Administrative Assistant for administrative assistance, (ii) an Education and Outreach Coordinator to assist in managing and coordinating the degree programs and educational activities, and (iii) research faculty and scientific staff at the CBCB to provide research infrastructure and core services in support of bioinformatics and systems biology research and education.

C. EXTERNAL FUNDING

The CBCB has received funding support from the Unidel Foundation and the UD administration for Center activities, including seminar series, training workshops and research symposiums, as well as key Center Personnel, including the Administrative Assistant, Education and Outreach Coordinator, and Bioinformatics Core Coordinator. The Education and Outreach Coordinator provides day-to-day management of the Master's program in Bioinformatics and Computational Biology and assists with student recruitment, admission, advising, progress assessment, and career planning. The Coordinator also will perform these duties for the Ph.D. program in Bioinformatics and Systems Biology.

Faculty affiliated with the Graduate Program in Bioinformatics and Systems Biology are active in research and will support graduate students from externally funded research.

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 Ph.D. program in Bioinformatics and Systems Biology, including personnel costs for program administration, annual costs for recruitment and marketing, materials and supplies, and educational program activities, will be absorbed by the CBCB as part of its business plan supported by the UD administration.

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.
The 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 Ph.D. program to increase the prestige of the program.

C.2. BUDGET PLAN

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 attract outstanding students to the program.

The proposed Ph.D. program in Bioinformatics and Systems Biology is fully endorsed by the Deans of the following participating Colleges and the Office of the Vice Provost for Graduate & Professional Education. 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
Office of the Vice Provost for Graduate & Professional Education

VII. IMPLEMENTATION AND EVALUATION

A. IMPLEMENTATION PLAN

The Ph.D. program in Bioinformatics and Systems Biology is planned for an official start in the Fall semester of 2012. The Program Committee will establish policies of their operation and for the program, and coordinate with 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 Ph.D. program in Bioinformatics and Systems 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.

B.2. CURRICULAR MAP AND LEARNING OUTCOMES

The Ph.D. program has five major curriculum components:

1. Science Core in Bioinformatics & Systems Biology
2. Science Electives in Bioinformatics & Systems Biology
3. Seminar
4. Research Methods
5. Dissertation

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

1. Core competency in Bioinformatics & Systems biology
2. Advanced knowledge of bioinformatics & systems biology and related disciplines
3. Ability to carry out independent, original research
4. Ability to use experimental, statistical and computational methods
5. Competence in written and oral scientific communication
6. Experience working with interdisciplinary teams, bridging life sciences and computational sciences
7. Ability to contribute effectively as an individual and as a team member in academia, industry and government

	Learning Outcomes						
Curriculum	Core competency in Bioinformatics and Systems Biology	Advanced knowledge of bioinformatics & related disciplines	Independent research experience	Ability to use experimental, statistical and computational methods	Competence in written and oral scientific communication	Experience working with interdisciplinary teams	Professional knowledge and skills
Science Core	x			x			
Science Electives		x		x			
Seminar		x			x	x	x
Research		x	x	x		x	x
Dissertation		x	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 & systems biology	Recruit high quality graduate students through faculty networks and leading researchers in the field.	Numbers, credentials 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 & systems biology (Science Core and Electives)	Faculty evaluation of student progress in course work; student's progress on schedule Survey of students in the program and post-graduation	Course work helped students secure initial employment; Students and graduates report applying knowledge from courses to work settings	Graduates enjoy long term success in academic or professional careers
Provide experiential training in research to prepare student for careers in bioinformatics and systems biology	Conduct cutting-edge research through mentored dissertation projects Lectures and discussions on specialized topics and cutting-edge developments (Seminar)	Survey of students focusing on their experiences; Survey 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 and internship mentors	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 Steering Committee and the Program 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 Ph.D. program in Bioinformatics and Systems Biology to their career.

VIII. APPENDIX I

LETTERS OF APPROVAL FROM CONTRIBUTING DEPARTMENTS/UNITS

College of Arts & Sciences

1. Dr. Randall Duncan, Chair, Department of Biological Sciences
2. Dr. John Pelesko, Chair, Department of Mathematical Sciences
3. Dr. Klaus Theopold, Chair, Department of Chemistry & Biochemistry
4. Dr. George Hadjipanayis, Department of Physics and Astronomy

College of Agriculture & Natural Resources

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

College of Engineering

8. Dr. Errol Lloyd, Chair, Department of Computer & Information Sciences
9. Dr. Kenneth Barner, Chair, Department of Electrical & Computer Engineering
10. Dr. Norman Wagner, Chair, Department of Chemical Engineering

College of Earth, Ocean & Environment

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

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 26, 2011

Cathy H. Wu, PhD
Edward G. Jefferson Chair and Director
Center for Bioinformatics & Computational Biology
Professor, Computer & Information Sciences and Biological Sciences
15 Innovation Way, Suite 205
Newark, DE 19711

Dear Dr. Wu,

The Department of Biological Sciences is pleased to support your application for a new Ph.D. program in Bioinformatics and Systems Biology. You and your colleagues have assembled an impressive program application, and we enthusiastically endorse it.

Our Department will support this new interdisciplinary Ph.D. program in a number of ways. Our faculty will be encouraged to participate fully in this program, including serving on the Graduate Program Committee, participating as a Program Faculty, functioning as a Primary or Secondary Faculty Advisor, and offering core and/or elective courses in the course curriculum. Furthermore, we welcome students from this new program to take graduate courses in Biological Sciences, which will serve as electives in your proposed Ph.D. program.

This is a great opportunity for the University of Delaware and we look forward to the collaboration this new program offers.

Best regards,

Randall L. Duncan

Professor and Chair

UNIVERSITY OF DELAWARE | Department of Mathematical Sciences

501 Ewing Hall
Newark, DE 19716-2553
Phone: 302-831-2653
Fax: 302-831-4511/4456

November 21, 2011

Cathy H. Wu, PhD
Edward G. Jefferson Chair and Director
Center for Bioinformatics & Computational Biology
Professor, Computer & Information Sciences and Biological Sciences
15 Innovation Way, Suite 205
Newark, DE 19711

Dear Dr. Wu,

The Department of Mathematical Sciences is pleased to support your application for a new Ph.D. program in Bioinformatics and Systems Biology. You and your colleagues have assembled an impressive program application, and we enthusiastically endorse it.

Our Department will support this new interdisciplinary Ph.D. program in a number of ways. Our faculty will be encouraged to participate in this program, including serving on the Graduate Program Committee, participating as a Program Faculty, functioning as a Primary or Secondary Faculty Advisor, and offering core and/or elective courses in the course curriculum.

