# PROGRAM POLICY	# PROGRAM POLICY STATEMENT FOR PHD IN BIOINFORMATICS DATA SCIENCE
## I. PROGRAM HISTORY	• **PROGRAM HISTORY**
### A. RATIONALE	### A. RATIONALE FOR CHANGING THE NAME OF THE PROGRAM TO BIOINFORMATICS DATA SCIENCE
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	The completion of the human genome sequence marked the beginning of a new era of biological research. Scientists have begun to systematically tackle gene functions and other complex regulatory processes by studying organisms at the global scales. Advances in high-throughput biotechnologies and large-scale bioscience have further enabled modeling and simulation over a multitude of length, time and biological scales from

biomolecules, cells, tissues and organs to organisms and population. With the enormous volume of data being produced, biology is becoming an increasingly quantitative science. Computational approaches, in combination with experimental methods, have become essential for generating novel hypotheses, deriving new scientific knowledge, and driving discovery and innovation. *Bioinformatics 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	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 Data Science* 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 data science is 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~~. • *Data Science*: The interdisciplinary field of inquiry in which quantitative and analytical approaches, processes, and systems are developed and used to extract knowledge and insights from increasingly large and/or complex sets of data. Fundamental to modern day biological studies and key to the basic understanding of complex biological systems, bioinformatics data science is impacting science and technology in fields ranging from agricultural and

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.	environmental sciences to pharmaceutical and medical sciences. The research requires close collaboration among multi-disciplinary teams of researchers in quantitative sciences, life sciences, and their interfaces.
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.	~~W~~The UD *Ph.D. in Bioinformatics & Data Science* is training the next-generation of researchers and professionals who are playing 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 Master's degree program in Bioinformatics and Computational Biology which was approved for permanent status Fall 2017 and further strengthen bioinformatics data science 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.	A unique feature of this program is that students will receive training in experimental, computational and mathematical disciplines through their coursework and research that is 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	Due to the interdisciplinary nature of bioinformatics data science, experts in these fields within the University of Delaware are housed in many Colleges and Departments on campus spanning several engineering, math or life sciences disciplines. Therefore, the PhD in Bioinformatics & Data Science is offered as a university-wide interdisciplinary graduate program that attracts students to many Departments across Colleges. The students will identify a Primary Faculty Advisor who will be responsible for defining the student's

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.	responsibilities and for evaluating the student's performance. The students ~~will be~~ are 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 Center for Bioinformatics and Computational Biology (CBCB) administers the Ph.D. program in Bioinformatics Data Science and coordinates 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 & Data Science. The newly launched Data Science Institute (DSI) research initiative will foster additional multidisciplinary research collaboration providing further synergy among data science research and academic programs.
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*.	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), College of Health Sciences (CHS) and Earth, Ocean & Environment (CEOE), as well as the curriculum from the existing Master's program in Bioinformatics & Computational Biology. In addition, this 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*~~. The core course requirements include: • *Bioinformatics:* A field that utilizes and applies computational biology to design, collect, organize, analyze, and share biological data through

	bioinformatics resources and database tools. • *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. • *Data Analytics*: The integration of health-care sciences, computer science, information science, and cognitive science to assist in the management of healthcare information. **B. DATE OF PERMANENT STATUS** Provisional status, March 2012; Pending review for permanent status in 2018 ~~**C. DEGREES OFFERED**~~
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).	~~The program will offer the degree Doctorate of Philosophy in Bioinformatics & Data Science (BINF PhD).~~ ~~The program will offer the degree Doctorate of Philosophy in Bioinformatics & Data Science (BINF PhD).~~
II. ADMISSION	**II. ADMISSION**
A. ADMISSION REQUIREMENTS	**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	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	requirements necessarily precluded from admission if they offer other appropriate strengths. The following are the admission requirements to the Ph.D. program in Bioinformatics Data Science: • 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 attended; • Applicants may have undergraduate degrees from biological, computational, or other disciplines~~.~~ ~~However, applicants,~~ but 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~~ 600 (paper-based or 100

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	(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 that includes answers to the following questions: • What educational background and scientific research or employment experience prepare you for this degree program? • What are your long-term professional objectives? • 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.	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.	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. APPLICATION**
	Application to the Doctorate's program in Bioinformatics Data Science will be submitted using the on-line graduate admission application that includes transcripts from all previous college or university study, letters of recommendation, resume, application essay, and official GRE and TOEFL scores (if applicable). If any part of an application is missing, evaluation of the application cannot begin. The applicant will apply to the Department of Computer & Information Sciences.
B.1. APPLICATION DEADLINES	**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	Admission decisions are made on a rolling basis as and when applications are complete. Decisions on financial aid awards are usually made in March-May for the Fall Semester, and in August-October for the Spring Semester.

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.	The central graduate admissions office continues to process applications and transcripts throughout the year and follows the stated two (2) week processing timeline for all materials received in the office. The application deadlines are: • Fall Semester: April 15th (regular application); February 15st (financial aid) • Spring Semester: October 15th (regular application); July 15th (financial aid) If there are remaining positions within the program, applications will be considered until July 15th for Fall enrollment and December 1st for Spring enrollment. *Late applications subject to availability.*
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.	**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 Doctorate of Philosophy program in Bioinformatics & Data Science. 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	**C. ADMISSION STATUS** Students may be admitted into the Doctorate's program in Bioinformatics & Data Science 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.	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.	~~**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.~~ Applicants offered as Direct Entry may lack one or more specified courses and will be required to complete these course requirements as part of and concurrent with the degree ~~requirements. 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.
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	**III. ACADEMIC**
A. DEGREE REQUIREMENTS	**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	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	
Prerequisites – if needed	
Electives	
Seminar and Research (21 Credits)	
Seminar	
Research	

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 3 credit hours of seminar, 6 credit hours of research and 9 credit hours of doctoral dissertation (summarized in Table 1). 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 1. PhD Program Course Requirements Summary

Degree Requirements (33 - 42 Credits)	
Core and Elective Courses (15 - 24 Credits)	
Bioinformatics Data Science Core	9 Credits
Prerequisites – if needed	3-9 Credits
Electives	6 Credits
Seminar and Research (18 Credits)	
Seminar*	6 Credits
Research	6 Credits

