UNC CHARLOTTE
Office of Academic Affairs

9201 University City Boulevard, Charlotte, NC 28223-0001

TO: Faculty Council Members

FROM: Charles Bodkin, Faculty President

DATE: April 19, 2011

RE: Consent Calendar

Attached is the Consent Calendar (See Article V, Section 3.A (3 & 4), J. (3 & 5) and K.3 of the Standing Rules of the Faculty Council.) consisting of these proposals:

- BINF 1-7-11 Course and Curriculum Additions and Changes in Bioinformatics and Genomics
- BINF 2-25-11 Graduate and Undergraduate Course Additions for the Department of Bioinformatics and Genomics

Below are the catalog copy descriptions. If you wish to read the full proposals, they are posted on the Academic Affairs website.

If there are any objections regarding these proposals, they must be registered with the Faculty Governance Assistant (Clarence Greene, ext. 5719) by **5 PM on May 3, 2011**. If no objections are registered, the proposals will stand approved.

Course and Curriculum Additions and Changes in Bioinformatics and Genomics

PROPOSED CATALOG COPY

BIOINFORMATICS

Department of Bioinformatics and Genomics

Bioinformatics Building, Room 309
704-687-8541
http://bioinformatics.uncc.edu/

Program Chair

Dr. Lawrence Mays

Undergraduate Faculty

Cory Brouwer, Associate Professor

Xiuxia Du, Assistant Professor
Anthony Fodor, Assistant Professor
Cynthia Gibas, Associate Professor
Jun-tao Guo, Assistant Professor
Dennis Livesay, Associate Professor
Ann Loraine, Associate Professor
Lawrence Mays, Professor
Jessica Schlueter, Assistant Professor
Shannon Schlueter, Assistant Professor
Susan Sell, Professor
ZhengChang Su, Assistant Professor
Jennifer Weller, Associate Professor

Adjunct Faculty

Marjorie Benbow

Minor in BIOINFORMATICS and GENOMICS

Designed to introduce students to the collection, informatics analysis and interpretation of data derived from genomic and biological macromolecular investigations, this minor field of study will provide students with a foundation of understanding and the computing skill necessary to communicate in the increasingly data-centric life sciences. In addition to gaining first-hand experience with current technologies for high-throughput data generation, students will receive training in up-to-date methods for data handling and interpretation while developing an understanding of critical issues in bioinformatics research design, statistical data analysis, and the application of genomics domain knowledge.

Program requirements:

The minor in Bioinformatics and Genomics requires 19 credit hours consisting of the following required courses.

- BINF 1101: Introduction to Bioinformatics and Genomics
- BINF 2101: Genomic Methods
- BINF 2101L: Genomic Methods Lab
- BINF 2111: Introduction to Bioinformatics Computing
- BINF 2121: Statistics for Bioinformatics
- BINF 3101: Sequence Analysis
- BINF 4600: Bioinformatics Seminar

BINF 1101 Introduction to Bioinformatics and Genomics (3). Designed to introduce students to the genomics perspective in the life sciences, this course combines a general introduction to genomic technologies and the bioinformatics methods used to analyze genome-scale data with a presentation of real world scientific problems where these technologies are having an impact. This course fulfills a general education science requirement. (*Fall*).

BINF 1101L Introduction to Bioinformatics and Genomics Lab (1). Prerequisite or corequisite: BINF 1101. Designed to introduce students to the genomics perspective in the life sciences, this course provides hands-on experience with biological sequence and structure databases, using small-scale projects to introduce students to the world of Bioinformatics research. One three-hour laboratory per week (*Fall*).

BINF 2101 Genomic Methods (3) Prerequisite: BIOL 1101 and 1101L [Principles of Biology I with Lab] or BIOL 2120 [General Biology I] or consent of instructor. Prerequisite or Corequisite: BINF 1101 [Introduction to Bioinformatics]; Corequisite: BINF2101L; Lecture topics are intended to introduce students to core concepts in genomics that allow bench scientists to acquire large datasets in a high-throughput manner as well as address the computational methods used to analyze these data resources. (*Spring*).

BINF 2101L Genomic Methods Lab (2) Corequisite: BINF 2101 [Genomic Methods]; This is the laboratory component of the genomics methods laboratory course. Labs are intended to give students hands-on experience in setting up and performing experiments with an emphasis on nucleic acid and protein profiling, understanding and trouble-shooting published protocols, interpreting the data using computational tools. (*Spring*).

BINF 2111 Introduction to Bioinformatics Computing (4) Prerequisite or Corequisite: BINF 1101 [Introduction to Bioinformatics and Genomics]. This course introduces fundamentals of programming for bioinformatics (sometimes called "scripting") using current programming languages and paradigms. This class will introduce both the language and the use of the language within a Unix environment, demonstrating how interpreted languages serve both as a useful tool for writing and testing programs interactively and as a powerful data analysis and processing tool for bioinformatics. (*Fall*).

BINF 2121 Statistics for Bioinformatics (3) Prerequisite or Corequisite: BINF 1101 [Introduction to Bioinformatics and Genomics]. Prerequisite: Satisfactory completion of either MATH 1103, MATH 1120, MATH 1121, MATH 1241, STAT 1220, STAT 1221, STAT 2122 or permission of instructor based on sufficient demonstration of foundational mathematics concepts. Concepts from probability, stochastic processes, information theory, and other statistical methods will be introduced and illustrated by examples from molecular biology, genomics and population genetics while exploring the use of the R and Bioconductor software for biostatistical analysis. (*Spring*)

BINF 3101 Sequence Analysis (3) Prerequisite or corequisite: BINF 2101 and BINF2101L [Genomics Methods and Genomic Methods Lab] or consent of instructor. This course covers the purpose, application, and biological significance of bioinformatics methods that identify sequence similarity, methods that rely on sequence similarity to produce models of biological processes and systems, as well as methods that use sequence characteristics to predict functional features in genomic sequence data. (*Fall*).