This is a great opportunity for the University of Delaware and we look forward to the collaboration this new program offers.

Sincerely,

John Pelesko
Professor and Chair
Department of Mathematical Sciences

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

November 28, 2011

Cathy H. Wu, PhD
Edward G. Jefferson Chair and Director
Center for Bioinformatics & Computational Biology
Professor, Computer & Information Sciences and Biological Sciences
15 Innovation Way, Suite 205
Newark, DE 19711

Dear Dr. Wu,

The Department of Chemistry and Biochemistry supports your application for a new Ph.D. program in Bioinformatics and Systems Biology. You and your colleagues have assembled a compelling program application, and we are pleased to endorse it.

Our Department will support this new interdisciplinary Ph.D. program in a number of ways. Our faculty will be encouraged to participate in the program, including serving on the Graduate Program Committee, participating as a program faculty member, functioning as a primary or secondary faculty advisor, and having our graduate courses open to this new Ph.D. program to serve as either core or elective courses in the course curriculum.

This is a great opportunity for the University of Delaware and we look forward to the collaboration this new program offers.

With best regards,

Klaus H. Theopold
Professor and Chair

e-mail: theopold@udel.edu

UNIVERSITY OF DELAWARE | Department of Physics & Astronomy

104 The Green
217 Sharp Lab
Newark, DE 19716-2570
Phone: 302-831-2661
Fax: 302-831-1637

November 7, 2011

Cathy H. Wu, PhD
Edward G. Jefferson Chair and Director
Center for Bioinformatics & Computational Biology
Professor, Computer & Information Sciences and Biological Sciences
15 Innovation Way, Suite 205
Newark, DE 19711

Dear Dr. Wu,

The Department of Physics and Astronomy is pleased to support your application for a new Ph.D. program in Bioinformatics and Systems Biology. You and your colleagues have assembled an impressive program application, and we enthusiastically endorse it.

Our Department will support this new interdisciplinary Ph.D. program in a number of ways. Our faculty will be encouraged to participate in this program, including serving on the Graduate Program Committee, participating as a Program Faculty, functioning as a Primary or Secondary Faculty Advisor, and offering core and/or elective courses in the course curriculum.

This is a great opportunity for the University of Delaware and we look forward to the collaboration this new program offers.

Sincerely,

George Hadjipanayis

George C. Hadjipanayis
RB Murray Professor and Chair
Physics and Astronomy

UNIVERSITY OF DELAWARE | College of Agriculture & Natural Resources
DEPARTMENT OF ANIMAL & FOOD SCIENCES

531 South College Avenue
44 Townsend Hall
Newark, DE 19716-2150
Phone: 302-831-2524

November 28, 2011

Cathy H. Wu, PhD
Edward G. Jefferson Chair and Director
Center for Bioinformatics & Computational Biology
Professor, Computer & Information Sciences and Biological Sciences
15 Innovation Way, Suite 205
Newark, DE 19711

Dr. Wu,

The Department of Animal and Food Sciences is pleased to support your application for a new Ph.D. program in Bioinformatics and Systems Biology. You and your colleagues have assembled an impressive program application, and we enthusiastically endorse it.

Our Department will support this new interdisciplinary Ph.D. program in a number of ways. Our faculty will be encouraged to participate in this program, including serving on the Graduate Program Committee, participating as a Program Faculty, functioning as a Primary or Secondary Faculty Advisor, and offering core and/or elective courses in the course curriculum.

We also look forward to providing highly qualified students to the program.

This is a great opportunity for the University of Delaware and we look forward to the collaboration this new program offers.

Sincerely,

Jack Gelb, Jr. Ph.D.
Professor and Department Chair

Mark S. Parcells, Ph.D.
Professor and Graduate Program Chair

c. Dr. Carl Schmidt

UNIVERSITY OF DELAWARE

COLLEGE OF AGRICULTURE AND NATURAL RESOURCES

DEPARTMENT OF FOOD AND RESOURCE ECONOMICS

213 Townsend Hall
University of Delaware
Newark, Delaware 19716-2130
Ph: 302-831-2511
Fax: 302-831-6243

November 10, 2011.

Cathy H. Wu, PhD
Edward G. Jefferson Chair and Director
Center for Bioinformatics & Computational Biology
Professor, Computer & Information Sciences and Biological Sciences
15 Innovation Way, Suite 205
Newark, DE 19711

Dear Dr. Wu,

The Department of Food and Resource Economics is pleased to support your application for a new Ph.D. program in Bioinformatics and Systems Biology. You and your colleagues have assembled an impressive program application, and we enthusiastically endorse it.

As the home of the statistics program at the University of Delaware, our Department will support this new interdisciplinary Ph.D. program in a number of ways. Our faculty will be encouraged to participate in this program, including serving on the Graduate Program Committee, participating as a Program Faculty, functioning as a Primary or Secondary Faculty Advisor, and offering core and/or elective courses in the course curriculum.

This is a great opportunity for the University of Delaware and we look forward to the collaboration this new program offers.

Sincerely,

Titus O. Awokuse
Professor and Chair

UNIVERSITY OF DELAWARE
College of Agriculture & Natural Resources
DEPARTMENT OF PLANT & SOIL SCIENCES

Dr. Blake C. Meyers
Edward F. and Elizabeth
Goodman Rosenberg Professor
Chair of Department
153 Townsend Hall
Newark, DE 19716-2170
Phone: (302) 831-3418
Email: meyers@dbi.udel.edu

October 24, 2011

Cathy H. Wu, PhD
Edward G. Jefferson Chair and Director
Center for Bioinformatics & Computational Biology
Professor, Computer & Information Sciences and Biological Sciences
15 Innovation Way, Suite 205
Newark, DE 19711

Dear Dr. Wu,

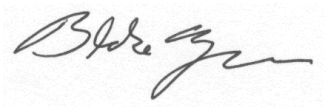
As chair of the Department of Plant & Soil Sciences, I am pleased to endorse your application for a new Ph.D. program in Bioinformatics and Systems Biology. You and your colleagues have assembled an impressive program application, and I strongly support this planned new graduate program.

Our Department will support this new interdisciplinary Ph.D. program in a number of ways. Our faculty will be encouraged to participate in this program, including serving on the Graduate Program Committee, participating as a Program Faculty, functioning as a Primary or Secondary Faculty Advisor, and offering core and/or elective courses in the course curriculum.

This is a great opportunity for the University of Delaware and we look forward to the collaboration this new program offers.

