Boston University

Graduate Program in Bioinformatics

Handbook

2012-2013

http://www.bu.edu/bioinformatics

Department of Biochemistry (School of Medicine)
Department of Biology (College of Arts and Sciences)
Biomedical Engineering Department (College of Engineering)
Department of Biostatistics (School of Public Health)
Department of Chemistry (College of Arts and Sciences)
Department of Computational Biomedicine (School of Medicine)
Department of Computer Science (College of Arts and Sciences)
Electrical and Computer Engineering Department (College of Engineering)
Genetics and Genomics Department (School of Medicine)
Department of Mathematics and Statistics (College of Arts and Sciences)
Department of Medicine (School of Medicine)
Department of Microbiology (School of Medicine)
Department of Mechanical Engineering (College of Engineering)
Molecular and Cell Biology (Goldman School of Dental Health)
Department of Neurology (School of Medicine)
Periodontology & Oral Biology (Goldman School of Dental Health)
Department of Physics (College of Arts and Sciences)
Pulmonary Medicine (School of Medicine)
Systems Engineering Division (College of Engineering)
Center for Computational Science
Center for Advanced Biotechnology
Center for Advanced Genomic Technology

Last Updated: 10/11/12

Bioinformatics Faculty and Staff

Faculty

Director

Thomas Tullius	Director of Bioinformatics

Associate Directors

Gary Benson*	Associate Director of IGERT
Scott Mohr	Administrative Director, Director of Graduate Studies

Department of Biochemistry (BUSM)

Joseph Zaia	Professor Associate Director, Center for Biomedical Mass Spectrometry

Department of Biology (CAS)

Cynthia Bradham	Assistant Professor
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John Finnerty	Associate Professor
Ulla Hansen	Professor
Edward Loechler	Professor
Kimberly McCall	Associate Professor
Daniel Segre*[#]	Associate Professor
Dean Tolan	Professor
David Waxman	Professor

Department of Biomedical Engineering (ENG)

Charles Cantor*	Professor, Director of Center for Advanced Biotechnology
James J. Collins*	Professor
Charles DeLisi*	Metcalf Professor
Maxim Frank-Kamenetskii	Professor
James Galagan	Associate Professor
Simon Kasif*[#]	Professor, Co-Director of CAGT and Director of Computational Genomics Lab
Cassandra Smith	Professor
Temple Smith*	Professor Emeritus
Sandor Vajda*	Professor, Director of Biomolecular Engineering Research Center

Department of Biostatistics (SPH)

Josée Dupuis	Professor, Associate Chair
Paola Sebastiani*	Professor

Department of Chemistry (CAS)

Karen Allen	Professor
Scott Mohr	Professor, Bioinformatics Director of Graduate Studies
John Straub*	Professor and Chair of Chemistry
Thomas Tullius	Professor
Yu (Brandon) Xia*	Assistant Professor

Department of Computational Biomedicine (BUSM)

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Gary Benson	Associate Professor, Bioinformatics Director of IGERT

Department of Electrical and Computer Engineering (ENG)

Douglas Densmore*	Assistant Professor
Lev Levitin	Professor

Department of Genetics and Genomics (BUSM)

Lindsay Farrer	Professor, Chief of Genetics Program and Director of Genetic Epidemiology

Department of Mathematics and Statistics (CAS)

Luis Carvalho*	Assistant Professor
Eric Kolaczyk*	Professor
Mark Kon*	Professor
Surajit Ray	Assistant Professor
Samuel Isaacson	Assistant Professor

Department of Mechanical Engineering (ENG)

Calin Belta*	Associate Professor

Department of Medicine (BUSM)

Stefano Monti	Associate Professor

Department of Microbiology (BUSM)

John Connor	Assistant Professor
Tom Kepler	Professor

Department of Molecular and Cell Biology (SDM)

John Samuelson	Professor

Department of Neurology (BUSM)

Alan Herbert	Associate Professor
Rick Myers	Professor

Periodontology & Oral Biology (SDM)

Salomon Amar	Professor

Department of Physics (CAS)

Pankaj Mehta*	Assistant Professor
H. Eugene Stanley*	Professor

Department of Pulmonary Medicine (BUSM)

Maria Ramirez	Associate Professor
Avrum Spira	Associate Professor, Chief, Division of Computational Biomedicine
Katrina Steiling	Assistant Professor

Systems Engineering Division (ENG)

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Staff

Caroline Lyman Lab Administrator
David King Graduate Program Coordinator
Johanna Squillacioti-Vasquez Administrative Coordinator
Mary Ellen Fitzpatrick Systems Administrator

Overview

The graduate program in bioinformatics at Boston University provides interdisciplinary training for students of exceptional motivation. The program includes some 40 active faculties from five Colleges: Engineering, Arts and Sciences, Dentistry, Medicine and Public Health, as well as 25 adjunct faculty, and focuses on the molecular biology and physics of the cell, emphasizing the use of advanced mathematics and computation. Because we are educating future leaders, the program also includes training designed to sensitize students to the social impact of technology, including ethical and legal implications of emerging technologies.

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The Bioinformatics Ph.D. Program

I. Degree Requirements

The post-bachelor's Ph.D. requires a total of **64** credits, consisting of the 38 required credits listed below, or their equivalents, and additional elective lecture, laboratory, seminar and/or research credits. The precise course of study will be determined in consultation with the student's academic advisor, and will reflect the student's background and interests. In order to be admitted to Ph.D. candidacy students must demonstrate mastery of the core subject matter (no lower than a **'B'** in each of the core courses) and successfully complete a qualifying examination (see below).