BINF 3111 Bioinformatics Algorithms (4) Prerequisite: ITCS 1212L [Programming I] or equivalent programming experience. Prerequisite or corequisite: BINF 3101 [Sequence Analysis]. This course introduces common algorithms and data structures used in Bioinformatics and Genomics. Consideration is given to the optimization and appropriate use of both through guided computational laboratory exercises. (*Spring*).

BINF 3211 Bioinformatics Databases and Data Mining Technologies (3) Prerequisite: BINF 1101 [Introduction to Bioinformatics and Genomics]. This is a lecture course that incorporates extensive computational exercises, some of which will be done in class. Lecture topics are intended to introduce students to core concepts in both database management system theory and implementation and in data modeling for genomics data types. Exercises are intended to give students practical experience in setting up and populating a database, using public data repositories and using standard tools for retrieving data (SQL), and further, using existing tools for data mining and visualization of genomics data types. Emphasis will be placed on standards and emerging practices. (*Spring*).

BINF 3900 Undergraduate Research (1-3). Prerequisites: BINF 1101 [Introduction to Bioinformatics and Genomics] and Permission of the instructor. Enables students in the Bioinformatics and Genomics program to initiate research projects in their respective fields of interest and to interact with faculty in pursuing research experience. May be repeated for credit. (*Fall, Spring, Summer*).

BINF 4101 Computational Systems Biology (3) Prerequisite: BINF 3101 [Sequence Analysis]. This course will cover the process of reconstructing complex biological networks. Reconstruction of metabolic networks, regulatory networks and signaling networks using bottom-up and top-down approaches will be addressed using collections of historical data as well as departmentally generated data. The principles underlying high-throughput experimental technologies and examples given on how this data is used for network reconstruction, consistency checking, and validation will be covered throughout the semester. (*On demand*).

BINF 4111 Structural Bioinformatics (3) Prerequisite: BINF 3101 [Sequence Analysis]. This course will cover: (*i.*) the physical forces that shape biological molecules, assemblies and cells; (*ii.*) overview of protein and nucleic acid structure; (*iii.*) experimental methods of structure determination; (*iv.*) data formats and software for structure visualization; (*v.*) computational methods to evaluate structure; (*vi.*) structural classification; (*vii.*) structure alignment; (*viii.*) computational algorithms for structure prediction; and (*ix.*) structural analysis of disease causing mutations. (*Spring*).

~~**BINF 4201. Introduction to Bioinformatics. (4)** Prerequisites: BIOL 2120 and BIOL 2130 or equivalent. Introduction to biological databases, commonly-used bioinformatics software for molecular sequence and structure analysis, and application of bioinformatics analysis in biological research. (Fall)~~

BINF 4450. Senior Project. (3) Prerequisites: senior standing and permission of the department. An individual or group project in the teaching, theory, or application of bioinformatics, genomics, or computational biology under the direction of a faculty member. Projects must be approved by the department before they can be initiated. (On demand)

BINF 4600 Bioinformatics and Genomics Seminar (1) Prerequisite: BINF 3101 [Sequence Analysis] or consent of instructor. This course is a senior level seminar course designed to introduce students to the research being conducted in both the Bioinformatics and Genomics Department here at UNCC as well as through invited speakers from other universities. (*Fall, Spring*).

BINF 2-25-11 Graduate and Undergraduate Course Additions for the Department of Bioinformatics and Genomics

PROPOSED CATALOG COPY

BIOINFORMATICS

Department of Bioinformatics and Genomics

Bioinformatics Building, Room 309
704-687-8541
http://bioinformatics.uncc.edu/

Degrees

Professional Science Masters in Bioinformatics
Ph.D. in Bioinformatics and Computational Biology

Program Chair

Dr. Lawrence Mays

Program Directors

Dr. Dennis Livesay (PhD program)
Dr. Cynthia Gibas (PSM program)

Graduate Faculty

Cory Brouwer, Associate Professor
Xiuxia Du, Assistant Professor
Anthony Fodor, Assistant Professor
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Susan Sell, Professor
ZhengChang Su, Assistant Professor
Jennifer Weller, Associate Professor

Adjunct Faculty
Marjorie Benbow

Ph.D. in BIOINFORMATICS and COMPUTATIONAL BIOLOGY

The Ph.D. in Bioinformatics and Computational Biology (BCB) is granted for planning, execution and defense of original research resulting in significant contributions to the discipline's body of knowledge. To that end, the BCB Ph.D. program also requires didactic coursework to prepare the student for research success. Student progress is primarily assessed by: (a) satisfactory coursework performance, (b) the Qualifying Examination, (c) the Dissertation Proposal and (d) the Dissertation Defense. Courses and the Qualifying Examination are used to ensure that the student has sufficient breadth of knowledge. The Dissertation Proposal is used to ensure that the scope of dissertation research is important, that the plan is well thought out and that the student has sufficient skills and thoughtfulness needed for success. The Dissertation Defense is used to assess the outcomes of the dissertation research, and whether or not the plan agreed upon by the Dissertation Committee has been appropriately adhered to.