Sincerely,

Sincerely,



Blake C. Meyers, Ph.D.
Professor & Chair

UNIVERSITY OF DELAWARE
College of Engineering
DEPARTMENT OF COMPUTER AND INFORMATION SCIENCES

December 6, 2011

Professor Cathy Wu

Re: Proposal for a PhD in Bioinformatics and Systems Biology

Dear Cathy,

It is with pleasure that I write in strong support of the proposed PhD program in Bioinformatics and System Biology. As you know bioinformatics is an important research area in computer science generally and for the CIS department. The PhD program that you are proposing will be an excellent complement to both your MS degree and to the PhD in computer science. Having a PhD specifically in Bioinformatics and System Biology will allow students to seamlessly combine work that is both computational and biological.

The support from the CIS Department for this program is provided in three ways:

- Several CIS faculty are already involved in the planning for this program (Liao, Shatkay and of course yourself). They and others are excited about the possibility of taking on PhD students from the program.

- The CIS Department is committed to having our faculty regularly teaching CISC636 (Bioinformatics) and CISC637 (Database Systems), as well as various 800-level seminar courses devoted to topics of interest to students in your program. We see these courses as attracting students from both the proposed program and from CIS. Unfortunately, due to our tight staffing issues, for the foreseeable future we will not be able to provide CIS faculty, other than yourself, to teach BINF courses.

- The CIS faculty voted to endorse and approve your proposal by a unanimous vote at a department faculty meeting on December 5, 2011.

In conclusion, you have the complete support of the CIS Department for this new and important PhD program, and we look forward to it being a resounding success!

Sincerely,

Errol L. Lloyd
Professor and Chair

101 Smith Hall | Newark, DE 19716-2586 | Ph: 302/831-2712 | Fax: 302/831-8458 | www.cis.udel.edu

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

October 26, 2011

Cathy H. Wu, PhD
Edward G. Jefferson Chair and Director
Center for Bioinformatics & Computational Biology
Professor, Computer & Information Sciences and Biological Sciences
15 Innovation Way, Suite 205
Newark, DE 19711

Dear Dr. Wu,

The Department of Computer & Electrical Engineering is pleased to support your application for a new Ph.D. program in Bioinformatics and Systems Biology. You and your colleagues have assembled an impressive program application, and we enthusiastically endorse it.

Our Department will support this new interdisciplinary Ph.D. program in a number of ways. Our faculty will be encouraged to participate in this program, including serving on the Graduate Program Committee, participating as a Program Faculty, functioning as a Primary or Secondary Faculty Advisor, and offering core and/or elective courses in the course curriculum.

This is a great opportunity for the University of Delaware and we look forward to the collaboration this new program offers.

Sincerely,

Kenneth E. Barner
Professor & Chair

UNIVERSITY OF DELAWARE | Department of Chemical Engineering
OFFICE OF THE CHAIRMAN

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

October 31, 2011

Cathy H. Wu, PhD
Edward G. Jefferson Chair and Director
Center for Bioinformatics & Computational Biology
Professor, Computer & Information Sciences and Biological Sciences
15 Innovation Way, Suite 205
Newark, DE 19711

Dear Dr. Wu,

The Department of Chemical Engineering is pleased to support your application for a new Ph.D. program in Bioinformatics and Systems Biology. You and your colleagues have assembled an impressive program application, and we enthusiastically endorse it.

Our Department will support this new interdisciplinary Ph.D. program in a number of ways. Our faculty will be encouraged to participate in this program, including serving on the Graduate Program Committee, participating as Program Faculty, functioning as a Primary or Secondary Faculty Advisor, and offering core and/or elective courses in the course curriculum.

This is a great opportunity for the University of Delaware and we look forward to the collaboration this new program offers.

Sincerely,

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

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

November 3, 2011

Cathy H. Wu, PhD
Edward G. Jefferson Chair
Director, Center for Bioinformatics & Computational Biology
Professor, Computer & Information Sciences and Biological Sciences
15 Innovation Way, Suite 205
Newark, DE 19711

Dear Dr. Wu:

The School of Marine Science and Policy is pleased to support your application for a new Ph.D. program in Bioinformatics and Systems Biology. You and your colleagues have assembled an impressive program application, and we enthusiastically endorse it.

Our School will support this new interdisciplinary Ph.D. program in a number of ways. Specifically, SMSP faculty who join your program will:

- serve on program committees
- serve as advisors for students in the program
- teach both core and elective courses for your program with the understanding that teaching requirements within the SMSP have first priority.

In terms of courses, SMSP faculty (currently Hanson and Marsh) will directly contribute a module to the planned Systems Biology I core course and we will support cross-listing of this course with an MAST designation. In addition, students from your program will be welcome to enroll in the following courses as electives in your curriculum plan:

MAST616: Methods in Molecular Biology
MAST618: Marine Microbial Ecology
MAST623: Physiology of Marine Organisms
MAST625: Microbial Physiology and Diversity
MAST634: Marine Molecular Sciences

Finally, students enrolled through SMSP who pursue this degree program and meet the requirements will be eligible for TA and fellowship support following our established policies for distributing these resources.

This is a great opportunity for the University of Delaware, and we look forward to the collaboration this new program offers.

Sincerely,

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

IX. APPENDIX II

LETTERS OF SUPPORT FROM DEANS OF PARTICIPATING COLLEGES

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

UNIVERSITY OF DELAWARE | College of Arts & Sciences
OFFICE OF THE DEAN

4 Kent Way
Newark, DE 19716
Phone: 302-831-2793
Fax: 302-831-6398

January 23, 2012

Cathy H. Wu, PhD
Edward G. Jefferson Chair and Director
Center for Bioinformatics & Computational Biology
Professor, Computer & Information Sciences and Biological Sciences
15 Innovation Way, Suite 205
Newark, DE 19711

Dear Dr. Wu,

The College of Arts & Sciences is pleased to support your application for a new interdisciplinary Ph.D. program in Bioinformatics and Systems Biology. As we have worked with you since your arrival at Delaware, we are well aware of your successes in developing the Masters and PSM programs in Bioinformatics.

As expected, you have assembled a very strong application for the Ph.D. program. I am pleased to endorse it, with enthusiasm. The proposed program provides training in a rapidly growing interdisciplinary area that is central to the future of life sciences research. It builds upon the existing research strength and established bioinformatics infrastructure, and will foster new collaborations at the University of Delaware.

This is a great opportunity for the University of Delaware to establish a nationally prominent graduate program, with great potential to attract excellent students. We wish you the best in launching this new degree program.