Doctoral Dissertation	Doctoral Dissertation
	*Attendance in seminar is required for six semesters.
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 **preliminary examination** should be taken before the end of the fourth semester and will consist of an oral exam in subjects based on the Bioinformatics and Data Science core. In recognition of the importance of the core curriculum in providing a good test of the student's knowledge, students must achieve a minimum 3.0 GPA in the core curriculum before taking the preliminary exam. The exam will be administered by the Preliminary Exam Committee, which will consist of one instructor from each of the three core courses. The student's primary adviser is invited to attend but they will not be an active participant in the examination. Each member of the Committee will provide a single grade (pass, conditional pass or fail) and the final grades will be submitted via the Results of Preliminary Exam Form: • **Pass.** The student may proceed to the next stage of his/her degree training. **2. Conditional pass. .** In the event that the examination committee feels that the student did not have an adequate background or understanding in one or more specific areas, the preliminary exam 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 preliminary exam Committee, the Graduate Program Director and Program Committee when these conditions have been completed. The preliminary exam 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. 3. **Failure.** This outcome would indicate that examination committee considers the student incapable of completing degree training. The student's academic progress will be reviewed by the Graduate Affairs Committee, who will make recommendations to the Program Director regarding the student's enrollment status. The Program Director may recommend to the Office of Graduate & Professional Education that the student be dismissed from the Program immediately. 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 **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,	The **candidacy examination** must be completed by the end of the ~~third year~~ sixth semester of enrollment. 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)

and (5) had a research project accepted by the Dissertation Committee.	demonstrated the ability to perform research, and ~~(5)~~ (v) had a research project accepted by the Dissertation Committee. Within one week of the candidacy exam, complete and submit the Recommendation for Candidacy for Doctoral Degree form for details.
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.	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.	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~~ Data Science 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~~ Education and Outreach Coordinator.
B. COURSE CURRICULUM	**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	The table below lists the course curriculum for the Ph.D. in Bioinformatics ~~and Systems Biology~~ & Data Science.

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 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 perm 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 ~~7~~ 2. PhD Program Course Curriculum

Course Curriculum (33-42 credits)	
Bioinformatics (3)	Data Science Core (9)
Bioinformatics (3) [select one]	BINFANFS644: Bioinforma
	CISC636: Bioinformatics an
Systems Biology (6) [select one]	BINF ~~694~~ 697/MAST698/A Experimental Techniques an Data (3)*
	BINF695~~698/MATH660~~: C ~~Computational Modeling of Systems~~ (3)
	[Or Systems Biology recom
	NURS/HLTH 844 Populatio
	CISC681 Artificial Intellige
	CISC683 Introduction to Da
	CISC684 Introduction to Ma
Prerequisites – if required (3-9)**	
Introduction to Discipline (3) [select one]	BISC609 Molecular Biolog
	BISC654: Biochemical Gen
	~~MAST697: Bioinformatics P~~
	~~PLSC636: Plant Genes and~~
	PLSC667: Applications of G Mammals (3)****
	BINF690: Programming for
Database (3) [select one]	BINF640: Databases for Bio
	CISC637: Database Systems
Biostatistics (3) [select one]	~~STAT613: Multivariate Stat Applications (3)~~
	STAT656: Biostatistics (3)
	STAT611: Regression Anal
Electives (6)	Select from Elective list (se
Seminar (~~3~~6)	
Seminar	BINF865: Seminar (0-1)***
Research (6)	
Research	BINF868: Research (1-6) - preliminary exam
	BINF964: Pre-Candidacy (1 candidacy exam
Doctoral Dissertation (9)	
Doctoral Dissertation	BINF969: Doctoral Dissertat

Table 8. PhD Program Electives		**Table ~~8~~ 3.** PhD Program Electives
Recommended Electives		
Bioinformatics	CISC841: Algorithms in Bioinformatics (3)	~~BISC609: Molecular Biology of the Cell (3)~~
	CISC/BINF849: Computational Biomedicine (3)	~~BINF630: Programming for Bioinformatics (3)~~
Systems Biology	CHEG621: Metabolic Engineering (3)	~~BINF695: Computational Systems Biology (3)~~
	CISC/BINF889: Modeling and Simulation of Biological Systems (3)	~~BISC654: Biochemical Genetics (3)~~
	ELEG671: Mathematical Physiology (3)	~~BISC667: Introduction to Human-Computer Interaction (3)~~****
Research Writing	EGGG867: Writing Academic Research in Engineering and Science (3)	~~CISC681: Artificial Intelligence (3)~~
	MAST607: Writing Papers in the Marine Sciences	~~CISC683: Introduction to Data Mining (3)~~
Electives		CISC684 Introduction to Machine Learning (3)
ANFS670: Principles of Molecular Genetics (3)		CISC685 Modeling and Simulations for Bioinformatics System
ANFS/PLSC671: Paradigms in Cell Signaling (3)		~~CISC841 Algorithms in Bioinformatics (3)~~
BINF601: Protein Modifications: a Proteomics and Bioinformatics Approach (3)		~~CISC844 Computational Biomedicine (3)~~
BISC600: Biotechnology and Molecular Medicine (3)		~~ELEG671 Mathematical Physiology (3)~~
BISC602: Molecular Biology of Animal Cells (3)		~~EGGG667 Technical and Scientific Writing (3)~~
BISC612: Advanced Cell Biology (3)		~~EGGG867: Writing Academic Research in Engineering and Sc~~
BISC615 Vertebrate Developmental Biology (3)		~~MAST607 Writing Papers in the Marine Sciences (3)~~
BISC631: Practice of Science (3)		~~MEEG621 Linear Systems (3)~~
BISC641: Microbial Ecology (3)		~~UAPP648 Environmental Ethics (3)~~
BISC645: Bacterial Evolution (3)		NURS/HLTH 844 Population Healthcare Informatics (3)
BISC656: Evolutionary Genetics (3)		PLSC667: Applications of Genome Science: From Microbes to
BISC665: Advanced Molecular Biology & Genetics (3)		~~UAPP650 Values Ethics and Leadership (3)~~
BISC671: Cellular and Molecular Immunology (3)		BUAD840 Ethical Issues in Global Business Environments (3)
BISC679: Virology (3)		Electives
BISC682: Bacterial Pathogens: Molecular Mechanisms (3)		~~ANFS670: Principles of Molecular Genetics (3)~~
BISC693: Human Genetics (3)		~~ANFS/PLSC671: Paradigms in Cell Signaling (3)~~
CHEG620: Biochemical Engineering (3)		BHAN 856 Multivariable Biostatistics (3)
CHEM624: Principles of Mass Spectrometry (3)		~~BINF601: Protein Modifications: a Proteomics and Bioinforma~~
CHEM645: Protein Structure and Function (3)		BINF650 Protein Modifications: Protein Structure and Functio
CHEM646: DNA-Protein Interactions (3)		~~BISC600: Biotechnology and Molecular Medicine (3)~~
CHEM649: Molecular Biophysics (3)		BISC602 Molecular Biology of Animal Cells (3)
CISC621: Algorithm Design and Analysis (3)		BISC605 Advanced Mammalian Physiology (3)
CISC681: Artificial Intelligence (3)		BISC612 Advanced Cell Biology (3)
CISC683: Introduction to Data mining (3)		BISC615 ~~Vertebrate~~ Developmental Biology (3)
CISC882: Natural Language Processing (3)		BISC61~~2~~0 Endocrine Physiology (3)
CISC886: Multi-Agent Systems (3)		BISC625 Cancer Biology (3)
CISC887: Internet Information Gathering (3)		~~BISC631: Practice of Science (3)~~
CISC888: Machine Learning (3)		~~BISC641: Microbial Ecology (3)~~
CPEG/ELEG657: Search and Data Mining (3)		~~BISC645: Bacterial Evolution (3)~~
ELEG633: Image Processing (3)		BISC656 Evolutionary Genetics (3)
ELEG652: Principles of Parallel Computer Archi		~~BISC665: Advanced Molecular Biology & Genetics (3)~~
ELEG655: High-Performance Computing with C		
ELEG679: Introduction to Medical Imaging Syste		