Didactic Curriculum
In consultation with their Academic Advisor and/or Program Director, students must take an appropriate selection of the following Gateway Courses. For example, an incoming student with a Computer Science background would be expected to take 8100 and 8101, but not 8111 and 8112. All students must complete the Core Courses prior to taking the Qualifying Examination. Each Ph.D. student must complete two Research Rotations in the first year. Each Research Rotation provides a semester of faculty supervised research experience to supplement regular course offerings. Graduate Research Seminar is taken every semester until the semester following advancement to candidacy. Finally, many additional Elective Courses are available, but are not explicitly required.

Gateway Courses:
- BINF 8100 Biological Basis of Bioinformatics
- BINF 8101 Energy and Interaction in Biological Modeling
- BINF 8111 Bioinformatics Programming I
- BINF 8112 Bioinformatics Programming II

Core Courses:
- BINF 8200 Statistics for Bioinformatics
- BINF 8201 Molecular Sequence Analysis
- BINF 8202 Computational Structural Biology

Research Rotations:
- BINF 8911 Research Rotation I
- BINF 8912 Research Rotation II

Graduate Research Seminar:

- BINF 8600 Seminar

Qualifying Examination

Prior to defining a research topic, students are required to pass a Qualifying Examination to demonstrate proficiency in bioinformatics and computational biology, as well as competence in fundamentals common to the field. The Qualifying Examination must be passed prior to the fifth semester of residence. It is composed of both written and oral components that emphasize material covered in the Core Courses listed above.

Dissertation Proposal

Each student must present and defend a Ph.D. Dissertation Research Proposal after passing the Qualifying Examination and within ten semesters of entering the Program. The Dissertation Proposal will be conducted by the student's Dissertation Committee, and will be open to faculty and students. The proposal must address a significant, original and substantive piece of research. The proposal must include sufficient preliminary data and a timeline such that the Dissertation Committee can assess its feasibility.

Dissertation

Each student must complete a well-designed original research contribution, as agreed upon by the student and Dissertation Committee at the Dissertation Proposal. The Ph.D. Dissertation is a written document describing the research and its results, and their context in the sub-discipline. The Dissertation Defense is a public presentation of the findings of the research, with any novel methods that may have been developed to support the conclusions. The student must present the Dissertation and defend its findings publicly, and in a private session with the Dissertation Committee immediately thereafter.

PROFESSIONAL SCIENCE MASTER'S IN BIOINFORMATICS

Additional Admission Requirements

In addition to the general requirements for admission to the Graduate School, the following are required for admission to the Professional Science Master's (PSM) in Bioinformatics:

Under most circumstances, students admitted to the program will have:

1) A baccalaureate degree from an accredited college or university in Biology, Biochemistry, Chemistry, Physics, Mathematics, Statistics, Computer Science, or another related field that provides a sound background in life sciences, computing, or both.
2) A minimum undergraduate GPA of 3.0 (4.0 scale) and 3.0 in the major.
3) A minimum combined score of 1000 on the verbal and quantitative portions of the GRE, and acceptable scores on the analytical and discipline-specific sections of the GRE.
4) A combined TOEFL score of 220 (computer-based), 557 (paper-based), or 83 (internet-based) is required if the previous degree was from a country where English is not the common language.
5) Positive letters of recommendation.

Degree Requirements

The Professional Science Masters (PSM) in Bioinformatics degree requires a minimum of 37 graduate credit hours, and a minimum of 33 credit hours of formal course work. A minimum of 24 credit hours presented toward a PSM in Bioinformatics must be numbered 6000 or higher. A maximum of 6 hours of graduate credit may be transferred from other institutions.

1. Total hours required. The program requires 37 post baccalaureate credit hours. Because of the interdisciplinary nature of this program, which is designed to provide students with a common graduate experience during their professional preparation for the PSM in Bioinformatics degree, all students will be required to take a general curriculum that includes a two-year sequence of courses as described below:

2. Core Requirements.
a. Fundamentals Courses
The **Fundamentals** course sequences are intensive graduate-level courses designed to provide accelerated training in a second discipline that complements the student's undergraduate training. Students entering the program are expected to have achieved proficiency in either Biological Sciences or
Computing, and to require at most two of the
Fundamentals courses.

Fundamental Biology track: This course sequence is designed for students entering with a degree in Computer Science or another quantitative science discipline. The Fundamental Biology course sequence provides accelerated training in Genetics, Cell and Molecular Biology, and Biochemistry. BINF 6100 (Biological Basis of Bioinformatics), 6101 (Energy and Interaction in Biological Modeling).

Fundamental Computing track: The Fundamental Computing track is designed for students entering with a degree in a life science discipline. The Fundamental Computing course sequence provides accelerated training in programming and data structures. BINF 6111, 6112 (Bioinformatics Programming I and II).
b. Core Bioinformatics Courses
Fundamentals courses prepare students for the
required **Core** courses. All students must take BINF 6200, Statistics for Bioinformatics. In addition, students must take 6 additional credit hours of **Core Genomics** courses from among BINF 6201 (Molecular Sequence Analysis), BINF 6203 (Genomics), BINF 6205 (Computational Molecular Evolution) and BINF 6350 (Biotechnology and Genomics Laboratory) and 6 credit hours from the **Core Computational** courses from among 6202 (Computational Structural Biology), BINF 6204 (Mathematical Systems Biology), BINF 6210 (Numerical Methods and Machine Learning for Bioinformatics) and BINF 6310 (Advanced Statistics for Genomics).
c. Professional Preparation Requirement
Students are required to take at least 3 credit hours of electives designed to prepare them to function effectively and ethically in a professional environment. Some recommended electives in this category include BINF 5171, Business of Biotechnology, BINF 5191, Biotechnology and the Law, BINF 6151, Professional Communications, PHIL 6050, Research Ethics, and ITIS 6362, Information Technology Ethics, Policy, and Security. Additional elective choices that may fulfill this requirement can be identified by the student and the student's Advisory Committee.
d. The remaining credit hours of formal course work can be completed in additional **Core Bioinformatics** courses and/or other recommended program electives.