Sincerely,

George H. Watson
Dean

UNIVERSITY OF DELAWARE
College of Agriculture & Natural Resources
OFFICE OF THE DEAN

113 Townsend Hall
531 South College Avenue
Newark, DE 19716-2103
Phone: 302-831-2501
Fax: 302-831-6758

December 5, 2011

Cathy H. Wu, Ph.D.
Edward G. Jefferson Chair of Bioinformatics & Computational Biology
Delaware Biotechnology Institute
University of Delaware
15 Innovation Way, Suite 205
Newark, DE 19711-5449

Dear Dr. Wu:

The College of Agriculture and Natural Resources at the University of Delaware enthusiastically endorses and supports the development of a new Ph.D. program in Bioinformatics and Systems Biology. This program will provide a great opportunity for collaboration across many disciplines at the University of Delaware.

The faculty members of the College of Agriculture and Natural Resources are proud to be a key component of this new Ph.D. program. We look forward to participating in its curriculum and future development as we "Dare to be first" in quality education at the University of Delaware.

Sincerely,

Robin W. Morgan
Dean

UNIVERSITY OF DELAWARE | College of Engineering
OFFICE OF THE DEAN

102 du Pont Hall
Newark, DE 19716-3101
Phone: 302-831-2401
Fax: 302-831-8179

December 7, 2011

Cathy H. Wu, PhD
Edward G. Jefferson Chair and Director
Center for Bioinformatics & Computational Biology
Professor, Computer & Information Sciences and Biological Sciences
15 Innovation Way, Suite 205
Newark, DE 19711

Dear Dr. Wu,

The College of Engineering is pleased to support your application for a new interdisciplinary Ph.D. program in Bioinformatics and Systems Biology. You and your colleagues have assembled an impressive program application, and we enthusiastically endorse it.

The proposed program represents an essential area to 21st life science research. It builds upon the existing research strengths and bioinformatics infrastructure at the University of Delaware and has the potential to attract excellent students.

This is a great opportunity for the University of Delaware and we look forward to the interdisciplinary collaboration this new program offers.

Sincerely,

Babatunde A. Ogunnaike, Ph.D.
William L. Friend Chaired Professor and
Interim Dean

UNIVERSITY OF DELAWARE | College of Earth, Ocean, & Environment
OFFICE OF THE DEAN

111 Robinson Hall
Newark, DE 19716-3501 U.S.A.
Phone: 302-831-2841
Fax: 302-831-4389
Email: ntargett@udel.edu

December 9, 2011

Dr. Cathy H. Wu
Edward G. Jefferson Chair of
Bioinformatics and Computational Biology
Delaware Biotechnology Institute
University of Delaware

Dear Dr. Wu,

It was a pleasure to review the proposal for the Ph.D. in **Bioinformatics and Systems Biology** that you and your cross-college UD colleagues have assembled. I am pleased to see that faculty in the CEOE School of Marine Science and Policy (Marine Biosciences Program) are planning to actively participate in this new graduate degree. Clearly this effort, which includes faculty from four of the seven colleges, is aligned with the strategic goals of the institution, particularly those that seek greater cross college engagement and innovative graduate educational opportunities.

I am pleased to lend my enthusiastic endorsement to this degree program.

Sincerely,

Nancy M. Targett

Nancy Targett
Dean, College of Earth, Ocean, and Environment

PART V

PROGRAM POLICY

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 scale. 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 and Systems Biology is an emerging and rapidly expanding field where biological, computational, and quantitative disciplines converge. According to the National Institutes of Health, the working definitions of bioinformatics and systems 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.
- *Systems Biology*: A discipline at the intersection of biology, mathematics, engineering and the physical sciences that integrates experimental and computational approaches to study and understand biological processes in cells, tissues and organisms.

Fundamental to modern day biological studies and key to the basic understanding of complex biological systems, bioinformatics & systems 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 and life sciences, and their interfaces.

We propose to offer a *Ph.D. in Bioinformatics and Systems Biology* 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 Ph.D. program will build upon the successful foundation of the newly established (Fall 2010) Master's degree programs in Bioinformatics and Computational Biology and further strengthen bioinformatics and systems biology research at the University of Delaware.

A unique feature of this program is that students will receive training in experimental, computational and mathematical disciplines through their coursework and research, in contrast to other graduate programs with solely experimental or solely computational focus. Students who complete this degree will be able to generate and analyze experimental data for biomedical research as well as develop physical or computational models of the molecular components that drive the behavior of the biological system.

Due to the interdisciplinary nature of bioinformatics and systems biology, experts in these fields within the University of Delaware are housed in many Colleges and Departments on campus and may be in one of several engineering, math or life sciences disciplines. Therefore, the Ph.D. in Bioinformatics and Systems Biology will be offered as a university-wide interdisciplinary graduate program that will attract students to many Departments across Colleges. The students will identify a Primary Faculty Advisor who will be responsible for defining the student's responsibilities and for evaluating the student's performance. The students will be housed in the Department associated with their Primary Advisor and the degree will be awarded by the College of residence.

The Center for Bioinformatics and Computational Biology (CBCB) will administer the Ph.D. program in Bioinformatics and Systems Biology and will coordinate with the individual Departments involved in the program. While this will be an interdisciplinary degree program offered to students within various Departments, students will be required to meet program specific requirements to be awarded the degree in Bioinformatics and Systems Biology.

The scientific curriculum will build upon the research and educational strength from departments across the Colleges of Engineering (CoE), Arts & Sciences (CAS), Agriculture & Natural Resources (CANR), and Earth, Ocean & Environment (CEOE), as well as the curriculum from the existing Master's program in Bioinformatics and Computational Biology. In addition, this new Ph.D. 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*.

B. DEGREES OFFERED

One degree is proposed: a Ph.D. in Bioinformatics and Systems Biology. Students will complete course requirements and carry out research related to Bioinformatics and Systems Biology. The Ph.D. program 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).

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 Ph.D. program in Bioinformatics and Systems Biology:

- A completed University of Delaware Graduate Studies application. Students may apply to the program prior to arranging a primary faculty advisor; however, all students in the program will need the agreement of a Program Faculty member to serve as the primary faculty advisor before admission into the program;
- 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;
- Official, up-to-date transcripts of all undergraduate and graduate programs;
- 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 if taken prior to August 1, 2011 or Quantitative: 151, Verbal + Quantitative: 307 if taken after August 1, 2011. 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. International applicants must have an official TOEFL score of at least 250 on computer-based, or 100 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 7.5 overall with no individual sub-score below 6.0.
- Three letters of recommendation are required. At least one letter must be from a professor, 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 degree program?
    2. What are your long-term professional objectives?
    3. What specific attributes of the program make you feel that this degree is appropriate to help you achieve your professional objectives?