ELEG680: Immunology for Engineers (3)	BISC671 Cellular and Molecular Immunology (3)
MAST616: Methods in Molecular Biology (3)	BISC679 Virology (3)
MAST618: Marine Microbial Ecology (3)	BISC682 Bacterial Pathogens: Molecular Mechanisms (3)
MAST623: Physiology of Marine Organisms (3	BISC690 Fundamentals of Pharmacology (3)
MAST625: Microbial Physiology and Diversity (	~~BISC693: Human Genetics (3)~~
MAST634: Marine Molecular Sciences (3)	BISC833 Special Topics in Biology: Grant Writing (1)
MATH607: Survey of Scientific Computing (3)	~~CHEG620 Biochemical Engineering (3)~~
MATH611: Introduction to Numerical Analysis a	CHEG621 Metabolic Engineering (3)
MATH667: Math for Life Scientists (3)*	CHEM624 Principles of Mass Spectrometry (3)
STAT608: Statistical Research Methods (3)	CHEM641 Biochemistry (3)
STAT615: Design and Analysis of Experiments (	CHEM645 Protein Structure and Function (3)
STAT619: Time Series Analysis (3)	CHEM646 DNA-Protein Interactions (3)
STAT670: Introduction to Statistical Analysis I (	CHEM649 Molecular Biophysics (3)
STAT671: Introduction to Statistical Analysis II (	CISC621 Algorithm Design and Analysis (3)
UAPP648: Environmental Ethics (3)	CISC640 Computer Graphics (3)
UAPP650: Values Ethics and Leadership (3)	CISC642 Introduction to Computer Vision (3)
BUAD840: Ethical Issues in Global Business Env	CISC650 Computer Networks (3)
	CISC675 Object Oriented Software Engineering (3)
	CISC683 Introduction to Data Mining (3)
	CISC849 Advanced Topics in Computer Applications (3)
	CISC882 Natural Language Processing (3)
	CISC886 Multi-Agent Systems (3)
	~~CISC887 Internet Information Gathering (3)~~
	~~CISC888 Machine Learning (3)~~
	CISC889 Advanced Topics in Artificial Intelligence (3)
	CPEG655 ~~ELEG655~~ High-Performance Computing with Comm
	CPEG~~/ELEG~~657 Search and Data Mining (3)
	ELEG633 Image Processing (3)
	ELEG652 Principles of Parallel Computer Architectures (3)
	ELEG671 Mathematical Physiology (3)
	ELEG679 Introduction to Medical Imaging Systems (3)
	ELEG680 Immunology for Engineers (3)
	KAAP602 Data Analysis and Interpretation in Health Sciences
	~~KAAP654 Medical Physiology (3)~~
	MAST607 Writing Papers in the Marine Sciences (3)
	MAST616 Methods in Molecular Biology (3)
	MAST618 Microbial Ecology (3)
	MAST623 Physiology of Marine Organisms (3)
	MAST625 Microbial Physiology and Diversity (3)

* new course being developed, submitted for perm status

	MAST626 Microbial Molecular Genetics (3)
	MAST634 Marine Molecular Sciences (3)
	~~MATH607: Survey of Scientific Computing (3)~~
	MATH611 Introduction to Numerical Discretization ~~Introductio~~ ~~Computing~~ (3)
	MATH637 Mathematical Techniques in Data Science (3)
	~~MATH667: Math for Life Scientists (3)~~*
	MEEG621 Linear Systems (3)
	~~PLSC644 Physiology of Plant Stress (3)~~
	~~PLSC667 Analytical Plant Genetics~~ (3)
	PLSC671 Paradigms in Cell Signaling (3)
	STAT608 Statistical Research Methods (3)
	STAT612 Advanced Regression Techniques (3)
	STAT615 Design and Analysis of Experiments (3)
	STAT617 Multivariate Methods (3)
	STAT619 Time Series Analysis (3)
	STAT621 Survival Analysis (3)
	STAT670 Introduction to Statistical Analysis I (3)
	STAT671 Introduction to Statistical Analysis II (3)
	STAT674 Applied Data Base Management (3)
	* substitution requires permission of Dissertation Committee and Graduate Program Director. ** necessary for students lacking equivalent courses *** must enroll in every semester for the first three years and present one seminar in the second and third years **** new course being developed
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. COMMITTEES AND DIRECTOR** **THE DEVELOPMENT, ADMINISTRATION AND PROGRESS ASSESSMENT OF THE ~~OVERALL~~ PH.D. PROGRAM IN BIOINFORMATICS & ~~SYSTEMS BIOLOGY~~ DATA SCIENCE WILL BE GUIDED BY THE DIRECTOR ~~AND THE GRADUATE PROGRAM COMMITTEE, AS OUTLINED BELOW.~~, THE BIOINFORMATICS STEERING COMMITTEE, AND THE BIOINFORMATICS GRADUATE COMMITTEE AS OUTLINED BELOW.C.1. BIOINFORMATICS STEERING COMMITTEE**

The Bioinformatics Steering Committee will advise the development and progress assessment of the Ph.D. program in Bioinformatics & Data Science. The committee consists of faculty members from ten Departments across five Colleges participating in this degree program.