The student's Advisory Committee will review the student's plan of study each semester.
Bioinformatics Electives: Any courses with BINF numbers, with the exception of **Fundamentals** courses, which require approval, are open to PSM students seeking to complete their coursework requirements.
Recommended Electives offered by other units: A wide range of courses in Biology, Chemistry, Computer Science, Software and Information Systems, and other departments may be appropriate electives for PSM in Bioinformatics students. As course offerings change frequently, the Bioinformatics Program maintains a list of current recommended electives, which can be found online at bioinformatics.uncc.edu.
e. Other requirements
• *Bioinformatics Seminar.* In addition to 33 hours
of formal coursework, students are required to enroll in the Bioinformatics Program seminar (BINF 6600) for at least one semester (1 credit hour) and to enroll in either an approved internal or external internship (BINF 6400) or a faculty-supervised original research project leading to a thesis (BINF 6900).
• *Grades required.* An accumulation of three C grades will result in suspension of the student's enrollment in the graduate program. If a student makes a grade of U in any course, enrollment in the program will be suspended.
• *Amount of transfer credit accepted.* A maximum of 6 credit hours of coursework from other institutions will count toward the PSM in Bioinformatics degree requirements. Only courses with grades of A or B from accredited institutions are eligible for transfer credit.

COURSES IN BIOINFORMATICS

BINF 4171. **Business of Biotechnology. (3)** Prerequisite: Junior or senior status in a scientific/technical course of study or if in a non-biological/technical or scientific program, special permission of the instructor. This course introduces students to the field of biotechnology and how biotech businesses are created and managed. The students should be able to define biotechnology and understand the difference between a biotech company and a pharmaceutical company. Additional concepts covered will include platform technology, biotechnology's history, biotechnology products and development processes, current technologies used by biotech companies today, biotechnology business fundamentals, research and development within biotech companies, exit strategies, and careers in the biotech field. (Spring)

BINF 4191. Biotechnology and the Law (3)
Prerequisite: Junior or senior status in a scientific/technical course of study or if in a non-biological/technical or scientific program, special permission of the instructor. At the intersection of biotechnology and the law, an intricate body of law is forming based on constitutional, case, regulatory and administrative law. This body of legal knowledge is interwoven with ethics, policy and public opinion. Because biotechnology impacts everything in our lives, the course will provide an overview of salient legal biotechnology topics, including but not limited to: intellectual property, innovation and approvals in agriculture, drug and diagnostic discovery, the use of human and animal subjects, criminal law and the courtroom, agriculture (from farm to fork), patient care, bioethics, and privacy. The body of law is quite complex and it is inundated with a deluge of acronyms. The course will provide a foundation to law and a resource to help students decipher laws and regulation when they are brought up in the workplace. (Fall)

BINF 5171. Business of Biotechnology. (3)
Prerequisite: Admission to a graduate program. This course introduces students to the field of biotechnology and how biotech businesses are created and managed. The students should be able to define biotechnology and understand the difference between a biotech company and a pharmaceutical company. Additional concepts covered will include platform technology, biotechnology's history, biotechnology products and development processes, current technologies used by biotech companies today, biotechnology business fundamentals, research and development within biotech companies, exit strategies, and careers in the biotech field. (Spring)

BINF 5191. Biotechnology and the Law (3)
Prerequisite: Admission to a graduate program. At the intersection of biotechnology and the law, an intricate body of law is forming based on constitutional, case, regulatory and administrative law. This body of legal knowledge is interwoven with ethics, policy and public opinion. Because biotechnology impacts everything in our lives, the course will provide an overview of salient legal biotechnology topics, including but not limited to: intellectual property, innovation and approvals in agriculture, drug and diagnostic discovery, the use of human and animal subjects, criminal law and the courtroom, agriculture (from farm to fork), patient care, bioethics, and privacy. The body of law is quite complex and it is inundated with a deluge of acronyms. The course will provide a foundation to law and a resource to help students decipher laws and regulation when they are brought up in the workplace. (Fall)

BINF 6100. Biological Basis of Bioinformatics. (3)
Prerequisites: Admission to graduate standing in Bioinformatics and undergraduate training in Computer Science or other non-biological discipline. This course provides a foundation in molecular genetics and cell biology focusing on foundation topics for graduate training in bioinformatics and genomics. (Fall)

BINF 6101. Energy and Interaction in Biological Modeling. (3)
Prerequisites: Admission to graduate standing in Bioinformatics. This course covers: (i.) the major organic and inorganic chemical features of biological macromolecules; (ii.) the physical forces that shape biological molecules, assemblies and cells; (iii.) the chemical driving forces that govern living systems; (iv.) the molecular roles of biological macromolecules and common metabolites; (v.) and the pathways of energy generation and storage. Each section of the course builds upon the relevant principles in biology and chemistry to explain the most common mathematical and physical abstractions used in modeling in the relevant context. (Spring)