Applicants must, at the time of admission, have a Primary Faculty Advisor who has agreed to direct and advise a program of study. Once the Graduate Program Committee has determined that the applicant meets all admission requirements, the application will be circulated to the Program Faculty in an effort to identify any faculty that may be interested in serving as the student's Primary Faculty advisor. The student is also encouraged to directly contact any Program Faculty whose research is of interest to them. The Graduate Program Committee must approve all advisor selections. It is the expectation of the Committee that graduate advisors will have active research programs with funding at a level sufficient to support graduate student training. If a student's advisor is unable or unwilling to continue as advisor, it is the student's responsibility to identify a faculty member willing to be the new advisor. If a student is unable to identify a new Primary Faculty Advisor, the Graduate Program Committee will review the situation and may recommend to the Program Director that the student be dismissed from the program for failing to make satisfactory academic progress.

Applicants will typically have an M.S. degree in related field. Direct admission to the Ph.D. program immediately after a B.S. degree will only be considered for exceptionally qualified candidates, as determined by the Graduate Program Committee. However, these candidates will have to complete an additional nine credit hours to fulfill course requirements associated with the Bioinformatics and Computational Biology M.S. curriculum.

B. APPLICATION

B.1. APPLICATION DEADLINES

Admission decisions are made on a rolling basis as and when applications are complete. Complete applications received by February 15th for Fall admission and August 15th for Spring admission will have the best opportunity for admission. If space remains, we will continue to review complete applications received prior to April 15th for Fall admission and October 15th for Spring admission.

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's 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's 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

The student needs to establish a Dissertation Committee within the first year of study. The Committee should consist of at least four faculty members, including the primary faculty advisor, a secondary faculty advisor (in a complementary field to the primary advisor), a second faculty from the home Department, and one CBCB affiliate faculty outside the Departments of the primary and secondary advisors.

The development of a program of study will be the joint responsibility of the student in consultation with the primary advisor and it must be approved by the two faculty advisors (primary and secondary) and the Program Director by the end of the first year.

Students must complete a minimum of 15 hours of coursework, plus 6 credit hours of seminar, 6 credit hours of research and 9 credit hours of doctoral dissertation (summarized in Table 6). Students who are admitted directly after a B.S. degree will be required to fulfill the Bioinformatics and Computational Biology M.S. core curriculum by completing an additional 9 credit hours as prerequisites (for a total of 24 coursework credits) in the following areas: Database Systems, Statistics, and Introduction to Discipline. In addition, if students entering the program with an M.S. degree are lacking equivalent prerequisites, they also will be required to complete courses in these three areas; however, these courses may fulfill the elective requirement in the Ph.D. program, if approved in the program of study. Students must maintain a 3.0 cumulative GPA and courses with a grade of C or below will not be counted towards the degree.

Table 6. PhD Program Course Requirements Summary

Degree Requirements (36 - 45 Credits)	
Core and Elective Courses (15 - 24 Credits)	
Bioinformatics and Systems Biology Core	9 Credits
Prerequisites – if needed	3-9 Credits
Electives	6 Credits
Seminar and Research (21 Credits)	
Seminar	6 Credits
Research	6 Credits
Doctoral Dissertation	9 Credits

The **preliminary examination** should be taken before the end of the fourth semester and will consist of a written exam in subjects based on the Bioinformatics and Systems Biology core. The student's primary advisor will chair the exam and the content will be determined by the Dissertation Committee. Each member of the Dissertation Committee will provide a single grade (pass, conditional pass or fail) and the final grades will be submitted to the Program Committee for final grade determination. A conditional pass may be appropriate if the committee felt that

the student did not have an adequate background or understanding in one or more specific areas. The dissertation committee will communicate the conditional pass to the student and must provide the student with specific requirements and guidelines for completing the conditional pass. The student must inform the Dissertation Committee, the Graduate Program Director and Program Committee when these conditions have been completed. The Dissertation committee will then meet with the student to ensure all recommendations have been completed and whether a re-examination is necessary. If required, the re-examination will be done using the same format and prior to the beginning of the next academic semester. If the student still does not perform satisfactorily on this re-examination, he/she will then be recommended to the Graduate affairs committee for dismissal from the graduate program. Finally, the examining committee may find that a candidate lacks the skills or motivation to successfully complete a graduate program and may then decide on failure without the possibility of reexamination and will recommend dismissal from the Ph.D. program.

The **candidacy examination** must be completed by the end of the third year. It requires a formal, detailed proposal be submitted to the Dissertation Committee and an oral defense of the student's proposed research project. Upon the recommendation of the Dissertation Committee, the student may be admitted to candidacy for the Ph.D. degree. The stipulations for admission to doctoral candidacy are that the student has (i) completed one academic years of full-time graduate study in residence at the University of Delaware, (ii) completed all required courses with the exception of BINF865 and BINF969, (iii) passed the preliminary exams, (iv) demonstrated the ability to perform research, and (5) had a research project accepted by the Dissertation Committee.

Students who need to complete prerequisite courses may request a deadline extension for the preliminary and subsequently the candidacy examination. Requests must be submitted to the Graduate Program Committee prior to the start of the third semester.

The **dissertation examination** of the Ph.D. program will involve the approval of the written dissertation and an oral defense of the candidate's dissertation. The written dissertation will be submitted to the Dissertation Committee and the CBCB office at least three weeks in advance of the oral defense date. The oral defense date will be publicly announced at least two weeks prior to the scheduled date. The oral presentation will be open to the public and all members of the Bioinformatics and Systems Biology program. The Dissertation Committee will approve the candidate's dissertation. The student and the primary faculty advisor will be responsible for making all corrections to the dissertation document and for meeting all Graduate School deadlines. A copy (electronic and printed hard copy) of the final completed dissertation should be provided to the CBCB and the degree-granting College.

B. COURSE CURRICULUM

The table below lists the course curriculum for the Ph.D. in Bioinformatics and Systems 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 2012 term.