C.1. Graduate Program Committee

The Graduate Committee will be responsible for admission, advising, and progress assessment of the students in the Ph.D. 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.

~~C.1.~~ C.2. Bioinformatics Graduate Committee

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

Member	College
Wu, Cathy (Chair)	Engineering/Arts &
Green, Pamela	Agriculture & Natur
Hanson, Thomas	Earth, Ocean & Envi
Boyd, Fidelma	Arts & Sciences
Papoutsakis, Eleftherios	Engineering
Braun, Richard	Arts & Sciences
Schmidt, Carl	Agriculture & Natur
Zurakowski, Ryan	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.

C.2. Director

The Director of the Ph.D. program in Bioinformatics & ~~Systems Biology~~ Data Science will be responsible for the overall implementation, quality and progress of the degree program, advised by the ~~Graduate~~

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.	~~Program~~ Steering Committee and the Industry Advisory Board. The Director will also be the Chair of the Bioinformatics Graduate Committee. We propose that the Director of the Ph.D. program in Bioinformatics & ~~Systems Biology~~ Data Science 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. 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).	**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~~ Data Science. 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).~~ (https://bioinformatics.udel.edu/people/affiliatedfaculty/).
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.	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~~ Data Science 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.2. ACADEMIC LOAD** Students in the Bioinformatics & ~~Systems Biology~~ Data Science 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~~ 6 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	**D.3. TRANSFERABILITY** Prior to admission to the Ph.D. program in Bioinformatics & Data Science, a prospective student from another institution can be approved by the Bioinformatics Graduate Committee to take up to 9 graduate credits that, if/when admitted to the degree program, would be applied to that degree. Once the student has successfully completed 9 approved graduate UD credits and been admitted to the degree program, then a maximum of 9 graduate credits, but not the grades or quality points, can be transferred into the Ph.D. program from another institution with the approval of the Graduate Committee.
Students who complete graduate credits with the classification of CEND (Continuing Education Non-degree) at the University of Delaware may use a maximum of 9 graduate	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. 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.	credits earned with this classification toward their graduate degree. All requests for transfer credit should be directed to the academic home department, Department of Computer & Information Sciences, using a "Request for Transfer of Graduate Credit" Form. Transfer credits will be accepted provided that such credits: (i) were earned with a grade of no less than B-, (ii) are approved by the ~~Graduate Program~~ Bioinformatics Graduate Committee, (iii) are in accord with the Program Policy Statement of the Ph.D. program in Bioinformatics & ~~Systems Biology~~ Data Science, (iv) are not older than five years, (v) are graduate level courses, and (vi) were completed at an accredited college or university. Graduate courses counted toward a degree received elsewhere may not be transferred into a degree at UD. Credits from institutions outside of the United States are generally not transferable to UD.
D.4. 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.	**D.4. DISSERTATION** The student needs to establish a Dissertation Committee within the first year of study. The Committee shall consist of no less than four and no more than six 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 primary faculty advisor will serve as the Committee Chair. The second member will serve as the Major Area Committee Member and must be in a complementary field to the primary advisor. The third member will serve as the Minor Area Committee Member and must represent the same field as the primary advisor. The final committee member will serve as the external committee member and must be outside the departments of the Committee Chair and the Major Area Committee member

	or be from outside the University. Students must complete the Dissertation Committee Formation form and submit to the Education and Outreach Coordinator. Students should convene their dissertation committee at least once every six months.
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	The **preliminary examination** should be taken before the end of the fourth semester and will consist of an oral exam in subjects based on the Bioinformatics and ~~Systems Biology~~ Data Science 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.	and will recommend dismissal from the Ph.D. program. In recognition of the importance of the core curriculum in providing a good test of the student's knowledge, **students must achieve a minimum 3.0 GPA in the core curriculum** before taking the preliminary exam. The exam will be administered by the Preliminary Exam Committee, which will consist of one instructor from each of the three core courses. The student's primary adviser is invited to attend but they will not be an active participant in the examination. Each member of the Committee will provide a single grade (pass, conditional pass or fail) and the final grades will be submitted via the Results of Preliminary Exam Form: • **Pass.** The student may proceed to the next stage of his/her degree training. • **Conditional pass.** In the event that the examination committee feels that the student did not have an adequate background or understanding in one or more specific areas, the preliminary exam 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 preliminary exam Committee, the Graduate Program Director and Graduate Committee when these conditions have been completed. The preliminary exam 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.

	• **Failure.** This outcome would indicate that examination committee considers the student incapable of completing degree training. The student's academic progress will be reviewed by the Graduate Affairs Committee, who will make recommendations to the Program Director regarding the student's enrollment status. The Program Director may recommend to the Office of Graduate & Professional Education that the student be dismissed from the program immediately. 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 Committee prior to the start of the third semester.
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.	The **candidacy examination** must be completed by the end of the ~~third year~~ sixth semester of enrollment. 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)~~ (v) had a research project accepted by the Dissertation Committee. Within one week of the candidacy exam, complete and submit the Recommendation for Candidacy for Doctoral Degree form for details.
Students who need to complete prerequisite courses may request a deadline extension for	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 Ph.D. 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 preliminary and subsequently the candidacy examination. Requests must be submitted to the Graduate 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~~ Data Science 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~~ Education and Outreach Coordinator. **D.5. GRADE REQUIREMENTS** Only graduate core courses completed with a grade of B or higher count towards the requirements of Bioinformatics Ph.D. 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 Ph.D.'s program in Bioinformatics & Systems Biology. Possible actions include (but are not limited to): (i) requirement for additional courses, (ii) suspension of financial support, and (iii) recommendation for dismissal.	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 Ph.D. program in Bioinformatics and Data Science. 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.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.8. DISMISSAL** The procedures for dismissal as detailed in the University Catalog will be followed. Briefly, the Bioinformatics Graduate Committee will report its recommendation and reason for dismissal to the Director of the Bioinformatics Ph.D. 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	**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 Ph.D. program prior to filing a formal grievance in an effort to resolve the situation informally.	Bioinformatics Ph.D. program prior to filing a formal grievance in an effort to resolve the situation informally.
D.10. ATTENDANCE AT CONFERENCES AND PROFESSIONAL MEETINGS	**D.10. ATTENDANCE AT CONFERENCES AND PROFESSIONAL MEETINGS**
The Bioinformatics Ph.D. 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.	The Bioinformatics Ph.D. 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	**IV. FINANCIAL AID**
A. FINANCIAL AWARDS	**A. FINANCIAL AWARDS**
Admission to the Ph.D. program in Bioinformatics and 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.	Admission to the Ph.D. program in Bioinformatics & Data Science ~~does not automatically entitle an applicant to financial aid.~~ Requires a Graduate Assistantship. 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.	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	Students in the Ph.D. program in Bioinformatics & Data Science may apply for the Graduate Assistantships: • Research Assistantships (RAs) are generally funded by research grants and contracts provided by external funding agencies. Students may be supported as an RA through their Faculty Advisor's research funds after their first year. A research assistantship provides full tuition and a stipend. The