BINF 6111. Bioinformatics Programming I. (3)
Prerequisites: Admission to graduate standing in Bioinformatics. This course introduces fundamentals of programming for bioinformatics using a high-level object-oriented language such as python. The first weeks cover core data types, syntax, and functional programming, focusing on construction of programs from small, testable parts. Students will learn productive use of the Unix environment, focusing on Unix utilities that are particularly useful in bioinformatics. The course will cover object-oriented programming, introduce analysis of algorithms and sequence alignment methods, and introduce computational environments that are particularly useful in bioinformatics analyses such as R, BioPython, and Web services in bioinformatics. By the end of the class, students

will have gained the ability to analyze data within the python interpreter (for example) and write well-documented, well-organized programs. (Fall)

BINF 6112. Bioinformatics Programming II. (3)
Prerequisite: BINF 6111. This course is the second semester of Introduction to Bioinformatics Programming I. In this semester, students will practice and refine skills learned in the first semester. New topics introduced will include: programming as part of a team, using sequence analysis algorithms in realistic settings; writing maintainable and re-usable code; Web programming; and graphical user interface development. At the end of the semester, students will be able to evaluate and deploy computer languages, tools, and software engineering techniques in bioinformatics research. (Spring)

BINF 6151/GRAD 6151. Professional Communications. (1) This course covers: Principles and useful techniques for effective oral presentations, poster presentations, scientific writing, use of references and avoiding plagiarism. Students in the class will critique and help revise each other's presentations and learn how to avoid common pitfalls. In addition, students will learn how to properly organize and run a meeting. Students will prepare a CV, job application letter and job talk. (Fall).

BINF 6200. Statistics for Bioinformatics. (3)
This course aims to introduce students to statistical methods commonly used in bioinformatics. Basic concepts from probability, stochastic processes, information theory, and other statistical methods will be introduced and illustrated by examples from molecular biology, genomics and population genetics with an outline of algorithms and software. R is introduced as the programming language for homework. (Fall)

BINF 6201. Molecular Sequence Analysis. (3)
Prerequisite: BINF 6100 or equivalent. Introduction to bioinformatics methods that apply to molecular sequences. Introduction to biological databases online includeing sequence databases, molecular sequence data formats, sequence data preparation and database submission; local and global sequence alignment, multiple alignment, alignment scoring and alignment algorithms for protein and nucleic acids, gene finding and feature finding in sequences, models of molecular evolution, phylogenetic analysis, and comparative modeling. (Fall)

BINF 6202. Computational Structural Biology. (3)
Prerequisite: BINF 6101, 6201 or equivalents. This course covers: **(a)** the fundamental concepts of structural biology (chemical building blocks, structure, superstructure, folding, etc.); **(b)** structural databases and software for structure visualization; **(c)** structure determination and quality assessment; **(d)** protein structure comparison and the hierarchical nature of biomacromolecular structure classification; **(e)** protein structure prediction and assessment; and **(f)** sequence- and structure-based functional site prediction. (Fall)

BINF 6203. Genomics. (3)
Prerequisite: BINF 6100 or equivalent. This course surveys the application of high-throughput molecular biology and analytical biochemistry methods and data interpretation for those kinds of high volume biological data most commonly encountered by bioinformaticians. The relationship between significant biological questions, modern genomics technology methods, and the bioinformatics solutions that enable interpretation of complex data is emphasized. Topics include: Genome sequencing and assembly, annotation, and comparison; genome evolution and individual variation; function prediction; gene ontologies; transcription assay design, data acquisition, and data analysis; proteomics methods; methods for identification of molecular interactions; and metabolic databases, pathways and models. (Spring)

BINF 6204. Mathematical Systems Biology. (3)
Prerequisites: BINF 6200 and 6210 or equivalents. This course introduces basic concepts, principles and common methods used in systems biology. The class emphasizes molecular networks, models and applications, and covers the following topics: the structure of molecular networks; network motifs, their system properties and the roles they play in biological processes; complexity and robustness of molecular networks; hierarchy and modularity of molecular interaction networks; kinetic proofreading; optimal gene circuit design; the rules for gene regulation. (Spring)

BINF 6205. Computational Molecular Evolution. (3)
Prerequisites: BINF 6201 (Molecular Sequence Analysis) and BINF 6200 Statistics for Bioinformatics (or permission of the instructor). This course covers major aspects of molecular evolution and phylogenetics with an emphasis on the modeling and computational aspects of the fields. Topics will include: models of nucleotide substitution, models of amino acid and codon substitution, phylogenetic reconstruction, maximum likelihood methods, Bayesian methods, comparison of phylogenetic methods and tests on trees, neutral and adaptive evolution and simulating molecular evolution. Students will obtain an in-depth knowledge of the various models of evolutionary processes, a conceptual understanding of the methods associated with phylogenetic reconstruction and testing of those methods and develop an ability to take a data-set and address fundamental questions with respect to genome evolution. *(On demand)*

BINF 6210. Numerical Methods and Machine Learning in Bioinformatics. (3)
Prerequisites: Ability to program in a high-level language (Perl, Java, C#, Python, Ruby, C/C++), Calculus. This course focuses on commonly used numerical methods and machine learning techniques. Topics will include: solutions to linear systems, curve fitting, numerical differentiation and integration, PCA, SVD, ICA, SVM, PLS. Time permitting, Hidden Markov Chains and Monte Carlo simulations will be covered as well. Students will learn both the underlying theory and how to apply the theory to solve problems. (Fall)