Table 7. PhD Program Course Curriculum

Course Curriculum (36 -45 credits)		
Core (9)	Bioinformatics (3) [choose one]	ANFS644: Bioinformatics (3)
		CISC636: Bioinformatics (3)
	Systems Biology (6)	BINF697/MAST698/ANFS667: Systems Biology I: Experimental Techniques and Bioinformatics Analysis of Omics Data (3)*
		BINF698/MATH660: Systems Biology II: Computational Modeling of Processes in Cells and Biological Systems (3)* [Or Systems Biology recommended elective upon approval**]
Electives (6)		Select from Elective list (see Table 8)
Prerequisites – if needed (3-9)	Introduction to Discipline (3) [choose one]	BISC654 Biochemical Genetics (3)
		MAST697: Bioinformatics Programming for Biologists (3)
		PLSC636: Plant Genes and Genomes (3)
	Database (3)	CISC637: Database Systems (3)
	Biostatistics (3)	STAT613: Multivariate Statistical Methods with Biology Applications (3)
		STAT656: Biostatistics (3)
Seminar (6)		BINF865: Seminar (1)***
Research (6)		BINF868: Research (1-5) - Until Successful Completion of preliminary exam****
		BINF964: Pre-Candidacy (1-5) - Until Successful Completion of candidacy exam****
Doctoral Dissertation (9)		BINF969: Doctoral Dissertation*****

* new course being developed, submitted for permanent status

** Substitution requires permission of dissertation committee and Graduate Program Director.

*** must enroll in every semester for the first three years and present one seminar in the second and third years

**** new course listing

Table 8. PhD Program Electives

Recommended Electives	
Bioinformatics	CISC841: Algorithms in Bioinformatics (3)
	CISC/BINF849: Computational Biomedicine (3)
Systems Biology	CHEG621: Metabolic Engineering (3)
	CISC/BINF889: Modeling and Simulation of Biological Systems (3)
	ELEG671: Mathematical Physiology (3)
Research Writing	EGGG867: Writing Academic Research in Engineering and Science (3)
	MAST607: Writing Papers in the Marine Sciences
Electives	
ANFS670: Principles of Molecular Genetics (3)	
ANFS/PLSC671: Paradigms in Cell Signaling (3)	
BINF601: Protein Modifications: a Proteomics and Bioinformatics Approach (3)*	
BISC600: Biotechnology and Molecular Medicine (3)	
BISC602: Molecular Biology of Animal Cells (3)	
BISC612: Advanced Cell Biology (3)	
BISC615 Vertebrate Developmental Biology (3)	

BISC631: Practice of Science (3)
BISC641: Microbial Ecology (3)
BISC645: Bacterial Evolution (3)
BISC656: Evolutionary Genetics (3)
BISC665: Advanced Molecular Biology & Genetics (3)
BISC671: Cellular and Molecular Immunology (3)
BISC679: Virology (3)
BISC682: Bacterial Pathogens: Molecular Mechanisms (3)
BISC693: Human Genetics (3)
CHEG620: Biochemical Engineering (3)
CHEM624: Principles of Mass Spectrometry (3)
CHEM645: Protein Structure and Function (3)
CHEM646: DNA-Protein Interactions (3)
CHEM649: Molecular Biophysics (3)
CISC621: Algorithm Design and Analysis (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)
CPEG/ELEG657: Search and Data Mining (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)
MAST616: Methods in Molecular Biology (3)
MAST618: Marine Microbial Ecology (3)
MAST623: Physiology of Marine Organisms (3)
MAST625: Microbial Physiology and Diversity (3)
MAST634: Marine Molecular Sciences (3)
MATH607: Survey of Scientific Computing (3)
MATH611: Introduction to Numerical Analysis and Scientific Computing (3)
MATH667: Math for Life Scientists (3)*
STAT608: Statistical Research Methods (3)
STAT615: Design and Analysis of Experiments (3)
STAT619: Time Series Analysis (3)
STAT670: Introduction to Statistical Analysis I (3)
STAT671: Introduction to Statistical Analysis II (3)
UAPP648: Environmental Ethics (3)
UAPP650: Values Ethics and Leadership (3)
BUAD840: Ethical Issues in Global Business Environments (3)

* new course being developed, submitted for permanent status

C. COMMITTEES AND DIRECTOR

The development, administration and progress assessment of the overall Ph.D. program in Bioinformatics & Systems Biology will be guided by the Director and the Graduate Program Committee, as outlined below.

C.1. GRADUATE PROGRAM COMMITTEE

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

Member	College	Department
Wu, Cathy (Chair)	Engineering/Arts & Sciences	Computer & Information Sciences/ Biological Science
Green, Pamela	Agriculture & Natural Resources	Plant & Soil Sciences/ Marine Biosciences
Hanson, Thomas	Earth, Ocean & Environment	Marine Biosciences
Boyd, Fidelma	Arts & Sciences	Biological Sciences
Papoutsakis, Eleftherios	Engineering	Chemical Engineering
Braun, Richard	Arts & Sciences	Mathematical Sciences
Schmidt, Carl	Agriculture & Natural Resources	Animal & Food Sciences
Zurakowski, Ryan	Engineering	Electrical & Computer Engineering

C.2. DIRECTOR

The Director of the Ph.D. program in Bioinformatics & Systems Biology will be responsible for the overall implementation, quality and progress of the degree program, advised by the Graduate Program Committee. The Director will also be the Chair of the Bioinformatics Graduate Committee. We propose that the Director of the Ph.D. program in Bioinformatics & Systems Biology be a rotating position. The CBCB Director, Dr. Cathy Wu, will serve as the Program Director for the initial three year term. The CBCB Education and Outreach Coordinator will provide administrative support to help manage day-to-day program activities.

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 Ph.D. program in Bioinformatics & Systems 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 Ph.D. program in Bioinformatics & Systems 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

Students in the Bioinformatics & Systems Biology Ph.D. program will typically complete the program in four to six years.

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

Previous graduate level courses (a maximum of 9 credit hours) will be considered towards the completion of the Ph.D. requirements, subject to approval by the Graduate Program Committee. 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 Graduate Program Committee, (iii) are in accord with the Program Policy Statement of the Ph.D. program in Bioinformatics & Systems 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.

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.

D.4. DISSERTATION

The student needs to establish a Dissertation Committee within the first year of study. The Committee should consist of at least four faculty members, including the primary faculty advisor, a secondary faculty advisor (in a complementary field to the primary advisor), a second faculty from the home Department, and one CBCB affiliate faculty outside the Departments of the primary and secondary advisors.