RA's advisor is responsible for defining the student's responsibilities and for evaluating the student's performance. The amount of service or research may vary from week to week but the average is usually expected to be 20 hours per week. • **Teaching Assistantships (TAs)** are offered for graduate students to perform teaching and other instructional activities. The amount of service may vary from week to week but the average is usually expected to be 20 hours per week. A teaching assistantship provides full tuition and a stipend. In accordance with University of Delaware regulations, foreign students must achieve a TOEFL score of at least 250 (computer-based) or 100 (Internet-based) in order to qualify for teaching assistantships.	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~~ 600 (paper-based) or 100 (Internet-based) in order to qualify for teaching assistantships.
B. CONTINUATION OF FINANCIAL AID	**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	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 Bioinformatics Graduate Committee at least four weeks prior to terminating the assistantship. he 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.	TA, the Course Director will notify the student and the Graduate Committee of the academic department offering the course. The Committee may recommend termination of the assistantship to the Department Chair.
X. APPENDIX III	**X. APPENDIX III**
COURSE DESCRIPTIONS	**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	**BIOINFORMATICS AND DATA SCIENCE CORE** • **Bioinformatics** BINF644: Bioinformatics (3) • Couples lectures and hands-on exercises to introduce the basic concepts and approaches of bioinformatics. The objectives are: (i) to introduce bioinformatics concepts, vocabularies, and basic algorithms, (ii) to familiarize with various bioinformatics tools, databases and resources, and (iii) provide an understanding of web-accessible bioinformatics applications. 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 • **Data Science**

• **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)	BINF694: Systems Biology I (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. BINF695: Computational Systems Biology (3) • Computational/mathematical techniques for modeling & analysis of biological systems. Includes properties of gene-regulatory and signaling networks; network reconstruction from data; stochastic modeling to study cellular variation & physiological modeling. • **Data Analytics** NURS/HLTH844: Population Healthcare Informatics (3) • Integrates knowledge of healthcare information

• 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.	technology and public health data to support and facilitate individual and population health management and improvement. Focuses on the analysis and application of information technologies that support the provision of care including social context, availability of technology, and structure of information along with legal, regulatory, and ethical concerns. Emerging technologies and contemporary issues are highlighted. 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. CISC684: Introduction to Machine Learning (3) • Development of methods to learn to solve a task using examples. Explore different machine learning algorithms/techniques and discuss their strengths and weaknesses and situations they are or are not suited for.
PREREQUISITES • **Introduction to Discipline** BISC654: Biochemical Genetics (3)	**PREREQUISITES** • **Introduction to Discipline**

• 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	BISC609: Molecular Biology of the Cell (3) • Introduction to the molecular biology of eucaryotes and procaryotes. Topics include structure and function of proteins and nucleic acids; replication and repair of DNA; biosynthesis of RNA and proteins; membranes, transport, composition and function of the eucaryotic cell, chromosomes, viruses, the immune system and recombinant DNA. BISC654: Biochemical Genetics (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. PLSC667: Applications of Genome Science: From Microbes to Mammals (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**	epigenetics, small RNAs, quantitative traits, chromosome structure and gene expression. PREREQ: PLSC300 and PLSC306. BINF690: Programming for Bioinformatics (3) • Examines principles of computer programming using Python language. Explores basic technique, syntax, best practices, advance programming concepts and basic algorithm designs through series of lectures, assignments and projects framed within the context of bioinformatics. Designed to teach Python to all levels, from beginner to experienced programmer. • **Database** BINF640: Databases for Bioinformatics (3) • Introduces data modeling, database management, and web hosting of relational databases. Coupling lectures and a modular, semester-long term project, students will: (i) collect bioinformatics data and design a relational data model; (ii) implement a relational database and write SQL queries and stored procedures; and (iii) create a simple website to access backend database. Upon completion, students will have the basic database management concepts and skills to develop a relational database supporting real-world bioinformatics applications CISC637: Database Systems (3)

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	• Physical and logical organization of databases. Data retrieval languages, relational database languages, security and integrity, concurrency, distributed databases. PREREQ: CISC220 and CISC304 or equivalent. • **Biostatistics** 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 STAT611: Regression Analysis (3) • Simple linear and nonlinear regression. Subset regression; principal component and ridge regression. Introduction to experimental design and design models.
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	**ELECTIVES** **Recommended Electives** CISC667: Introduction to Human-Computer Interaction (3) • Seminar 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

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

application areas. PREREQ: CISC220 and CISC304 or equivalent.

CISC684: Introduction to Machine Learning (3)

- Development of methods to learn to solve a task using examples. Explore different machine learning algorithms/techniques and discuss their strengths and weaknesses and situations they are or are not suited for.

CISC685: Modeling and Simulations for Bioinformatics Systems (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: CISC636.

~~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.~~

CISC844: Computational Biomedicine (3)

- Survey methods and approaches in algorithms, statistics and machine learning, along with their current

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

applications in bio- and medical- informatics.

EGGG667: Technical and Scientific Writing (3)

- Seminar

MAST607: Writing Papers in the Marine Sciences (3)

- The process and mechanics of publishing scientific papers in scientific journals. Covers organizing data in tables and figures; mechanics of drawing up effective figures; marshaling 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.