BINF 6211. Design and Implementation of Bioinformatics Databases. (3)
In this course students learn the necessary skills to access and utilize public biomedical data repositories, and will be expected to design, instantiate, populate, query and maintain a personal database to support research in an assigned domain of bioinformatics. The course content includes common data models and representation styles, use of open-source relational DBMS, and basic and advanced SQL. The course focuses on how data integration is achieved, including the use of standardized schemas, exchange formats and ontologies. We examine large public biomedical data repositories such as GenBank and PDB, learn how to locate and assess the quality of data in Web-accessible databases, and look at representation, standards and access methods for such databases. (Spring)

BINF 6310. Advanced Statistics for Genomics. (3)
Prerequisite: BINF 6200 or equivalent. The first half of this course emphasizes canonical linear statistics (t-test, ANOVA, PCA) and their non-parametric equivalents. The second half of the course emphasizes Bayesian statistics and the application of Hidden Markov Models to problems in bioinformatics. Students should have fluency in a high-level programming language (PERL, Java, C# or equivalent) and will be expected, in assignments, to manipulate and analyze large public data sets. The course will utilize the R statistical package with the bioconductor extension. (Spring)

BINF 6311. Biophysical Modeling. (3)
This course covers: **(a)** an overview of mechanical force fields; **(b)** energy minimization; **(c)** dynamics simulations (molecular and coarse-grained); **(d)** Monte-Carlo methods; **(e)** systematic conformational analysis (grid searches); **(f)** classical representations of electrostatics (Poisson-Boltzmann, Generalized Born and Coulombic); **(g)** free energy decomposition schemes; and **(h)** hybrid quantum/classical (QM/MM) methods. *(On demand)*

BINF 6312. Computational Comparative Genomics. (3)
Prerequisite: BINF 6201 or equivalent. This course introduces computational methods for comparative genomics analyses. The course covers the following topics: the architecture of prokaryotic and eukaryotic genomes; the evolutionary concept in genomics; databases and resources for comparative genomics; principles and methods for sequence analysis; evolution of genomes; comparative gene function annotation; evolution of the central metabolic pathways and regulatory networks; genomes and the protein universe; *cis*-regulatory binding site prediction; operon and regulon predictions in prokaryotes; regulatory network mapping and prediction. *(On demand)*

BINF 6313. Structure, Function, and Modeling of Nucleic Acids. (3)
Prerequisite: BINF 6100-6101 or equivalent. This course covers the following topics: atomic structure, macromolecular structure-forming tendencies and dynamics of nucleic acids; identification of genes which code for functional nucleic acid molecules; cellular roles and metabolism of nucleic acids; 2D and 3D abstractions of nucleic acid macromolecules and methods for structural modeling and prediction; modeling of hybridization kinetics and equilibria; hybridization-based molecular biology protocols, detection methods and molecular genetics methods; and the role of modeling in designing these experiments and predicting their outcome. *(On demand)*

BINF 6350. **Biotechnology and Genomics Laboratory. (3)** Prerequisite: none. This course teaches basic wet-lab techniques commonly used in biotechnology to generate genomics data. Lectures will cover methods for sample isolation, cell disruption, nucleic acid and protein purification, nucleic acid amplification, protein isolation and characterization, molecular labeling methods and commonly used platforms for characterizing genome-wide molecular profiles. In particular we will discuss and learn to perform: tissue culture and LCM isolation of cells, DNA sequencing methods, DNA fingerprinting methods, RT-qPCR and microarrays of cDNA, 1D and 2D gels for protein separation, protein activity assays, and proteomics platforms. Lectures will describe emerging methodologies and platforms, and will discuss the ways in which the wet-lab techniques inform the design and use of bioinformatics tools, and how the tools carry out the processing and filtering that leads to reliable data. The course will also discuss the commercial products beginning to emerge from genomics platforms. (Spring)

BINF 6380. Programming III. (3)
Prerequisite: BINF 6112 or equivalent.
This course emphasizes implementation of bioinformatics algorithms in the context of parallel processing. Topics covered depend on instructor expertise and student interest but may include development of multi-threaded applications, developing for multi-core processors and utilization of large clusters and "cloud" supercomputers. Students will be expected to complete a significant independent project (Fall).

BINF 6400. Internship Project. (1-3)
Prerequisite: Admission to graduate standing in Bioinformatics. Project is chosen and completed under the guidance of an industry partner, and will result in an acceptable technical report. (Fall, Spring)

BINF 6600. Seminar. (1)
Prerequisite: Admission to graduate standing in Bioinformatics. Departmental seminar. Weekly seminars will be given by bioinformatics researchers from within the University and across the world. (Fall, Spring)

BINF 6601. Journal Club. (1)
Prerequisites: Admission to graduate standing in Bioinformatics. Each week, a student in the class is assigned to choose and present a paper from the primary bioinformatics literature. (Fall, Spring)

BINF 6900. Masters' Thesis. (1-3)
Prerequisites: Twelve graduate credits and permission of instructor. Project is chosen and completed under the guidance of a graduate faculty member, and will result in an acceptable master's thesis and oral defense. *(On demand)*

BINF 6880. Independent Study. (1-3) Faculty supervised research experience to supplement regular course offerings.