The **preliminary examination** should be taken before the end of the fourth semester and will consist of a written exam in subjects based on the Bioinformatics and Systems Biology core. The student's primary advisor will chair the exam and the content will be determined by the Dissertation Committee. Each member of the Dissertation Committee will provide a single grade (pass, conditional pass or fail) and the final grades will be submitted to the Program Committee for final grade determination. A conditional pass may be appropriate if the committee felt that the student did not have an adequate background or understanding in one or more specific areas. The dissertation committee will communicate the conditional pass to the student and must provide the student with specific requirements and guidelines for completing the conditional pass. The student must inform the Dissertation Committee, the Graduate Program Director and Program Committee when these conditions have been completed. The Dissertation committee will then meet with the student to ensure all recommendations have been completed and whether a re-examination is necessary. If required, the re-examination will be done using the same format and prior to the beginning of the next academic semester. If the student still does not perform satisfactorily on this re-examination, he/she will then be recommended to the Graduate affairs committee for dismissal from the graduate program. Finally, the examining committee may find that a candidate lacks the skills or motivation to successfully complete a graduate program and may then decide on failure without the possibility of reexamination and will recommend dismissal from the Ph.D. program.

The **candidacy examination** must be completed by the end of the third year. It requires a formal, detailed proposal be submitted to the Dissertation Committee and an oral defense of the student's proposed research project. Upon the recommendation of the Dissertation Committee, the student may be admitted to candidacy for the Ph.D. degree. The stipulations for admission to doctoral candidacy are that the student has (i) completed one academic years of full-time graduate study in residence at the University of Delaware, (ii) completed all required courses with the exception of BINF865 and BINF969, (iii) passed the preliminary exams, (iv) demonstrated the ability to perform research, and (5) had a research project accepted by the Dissertation Committee.

Students who need to complete prerequisite courses may request a deadline extension for the preliminary and subsequently the candidacy examination. Requests must be submitted to the Graduate Program Committee prior to the start of the third semester.

The **dissertation examination** of the Ph.D. program will involve the approval of the written dissertation and an oral defense of the candidate's dissertation. The written dissertation will be submitted to the Dissertation Committee and the CBCB office at least three weeks in advance of the oral defense date. The oral defense date will be publicly announced at least two weeks prior to the scheduled date. The oral presentation will be open to the public and all members of the Bioinformatics and Systems Biology program. The Dissertation Committee will approve the candidate's dissertation. The student and the primary faculty advisor will be responsible for making all corrections to the dissertation document and for meeting all Graduate School deadlines. A copy (electronic and printed hard copy) of the final completed dissertation should be provided to the CBCB and the degree-granting College.

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 Ph.D. program in Bioinformatics & Systems 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 Ph.D. program in Bioinformatics & Systems Biology may apply for 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 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 6 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 Program 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 Program Committee of the academic department offering the course. The Committee may recommend termination of the assistantship to the Department Chair.

X. APPENDIX III

COURSE DESCRIPTIONS

BIOINFORMATICS AND SYSTEMS BIOLOGY CORE

- **Bioinformatics**

  ANFS644: Bioinformatics (3)
  - Examines computer applications to biological sciences with emphasis placed upon genomics and proteomics applications. No computer programming experience required. TERM: Fall Semester

  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

- **Systems Biology**

  ANFS 667 Introduction to Systems Biology Techniques (3)
  - This lecture course is designed to introduce graduate and upper level undergraduate students to the genomic techniques used in Systems Biology. In addition to lectures, current articles from high impact journals will be used as practical examples

  BINF697 Systems Biology I: Experimental Techniques and Bioinformatics Analysis of Omics Data (3)
  - This course couples lectures and hands-on exercises to introduce students to experimental methods and bioinformatics analysis in systems biology, showing how global analysis of "omics" data improves understanding of biological systems. This course has three units: (i) experimental techniques; (ii) genomics and transcriptomics data analysis; and (iii) proteomics and pathway/network data analysis.

  BINF698 Systems Biology II: Computational Modeling of Processes in Cells and Biological Systems (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.

  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.

MAST698: Environmental and Systems Bioinformatics (3)

- Use bioinformatic methods to link genomic/proteomic sequence features to specific mechanisms of environmental adaptations or metabolic systems organization. It is designed for graduate students and advanced undergraduates wanting to apply basic informatic approaches and computational tools to specific research topics that interest them. Students are expected to have some experience with programming (i.e., MAST697). Computational tools presented to students include: PERL, PYTHON, R, and MatLab. It is expected that students will conduct an individual research project as a component of this course.

PREREQUISITES

- **Introduction to Discipline**

  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

  MAST697: Bioinformatics Programming for Biologists (3)

  - Basic PERL programming for biologists interested in doing bioinformatics research but who have no prior experience in computer programming. The goal is to familiarize students with PERL syntax sufficiently so that they will be able to edit and trouble-shoot existing PERL programs and modules to suite their own research needs without having to write their own de novo programs and scripts. Students are given class accounts on the Biowolf parallel computing cluster at DBI. Students are also expected to become proficient at working with computers from a command-line, unix-based, terminal interface.

  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.

- **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 and Spring 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

ELECTIVES

Recommended Electives

- **Bioinformatics**

  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.

  CISC849: Computational Biomedicine (3)
  - A graduate seminar exploring machine learning methods and their current applications in biology and medicine. Cross-listed with BINF849.

- **Systems Biology**

  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.

  CISC889: Modeling and Simulation of Biological Systems (3)
  - Concepts, techniques, and tools for modeling and simulation of biological systems. Gene regulation, signal transduction, and metabolism. Boolean networks, Bayesian networks. Monte Carlo and gibbs sampling.

  ELEG671: Mathematical Physiology (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.

- **Research Writing**

  EGGG867: Writing Academic Research in Engineering and Science (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.

  MAST607: Writing Papers in the Marine Sciences (3)
  - The process and mechanics of publishing papers in scientific journals. Covers organizing data in tables and figures; mechanics of drawing up effective figures; marshalling of tables, figures and scientific ideas into a coherent story; and strategies and techniques used in effective writing. Examples taken from and principles applicable to all fields of science.

Electives

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.

ANFS671: Paradigms in Cell Signaling (3)
- Overview of important signaling paradigms in animal and plant cells. Primarily literature based, with class discussion and presentations. Topics include direct cell-cell interactions, cell-matrix interactions and various ligand-receptor signaling paradigms.

BINF601: Protein Modifications: a Proteomics and Bioinformatics Approach (3)
- This will be a survey of protein modifications, methods for detecting them and determining their structure and occurrence using NMR, diffraction, and mass-spectrometry with an emphasis on proteomic and bioinformatic approaches. An overview will consider how modifications arise, their roles in metabolism and disease, and methods for predicting them.

BISC600: Biotechnology and Molecular Medicine (3)
- Application of molecular and cellular biology techniques and principles to the field of biotechnology. Stresses the applied side of science and focuses on the practical side of molecular biology and how scientists and companies reduce the basic knowledge to practice. Emphasis on product formation and the skills required to meet such goals. Covers tangential issues of biotechnology and the ethical choices made in developing clinical trial protocols. PREREQ: Undergraduate course in biology or chemistry or permission of the instructor.