MEEG621: Linear Systems (3)

- State-space analysis of linear dynamical systems. Solution of state-space equations, and analysis of structural system properties based on eigenvalues and eigenvectors. Similarity transformations and decompositions. Lyapunov stability. Observability and controllability. State feedback control design. PREREQ: MATH349 or MATH351 or graduate status.

UAPP648: Environmental Ethics (3)

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

NURS/HLTH844: Population Healthcare Informatics (3)

- Integrates knowledge of healthcare information technology and public health

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.

data to support and facilitate individual and population health management and improvement. Focuses on the analysis and application of information technologies that support the provision of care including social context, availability of technology, and structure of information along with legal, regulatory, and ethical concerns. Emerging technologies and contemporary issues are highlighted.

~~UAPP650: Values Ethics and Leadership (3)~~

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

BUAD840: Ethical Issues in Global Business Environments (3)

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

Electives

BHAN856: Multivariable Biostatistics (3)

- Provides an understanding of the theory and application of the general and generalized linear models to the analysis of population-based data. Emphasis will be placed on generating and interpreting results and health-related

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 applications. PREREQ: STAT656 or permission of instructor

BINF650: Protein Modifications: Protein Structure and Function (3)

- Presents a survey of protein modifications, how to detect them and determine their structure using mass-spectrometry, diffraction, and NMR with an emphasis on proteomic and bioinformatic approaches. An overview will consider how modifications arise and evolve, their roles in metabolism and disease, and methods for predicting them.

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.

BISC605: Advanced Mammalian Physiology (3)

- Systemic mammalian physiology: cellular mechanisms, muscle, cardiovascular, respiratory, renal, digestive and endocrine systems. Emphasizes human physiology and includes discussions of primary literature in the field of physiology research. PREREQ: BISC306 or instructor's approval.

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	BISC610~~620~~: Endocrine Physiology (3) • Focus on how hormones produced by endocrine glands regulate physiological functions. Endocrine glands include pancreas, thyroid, adrenal, pituitary and reproductive organs, which produce hormones affecting reproduction, metabolism, growth and development. Endocrine dysfunction underlies disorders such as diabetes, cancer, stress, obesity, osteoporosis, and infertility. PREREQ: BISC305, BISC306 and permission of instructor. 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) • Explore mechanisms underlying development. Topics: gamete interactions, establishment of body plans, cell signaling and tissue interactions, morphogenetic pattern formation, developmental regulation of gene expression, molecular control of tissue specification and diversification, and the evolutionary comparison of developmental processes. Diseases resulting from

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	developmental defects will be discussed. PREREQ: BISC401 and BISC403. Requires instructor approval. BISC625: Cancer Biology (3) • Provides an integrated lecture series summarizing current knowledge in cancer biology. Topics include: statistics of incidence/survival, pathology, the process of chemical carcinogenesis and sources of carcinogens, genetic and epigenetic mechanisms and consequences, viral and hormonal carcinogenesis as well as current treatment options. PREREQ: BISC207, BISC401, CHEM103, CHEM104, CHEM321 and permission of instructor. 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 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.

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	Requires permission of instructor. 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. PREREQ: BISC300 BISC690: Fundamentals of Pharmacology (3) • Focus on basic principles of drug/receptor interactions, mechanisms of drug action, and pharmacokinetics. Emphasis on pharmacological problems in the current experimental literature. Goals are to understand drug-receptor theory, interpret agonist/antagonist dose-reponse relationships, and interpret results from experimental literature in written and oral formats. BISC833: Special Topics in Biology: Grant Writing (1) • Various topics in biology.

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)	~~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~~ 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:

• 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)	CHEM527 or CHEM641; MATH305. 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 or permission of instructor. CHEM641: Biochemistry (3) • Structure and function of proteins, enzymes and coenzymes; kinetics and mechanisms; carbohydrate metabolism and its regulation; and citric acid cycle.. PREREQ: CHEM322 or CHEM332. 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. 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. CHEM649: Molecular Biophysics (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

- 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.

CISC640: Computer Graphics (3)

- Computer graphics technology, two- and three-dimensional systems, graphics software systems, modeling and object hierarchy, and animation. PREREQ: CISC220 or equivalent.

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	CISC642: Introduction to Computer Vision (3) • An introduction to the analysis of images and video in order to recognize, reconstruct, model, and otherwise infer static and dynamic properties of objects in the three-dimensional world. Studies the geometry of image formation; basic concepts in image processing such as smoothing, edge and feature detection, color, and texture; segmentation; shape representation including deformable templates; stereo vision; motion estimation and tracking; techniques for 3-D reconstruction; image registration methods.. PREREQ: CISC220 equivalent. CISC650: Computer Networks II (3) • Foundation principles, architectures, and techniques employed in computer and communication networks. Focuses on mechanisms used in TCP/IP protocol suite. Topics include connection management, end-to-end reliable data transfer, sliding window protocols, quality of service, flow control, congestion control, routing, LANs, framing, error control, analog versus digital transmission, packet versus circuit switching, multiplexing. PREREQ: An undergraduate level course in computer architecture and operating systems. CISC675: Object Oriented Software Engineering (3)

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.

- Understand and apply a complete modern software engineeringprocess. Topics include requirements analysis, specification, design,implementation, verification, and project management. Real-life teamprojects cover all aspects of software development lifecycle, from requirements to acceptance testing. Use of formal methods in the specification, design, and verification of software will be explored. PREREQ: By permission of instructor only.

~~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.

CISC849: Advanced Topics in Computer Applications (3)

- Contents vary to coincide with the interests of students and

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.	faculty. PREREQ: Requires permission of instructor 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. 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~~

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

~~that learn from data to solve a task will be discussed. A range of modern machine learning algorithms will be covered.~~

CISC889: Advanced Topics in Artificial Intelligence (3)

- Contents vary to coincide with the interests of students and faculty. PREREQ: CISC681.

CPEG655 ~~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

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)

- Fourier transform, z-transform, digital filter design, relationship to analog. RESTRICTIONS: Requires permission of instructor.

ELEG652: Principles of Parallel Computer Architectures (3)

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
- 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.