BINF 7999. Master's Degree Graduate Residency Credit. (1)
(Fall, Spring, Summer)

BINF 8100. Biological Basis of Bioinformatics. (3)
Prerequisites: Admission to graduate standing in Bioinformatics and undergraduate training in Computer Science or other non-biological discipline. This course provides a foundation in molecular genetics and cell biology focusing on foundation topics for graduate training in bioinformatics and genomics. (Fall)

BINF 8101. Energy and Interaction in Biological Modeling. (3)
Prerequisites: Admission to graduate standing in Bioinformatics. This course covers: (i.) the major organic and inorganic chemical features of biological macromolecules; (ii.) the physical forces that shape biological molecules, assemblies and cells; (iii.) the chemical driving forces that govern living systems; (iv.) the molecular roles of biological macromolecules and common metabolites; (v.) and the pathways of energy generation and storage. Each section of the course builds upon the relevant principles in biology and chemistry to explain the most common mathematical and physical abstractions used in modeling in the relevant context. (Spring)

BINF 8111. Bioinformatics Programming I. (3)
Prerequisite: Admission to graduate standing in Bioinformatics. This course introduces fundamentals of programming for bioinformatics using a high-level object-oriented language such as python. The first weeks cover core data types, syntax, and functional programming, focusing on construction of programs from small, testable

parts. Students will learn productive use of the Unix environment, focusing on Unix utilities that are particularly useful in bioinformatics. The course will cover object-oriented programming, introduce analysis of algorithms and sequence alignment methods, and introduce computational environments that are particularly useful in bioinformatics analyses such as R, BioPython, and Web services in bioinformatics. By the end of the class, students will have gained the ability to analyze data within the python interpreter (for example) and write well-documented, well-organized programs. (Fall)

BINF 8112. Bioinformatics Programming II. (3)
Prerequisite: BINF 8111. This is a continuation of Bioinformatics Programming I (BINF 8111). This course is the second semester of Introduction to Bioinformatics Programming I. In this semester, students will practice and refine skills learned in the first semester. New topics introduced will include: programming as part of a team, using sequence analysis algorithms in realistic settings; writing maintainable and re-usable code; Web programming; and graphical user interface development. At the end of the semester, students will be able to evaluate and deploy computer languages, tools, and software engineering techniques in bioinformatics research. (Spring)

BINF 8151/GRAD 8151. Professional Communications. (1) This course covers: Principles and useful techniques for effective oral presentations, poster presentations, scientific writing, use of references and avoiding plagiarism. Students in the class will critique and help revise each other's presentations and learn how to avoid common pitfalls. In addition, students will learn how to properly organize and run a meeting. Students will prepare a CV, job application letter and job talk. (Fall).

BINF 8200. Statistics for Bioinformatics. (3)
This course aims to introduce statistical methods commonly used in bioinformatics. Basic concepts from probability, stochastic processes, information theory, and other statistical methods will be introduced and illustrated by examples from molecular biology, genomics and population genetics with an outline of algorithms and software. R is introduced as the programming language for homework. (Fall)

BINF 8201. Molecular Sequence Analysis. (3)
Prerequisite: BINF 8100 or equivalent. BINF 8100 or equivalent. Introduction to bioinformatics methods that apply to molecular sequences. Introduction to biological databases online includeing sequence databases, molecular sequence data formats, sequence data preparation and database submission; local and global sequence alignment, multiple alignment, alignment scoring and alignment algorithms for protein and nucleic acids, gene finding and feature finding in sequences, models of molecular evolution, phylogenetic analysis, and comparative modeling. (Fall)

BINF 8202. Computational Structural Biology. (3)
Prerequisite: BINF 8101, 8201 or equivalents. This course covers: **(a)** the fundamental concepts of structural biology (chemical building blocks, structure, superstructure, folding, etc.); **(b)** structural databases and software for structure visualization; **(c)** structure determination and quality assessment; **(d)** protein structure comparison and the hierarchical nature of biomacromolecular structure classification; **(e)** protein structure prediction and assessment; and **(f)** sequence- and structure-based functional site prediction. (Fall)

BINF 8203. Genomics. (3)
Prerequisite: BINF 8100 or equivalent. This course surveys the application of high-throughput molecular biology and analytical biochemistry methods and data interpretation for those kinds of high volume biological data most commonly encountered by bioinformaticians. The relationship between significant biological questions, modern genomics technology methods, and the bioinformatics solutions that enable interpretation of complex data is emphasized. Topics include: Genome sequencing and assembly, annotation, and comparison; genome evolution and individual variation; function prediction; gene ontologies; transcription assay design, data acquisition, and data analysis; proteomics methods; methods for identification of molecular interactions; and metabolic databases, pathways and models. (Spring)

BINF 8204. Mathematical Systems Biology. (3)
Prerequisites: BINF 8200 and 8210 or equivalents. This course introduces basic concepts, principles and common methods used in systems biology. The class emphasizes molecular networks, models and applications, and covers the following topics: the structure of molecular networks; network motifs, their system properties and the roles they play in biological processes; complexity and robustness of molecular networks; hierarchy and modularity of

molecular interaction networks; kinetic proofreading; optimal gene circuit design; the rules for gene regulation. (Spring)

BINF 8205. Computational Molecular Evolution. (3)
Pre-requisites: BINF 8201 (Molecular Sequence Analysis) and BINF 8200 (Statistics for Bioinformatics) or permission of the instructor. This course will cover major aspects of molecular evolution and phylogenetics with an emphasis on the modeling and computational aspects of the fields. Topics will include: models of nucleotide substitution, models of amino acid and codon substitution, phylogenetic reconstruction, maximum likelihood methods, Bayesian methods, comparison of phylogenetic methods and tests on trees, neutral and adaptive evolution and simulating molecular evolution. Students will obtain an in-depth knowledge of the various models of evolutionary processes, a conceptual understanding of the methods associated with phylogenetic reconstruction and testing of those methods and develop an ability to take a data-set and address fundamental questions with respect to genome evolution. *(On demand)*