BISC602: Molecular Biology of Animal Cells (3)
- Examination of eukaryotic 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.

BISC615 Vertebrate Developmental Biology (3)

- Introduces the basic principles of vertebrate development including formation of the basic body plan and the molecular control of tissue morphogenesis. The importance of each developmental milestone will be illustrated by discussing the underlying causes of birth defects. PREREQ: BISC401 and BISC403. Requires instructor approval.

BISC631: 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."

BISC641: Microbial Ecology (3)

- Principles of microbial interactions in natural environments, including applications to industrial microbiology and certain types of pollution. PREREQ: BISC300

BISC645: Bacterial Evolution (3)

- Explores the development of the enormous bacterial diversity beginning with current theories on the origin of life. Examines the evolution of viruses and the "directed evolution" controversy which concerns mechanisms of bacterial evolution. PREREQ: BISC300 or equivalent. TERM: Fall Semester

BISC656: Evolutionary Genetics (3)

- Exploration of the theory, methods and experiments underlying current research in evolutionary processes determining genetic variation within and between species, estimation of population structure from genetic data, and the genetics of speciation. PREREQ: BISC403

BISC665: Advanced Molecular Biology & Genetics (3)

- Presents concepts and approaches regarding our current understanding of molecular biology and molecular genetics in eukaryotic organisms. Requires a solid background in biochemistry, cell biology and introductory molecular biology. Cross listed with PLSC671

BISC671: Cellular and Molecular Immunology (3)

- Introduces the basic concepts of immunology and describes how different immune responses can either protect the body from infection or lead to immunological based diseases. Focuses on cellular interactions and the resultant molecular responses that lead to immune protection. PREREQ: BISC401 or BISC305 or BISC300. Requires permission of instructor. TERM: Fall Semester

BISC679: Virology (3)

- Molecular biology of animal viruses. Virus structure and organization; mechanisms of penetration, replication, maturation and transformation. PREREQ: BISC401 or biochemistry

BISC682: Bacterial Pathogens: Molecular Mechanisms (3)

- Explore the molecular mechanisms of infectious diseases. Disease transmission and infection, horizontal gene transfer and pathogenomics are reviewed using primary research literature. Topics include water and food borne, airborne, vector borne and human borne pathogens, their molecular mechanisms of invasion, colonization, virulence and immune avoidance.

BISC693: Human Genetics (3)

- Emphasis on the medical and social implications of our knowledge of human genetics. Discusses theoretical and practical principles of genetics useful in studying human variation such as cytogenetics and cell genetics, biochemical genetics, developmental genetics and teratology, principles of genetic counseling, multi-factoral inheritance and the genetics of cancer. PREREQ: BISC403

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.

CHEG604: Probability and Statistics for Engineering Problem Solving (3)

- Fundamental approach to modeling, characterization and analysis of random phenomena with the objective of providing students with the basic principles, methods and tools for solving engineering problems involving randomly varying phenomena. Application areas explored include experimental design, manufacturing, system reliability, and cellular biology.

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

CHEM624: Principles of Mass Spectrometry (3)

- Principles of mass spectral measurements for the elucidation of molecular structure; applications to biomolecular materials and topics from the current literature. PREREQ: CHEM437

CHEM645: Protein Structure and Function (3)

- Overview of structural biology, including how x-ray crystallography, NMR spectroscopy, homology modeling and other techniques are used to solve or model structures of macromolecules. Representative proteins discussed in terms of how a protein's structure relates to its function. PREREQ: CHEM641. TERM: Fall Semester

CHEM646: DNA-Protein Interactions (3)

- Current topics of DNA-protein interactions which focus on DNA replication, DNA recombination, DNA damage repair, transcription and translation processes. PREREQ: CHEM642. TERM: Fall Semester

CHEM649: Molecular Biophysics (3)

- Biophysical principles and methods: thermodynamic and kinetic analysis of folding; protein-nucleic acid interactions; ligand binding; spectroscopy; structural methods; modeling; calorimetry; ultracentrifugation; SPR. Problem solving in macromolecular interactions: protein refolding; altering ligand affinity; increasing protein stability; drug design and HTS; protein expression and solubility; protein

engineering. PREREQ: Introductory-level courses in chemistry, physics biochemistry.

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

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.

CPEG657: Search and Data Mining (3)

- With the increasing amount of textual information, it is important to develop effective search engines, such as Google, to help users manage and exploit the information. Examine the underlying technologies of search engines and get hands-on project experience. Requires good programming skills. Cross listed with ELEG657.

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)

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

MAST618: Marine Microbial Ecology (3)

- Examines role of microbes in the oceans and their impact on oceanographic processes and biogeochemical cycles in marine environments. Emphasis is on bacteria and their interactions with other marine organisms. Introduces use of molecular tools to examine uncultivated microbes.

MAST623: Physiology of Marine Organisms (3)

- Processes and mechanisms of adaptation of organisms to marine environments. Examines how environmental factors affect physiological processes in marine organisms. Lectures address physiological processes at cellular, whole organism

and habitat levels. PREREQ: MAST634 or equivalent. Requires permission of instructor

MAST625: Microbial Physiology and Diversity (3)

- Emphasis on diversity of physiological strategies developed by prokaryotic microbes and some simple eukaryotes. Approach is to examine and dissect specific metabolic pathways both in isolation and in how they integrate with central metabolism. PREREQ: BISC 207/208, CHEM 321 or CHEM 331, or permission of instructor. Juniors, Seniors, and Graduate Students

MAST634: Marine Molecular Sciences (3)

- This course surveys the dominant molecular processes in marine organisms that are essential for survival. Students are introduced to metabolic pathways, protein structure and function, DNA replication and repair, gene transcription and translation, and mitochondrial and chloroplast organelle function. TERM: Fall Semester

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

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.

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.

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.

SEMINAR

BINF865: Seminar (1)

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

RESEARCH

BINF868: Research (1-6)

- Upper-level graduate research oriented toward a student's potential master's thesis or Ph.D. dissertation.

BINF964: Pre-Candidacy (1-6)

- Research and readings in preparation of dissertation topic and/or preliminary examinations for doctoral students before admission to candidacy but after completion of all required course work. RESTRICTIONS: Not open to students who have been admitted to candidacy.

BINF964: Doctoral Dissertation (1-6)

- Independent dissertation research after completion of the Candidacy Examination.