CPEG655 ~~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

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,

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)

Lyapunov stability analysis, mass action kinetics, Hamming spaces, reaction-diffusion equations, and numerical simulation. 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)

- 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

KAAP602: Data Analysis and Interpretation in Health Sciences (3)

- Overview of statistical practice in health sciences research, particularly experimental research. Topics include experimental design, regression, analysis of variance including repeated measures designs and nonparametric tests.

~~KAAP654: Medical Physiology (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~~

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

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.	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 MAST626: Microbial Molecular Genetics (3) • A survey of molecular genetic methods to interrogate and modify the function of bacterial and archaeal genomes. PREREQ: MAST634 or BISC654 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. ~~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 Discretization ~~Introduction to Numerical Analysis and Scientific Computing~~ (3) • Piecewise polynomial and global interpolation, adaptive, Gaussian, and multidimensional quadrature, Runge-Kutta and multistep methods for initial value problems, finite differences for boundary value problems, method of lines for partial differential equations. 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: Multivariate calculus and ordinary differential equations ~~Linear algebra and multivariate calculus~~. ~~TERM: Fall Semester~~ MATH637: Mathematical Techniques in Data Science (3) • Linear methods for regression (subset selection, ridge, lasso), Logistic regression. Analysis of the convergence and complexity of common algorithms. Linear discriminant analysis, Principal component analysis, Additive Models, Kernel Smoothing. Cross-validation, Bootstrap, Support Vector Machines, Cluster analysis (K-means, spectral clustering), Undirected graphical models, Expectation maximization algorithm, Introduction to deep learning, Introduction to Bayesian methods. PREREQ: Probability theory and basic statistics (e.g. MATH 350), Multivariable calculus (e.g. MATH 243), Linear Algebra (e.g. MATH 349), Optimization background (e.g. MATH 529) desirable but not necessary, basic computing skills. PHYT632: Applied Physiology I (3) • In-depth analysis of the physiological mechanisms of the cardio-pulmonary system. Lectures in normal and abnormal function of this system. Emphasis on cardiopulmonary testing and rehabilitation techniques

	including stress tests and pulmonary function tests. PREREQ: PHYT 622; PHYT 631; PHYT 801. ~~PLSC667: Analytical Plant Genetics~~ (3) PLSC671: 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. STAT608: Statistical Research Methods (3) • An introductory statistics course for advanced undergraduate and graduate students with applications for life sciences, business, health, engineering, and the social sciences. The course managing and describing data; the normal, t, F and chi squared distributions; the logic of inference; inferential statistics for one and two sample problems; analysis of table data; analysis of variance; and multiple regression. The course is taught using statistical software. ~~Experimental design and plot plans, collection, analysis and presentation of data in agricultural and biological research. TERM: Fall Semester~~ STAT612: Advanced Regression Techniques (3) • Selected topics in advanced regression analysis.

	RESTRICTIONS: Requires permission of instructor. 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: STAT471 ~~STAT371. TERM: Fall Semester~~ STAT617: Multivariate Methods (3) • Multivariate analysis of variance and covariance; classification and discrimination; canonical correlation; principal components; factor analysis. PREREQ: STAT602. 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. RESTRICTIONS: Requires permission of instructor. STAT621: Survival Analysis (3) • Statistical techniques used in the analysis of censored data including the Kaplan-Meier estimator, the analysis of one, two and K sample problems, and regression analysis based on the Cox proportional hazards model. RESTRICTIONS: Requires permission of instructor. STAT670: Introduction to Statistical Analysis I (3) • Basic probability, De Morgan's laws, conditional probabilities, Bayes' rule; discrete and continuous distributions;

	Bernoulli, Binomial, Poisson, Normal, Gamma and Cauchy distributions; transformations; joint and marginal distributions; moment generating functions; sums of independent normal and Gamma random variables; Chi-squared distributions; the Central Limit Theorem. ~~Basic probability; continuous, discrete and joint distributions; distribution of functions of random variables; order statistics; expected value and central limit theorem.~~ PREREQ: MATH222 or MATH242. STAT671: Introduction to Statistical Analysis II (3) • Definition of a statistic; distribution of common statistics; sampling, maximum likelihood and moment estimators, unbiased estimators; hypothesis testing, Type I and Type II errors, one- and two-sample tests for the mean; categorical data, the Chi-Squared test; simple linear regression, ANOVA table. ~~Distributions of common statistics, sampling techniques, estimation, confidence intervals, hypotheses testing and selected topics.~~ PREREQ: MATH222 or MATH242. STAT674: Applied Data Base Management (3) • Provides an in-depth understanding of using computers to manage data using programs such as SAS and Microsoft/Access. May be offered concurrently with STAT 474. RESTRICTIONS:

	Requires permission of instructor. **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. BINF969 ~~964~~: Doctoral Dissertation (1-6) • Independent dissertation research after completion of the Candidacy Examination.

TABLES

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

Table ~~6~~1. Ph.D. Program Course Requirements Summary

Degree Requirements (~~36 - 45~~33 - 42 Credits)	
Core and Elective Courses (15 - 24 Credits)	
Bioinformatics and ~~Systems Biology~~Data Science Core	9 Credits
Prerequisites – Direct Admit Students	3-9 Credits
Electives	6 Credits
Seminar and Research (18 Credits)	
Seminar*	~~6~~3 Credits
Research	6 Credits
Doctoral Dissertation	9 Credits

*Attendance in seminar is required for six semesters.

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 ~~7~~ 2. PhD Program Course Curriculum