BINF 8210. Numerical Methods and Machine Learning in Bioinformatics. (3)
Prerequisites: Ability to program in a high-level language (Perl, Java, C#, Python, Ruby, C/C++), Calculus. This course focuses on commonly used numerical methods and machine learning techniques. Topics will include: solutions to linear systems, curve fitting, numerical differentiation and integration, PCA, SVD, ICA, SVM, PLS. Time permitting, Hidden Markov Chains and Monte Carlo simulations will be covered as well. Students will learn both the underlying theory and how to apply the theory to solve problems. (Fall)

BINF 8211. Design and Implementation of Bioinformatics Databases. (3)
In this course students will acquire skills needed to access and utilize public biomedical data repositories, and will be expected to design, instantiate, populate, query and maintain a personal database to support research in an assigned domain of bioinformatics. The course content includes common data models and representation styles, use of open-source relational DBMS, and basic and advanced SQL. The course focuses on how data integration is achieved, including the use of standardized schemas, exchange formats and ontologies. We will examine large public biomedical data repositories such as GenBank and PDB, learn how to locate and assess the quality of data in Web-accessible databases, and look at representation, standards and access methods for such databases. (Spring)

BINF 8310. Advanced Statistics for Genomics. (3)
Prerequisite: BINF 8200 or equivalent. The first half of this course emphasizes canonical linear statistics (t-test, ANOVA, PCA) and their non-parametric equivalents. The second half of the course emphasizes Bayesian statistics and the application of Hidden Markov Models to problems in bioinformatics. Students should have fluency in a high-level programming language (PERL, Java, C# or equivalent) and will be expected, in assignments, to manipulate and analyze large public data sets. The course will utilize the R statistical package with the Bioconductor extension. (Spring)

BINF 8311. Biophysical Modeling. (3)
This course covers: **(a)** an overview of mechanical force fields; **(b)** energy minimization; **(c)** dynamics simulations (molecular and coarse-grained); **(d)** Monte-Carlo methods; **(e)** systematic conformational analysis (grid searches); **(f)** classical representations of electrostatics (Poisson-Boltzmann, Generalized Born and Coulombic); **(g)** free energy decomposition schemes; and **(h)** hybrid quantum/classical (QM/MM) methods. *(On demand)*

BINF 8312. Computational Comparative Genomics. (3)
Prerequisite: BINF 8201 or equivalent. This course introduces computational methods for comparative genomics analyses. The course covers the following topics: the architecture of prokaryotic and eukaryotic genomes; the evolutionary concept in genomics; databases and resources for comparative genomics; principles and methods for sequence analysis; evolution of genomes; comparative gene function annotation; evolution of the central metabolic pathways and regulatory networks; genomes and the protein universe; *cis*-regulatory binding site prediction; operon and regulon predictions in prokaryotes; and regulatory network mapping and prediction. *(On demand)*

BINF 8313. Structure, Function, and Modeling of Nucleic Acids. (3)
Prerequisite: BINF 8100-8101 or equivalent. The course covers the following topics: atomic structure, macromolecular structure-forming tendencies and dynamics of nucleic acids; identification of genes which code for functional nucleic acid molecules, cellular roles and metabolism of nucleic acids; 2D and 3D abstractions of nucleic acid macromolecules and methods for structural modeling and prediction; modeling of hybridization kinetics and

equilibria; hybridization-based molecular biology protocols, detection methods and molecular genetics methods, and the role of modeling in designing these experiments and predicting their outcome. *(On demand)*

BINF 8350. Biotechnology and Genomics Laboratory. (3) Prerequisite: none. This course teaches basic wet-lab techniques commonly used in biotechnology to generate genomics data. Lectures will cover methods for sample isolation, cell disruption, nucleic acid and protein purification, nucleic acid amplification, protein isolation and characterization, molecular labeling methods and commonly used platforms for characterizing genome-wide molecular profiles. In particular we will discuss and learn to perform: tissue culture and LCM isolation of cells, DNA sequencing methods, DNA fingerprinting methods, RT-qPCR and microarrays of cDNA, 1D and 2D gels for protein separation, protein activity assays, and proteomics platforms. Lectures will describe emerging methodologies and platforms, and will discuss the ways in which the wet-lab techniques inform the design and use of bioinformatics tools, and how the tools carry out the processing and filtering that leads to reliable data. The course will also discuss the commercial products beginning to emerge from genomics platforms. (Spring)

BINF 8380. Programming III. (3)
Prerequisite: BINF 8112 or equivalent. This course emphasizes implementation of bioinformatics algorithms in the context of parallel processing. Topics covered depend on instructor expertise and student interest but may include development of multi-threaded applications, developing for multi-core processors and utilization of large clusters and "cloud" supercomputers. Students will be expected to complete a significant independent project (Fall).

BINF 8600. Seminar. (1)
Prerequisites: Admission to graduate standing in Bioinformatics. Departmental seminar. Weekly seminars will be given by bioinformatics researchers from within the university and across the world. (Fall, Spring)

BINF 8601. Journal Club. (1)
Prerequisites: Admission to graduate standing in Bioinformatics. Each week, a student in the class is assigned to choose and present a paper from the primary bioinformatics literature. (Fall, Spring)

BINF 8911 Research Rotation I (2), BINF 8912 Research Rotation II (2).
Faculty supervised research experience in bioinformatics to supplement regular course offerings. (Fall, Spring, Summer)

BINF 8991 Doctoral Dissertation Research (1-9).
Individual investigation culminating in the preparation and presentation of a doctoral dissertation. (Fall, Spring, Summer)

BINF 9999. Doctoral Degree Graduate Residency Credit. (1)
(Fall, Spring, Summer)