Course Curriculum (33-42 credits)	
Bioinformatics Data Science Core (9)	
Bioinformatics (3) [select one]	
Bioinformatics	BINF~~ANFS~~644: Bioinformatics (3)
	CISC636: Bioinformatics and Computational Biology (3)
Data Science (6) [select two]	
Systems Biology [select one]	BINF694 ~~697/MAST698/ANFS667~~: Systems Biology I: ~~Experimental Techniques and Bioinformatics Analysis of Omics Data~~ (3)
	BINF695~~698/MATH660~~: Computational Systems Biology ~~II: Computational Modeling of Processes in Cells and Biological Systems~~ (3) ~~[Or Systems Biology recommended elective upon approval*]~~
Data Analytics* [select one]	NURS/HLTH 844 Population Healthcare Informatics (3)
	CISC681 Artificial Intelligence (3)
	CISC683 Introduction to Data Mining (3)
	CISC684 Introduction to Machine Learning (3)
Prerequisites – if required (3-9)**	
Introduction to Discipline (3) [select one]	BISC609: Molecular Biology of the Cell (3)
	BISC654: Biochemical Genetics (3) ~~PLSC636: Plant Genes and Genomes (3)~~
	BINF690: Programming for Bioinformatics (3)~~MAST697: Bioinformatics Programming for Biologists (3)~~
	PLSC667: Applications of Genome Science: From Microbes to Mammals (3)****
Database (3) [select one]	BINF640: Databases for Bioinformatics (3)
	CISC637: Database Systems (3)
Biostatistics (3) [select one]	~~STAT613: Multivariate Statistical Methods with Biology Applications (3)~~
	STAT656: Biostatistics (3)
	STAT611: Regression Analysis (3)
Electives (6)	Select from Elective list (see Table 3~~8~~)
Seminar (3~~6~~)	
Seminar	BINF865: Seminar (0-1)***
Research (6)	
Research	BINF868: Research (1-6) - Until successful completion of preliminary exam
	BINF964: Pre-Candidacy (1-6) - Until successful completion of candidacy exam
Doctoral Dissertation (9)	
Doctoral Dissertation	BINF969: Doctoral Dissertation (1-9)

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

Table ~~8~~ 3. PhD Program Electives

Recommended Electives
BISC609: Molecular Biology of the Cell (3)
BINF690: Programming for Bioinformatics (3)
BINF695: Computational Systems Biology (3)
BISC654: Biochemical Genetics (3)
CISC667 Introduction to Human-Computer Interaction (3)****
CISC681 Artificial Intelligence (3)
CISC683 Introduction to Data Mining (3)
CISC684 Introduction to Machine Learning (3)
CISC685 Modeling and Simulations for Bioinformatics Systems (3)
~~CISC841 Algorithms in Bioinformatics (3)~~
CISC844 Computational Biomedicine (3)
~~ELEG671 Mathematical Physiology (3)~~
~~EGGG667 Technical and Scientific Writing (3)~~
~~EGGG867: Writing Academic Research in Engineering and Science (3)~~
~~MAST607 Writing Papers in the Marine Sciences (3)~~
~~MEEG621 Linear Systems (3)~~
~~UAPP648 Environmental Ethics (3)~~
NURS/HLTH 844 Population Healthcare Informatics (3)
PLSC667: Applications of Genome Science: From Microbes to Mammals (3)****
~~UAPP650 Values Ethics and Leadership (3)~~
BUAD840 Ethical Issues in Global Business Environments (3)
Electives
~~ANFS670: Principles of Molecular Genetics (3)~~
~~ANFS/PLSC671: Paradigms in Cell Signaling (3)~~
BHAN 856 Multivariable Biostatistics (3)
~~BINF601: Protein Modifications: a Proteomics and Bioinformatics Approach (3)*~~
BINF650 Protein Modifications: Protein Structure and Function (3)
~~BISC600: Biotechnology and Molecular Medicine (3)~~
BISC602 Molecular Biology of Animal Cells (3)
BISC605 Advanced Mammalian Physiology (3)
BISC612 Advanced Cell Biology (3)
BISC615 ~~Vertebrate~~ Developmental Biology (3)
BISC61~~2~~0 Endocrine Physiology (3)
BISC625 Cancer 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)
BISC690 Fundamentals of Pharmacology (3)
~~BISC693: Human Genetics (3)~~
BISC833 Special Topics in Biology: Grant Writing (1)
~~CHEG620 Biochemical Engineering (3)~~
CHEG621 Metabolic Engineering (3)
CHEM624 Principles of Mass Spectrometry (3)
CHEM641 Biochemistry (3)
CHEM645 Protein Structure and Function (3)
CHEM646 DNA-Protein Interactions (3)
CHEM649 Molecular Biophysics (3)
CISC621 Algorithm Design and Analysis (3)
CISC640 Computer Graphics (3)
CISC642 Introduction to Computer Vision (3)
CISC650 Computer Networks (3)
CISC675 Object Oriented Software Engineering (3)
CISC683 Introduction to Data Mining (3)
CISC849 Advanced Topics in Computer Applications (3)
CISC882 Natural Language Processing (3)
CISC886 Multi-Agent Systems (3)
~~CISC887 Internet Information Gathering (3)~~
~~CISC888 Machine Learning (3)~~
CISC889 Advanced Topics in Artificial Intelligence (3)
CPEG655 ~~ELEG655~~ High-Performance Computing with Commodity Hardware (3)
CPEG~~/ELEG~~657 Search and Data Mining (3)
ELEG633 Image Processing (3)
ELEG652 Principles of Parallel Computer Architectures (3)
ELEG671 Mathematical Physiology (3)
ELEG679 Introduction to Medical Imaging Systems (3)
ELEG680 Immunology for Engineers (3)
KAAP602 Data Analysis and Interpretation in Health Sciences (3)
~~KAAP654 Medical Physiology (3)~~
MAST607 Writing Papers in the Marine Sciences (3)
MAST616 Methods in Molecular Biology (3)
MAST618 Microbial Ecology (3)
MAST623 Physiology of Marine Organisms (3)
MAST625 Microbial Physiology and Diversity (3)
MAST626 Microbial Molecular Genetics (3)

MAST634 Marine Molecular Sciences (3)
~~MATH607: Survey of Scientific Computing (3)~~
MATH611 Introduction to Numerical Discretization ~~Introduction to Numerical Analysis and Scientific Computing~~ (3)
MATH637 Mathematical Techniques in Data Science (3)
~~MATH667: Math for Life Scientists (3)~~*
MEEG621 Linear Systems (3)
~~PLSC644 Physiology of Plant Stress (3)~~
~~PLSC667 Analytical Plant Genetics~~ (3)
PLSC671 Paradigms in Cell Signaling (3)
STAT608 Statistical Research Methods (3)
STAT612 Advanced Regression Techniques (3)
STAT615 Design and Analysis of Experiments (3)
STAT617 Multivariate Methods (3)
STAT619 Time Series Analysis (3)
STAT621 Survival Analysis (3)
STAT670 Introduction to Statistical Analysis I (3)
STAT671 Introduction to Statistical Analysis II (3)
STAT674 Applied Data Base Management (3)

* substitution requires permission of Dissertation Committee and Graduate Program Director.

** necessary for students lacking equivalent courses

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

**** new course being developed