The post-master's Ph.D. requires **40** credits, consisting of satisfactory fulfillment (no lower than a 'B') of the core course requirements, or their equivalents, with a **minimum** of **four** lecture/laboratory courses taken at BU while enrolled in the PhD program. A student is required to take 4 classes (16 credits) to complete program. A student's academic advisors recommend the appropriate combination of lecture, laboratory, and/or research courses. Two credits of research (BF900/901) must also be completed. The admission to Ph.D. candidacy is the same as for the post-bachelor's Ph.D.

Core Course Requirements:

Course #	Course Name	Credits	Offered
BF 751	Molecular Biology and Biochemistry: Molecules and Processes	4	Fall
BE 562	Computational Biology: Genomes, Networks, Evolution	4	Fall
BE 768	Biological Database Analysis	4	Spring
BE 777	Computational Genomics I	4	Fall
BF 690	Bioinformatics Challenge Project	2 each; 4 total	Spring & Fall
BF 778	Physical Chemistry for Systems Biology	4	Spring
BF 752	Legal & Ethical Issues of Science & Technology	4	Spring
BF 810	Laboratory Rotation System	1 each rotation; 3 total	Fall & Spring
BF 820	Research Opportunities in Bioinformatics	1	Fall
BF 821	Bioinformatics Graduate Seminar	2 each; 4 total	Spring & Fall
BF 699	Bioinformatics TA/TF	2	Spring & Fall

Fulfillment of core course **equivalents** will be determined based on documented previous academic and/or work experience. The student and his or her advisors will petition the curriculum committee for such equivalencies. When either past work or an alternate course has been accepted as a core equivalent, the student's advisors will recommend another course to fulfill the 38 core credit hours. **Advanced elective courses should be taken in place of any waived course requirements.**

Students are also required to complete Boston University's Program in Advanced Responsible Conduct of Research (RCR). The goal of the Advanced RCR program is to achieve RCR Certification of every doctoral and postdoctoral trainee in scientific research, whether in the physical, social and behavioral, clinical or other basic or applied sciences at Boston University and Boston Medical Center. The program orients both trainees and faculty discussion facilitators to the complex ethical and regulatory context of research today. Participants develop the skills needed to make appropriate ethical decisions to survive in this challenging context.

Award of a Certificate of Completion of the Advanced RCR Program requires completion of the Advanced RCR-Online Preparation component and all four live sessions in any sequence, over a two-year period. Recertification is required four years after completing the initial Advanced RCR program. Recertification is obtained by successful retaking the online preparation component and each of the four live sessions. Additional information on the Advanced RCR program, including session dates and locations can be found at the Research at Boston University website: http://www.bu.edu/research/.

Electives:

For the **post-bachelor's Ph.D**. degree: In addition to the core courses listed above, students are required to complete at least **one** additional elective course (i.e., non-research). The remainder of the 64 credits may be satisfied by research/thesis credits (BF 900 and/or BF 901). A minimum of 2 research credits is required.

For the **post-master's Ph.D.** degree: In addition to the core courses listed above, at least 2 credits of research (BF 900/901) is required. (Note: BF 900 is taken as research credit for Ph.D. students who have not yet passed the qualifying examination. After admission to Ph.D.-candidate status, students enroll in BF 901 for research credit.)

Approved Elective Courses

ENG BE 560: Biomolecular Architecture
ENG BE 565: Molecular Biotechnology
ENG BE 566: DNA Structure and Function
ENG BE 569: Next Generation Sequencing: Technology, Data Analysis & Biomedical Applications
ENG BE 764: Biophysics of Large Molecules
ENG BF 527: Applications in Bioinformatics
ENG BF 571: Dynamics and Evolution of Biological Networks
CAS BI/CH527: Biochemistry Laboratory I
CAS BI/CH528: Biochemistry Laboratory II
CAS BI 502: Topics in the Theory of Biological Networks
CAS BI 504: Evolution
CAS BI 549: Molecular Phylogenetics and Evolution
CAS BI 553: Molecular Biology II
CAS BI 556: Membrane Biochemistry
CAS BI 572: Advanced Genetics
GRS BI 610: Cellular Aspects of Development and Differentiation
GRS BI 735: Advanced Cell Biology
GRS BI 755: Cellular and Systems Neuroscience
CAS BB 522: Molecular Biology Laboratory
CAS CH 525: Physical Biochemistry
GRS CH 751: Advanced Topics in Physical Chemistry
GRS CH 752: Advanced Topics and Chemical Physics
CAS CS 542: Machine Learning
CAS CS 549: Pattern Matching and Detection with Applications in Biological Sequence Analysis
CAS CS 565: Data Mining

SPH BS 703: Biostatistics
SPH BS 830: Design and Analysis of Microarray Experiments
SPH BS 850: Advanced Statistical Methodology for the Computational Biosciences
SPH BS 855: Bayesian Modeling for Biomedical Research & Public Health
SPH BS 858: Statistical Genetics I
SPH BS 859: Applied Genetic Analysis
SPH BS 860: Statistical Genetics II
CAS MA 555: Numerical Analysis I
CAS MA 565: Mathematical Models in the Life Sciences
CAS MA 575: Linear Models
CAS MA 576: Generalized Linear Models
CAS MA 581: Probability
CAS MA 582: Mathematical Statistics
CAS MA 583: Introduction to Stochastic Processes
CAS MA 584: Multivariate Statistical Analysis
CAS MA 614: Statistical Methods
CAS MA 684: Applied Multiple Regression and Multivariable Methods
GRS MA 770: Mathematical and Statistical Methods of Bioinformatics
GRS MA 881: Statistics Seminar I
GRS MA 882: Statistics Seminar II
GRS MB 721: Graduate Level Biochemistry
GRS MB 722: Advanced Biochemistry
GRS PY 771: Systems Biology for Physical Scientists and Engineers
GMS PA 600: Intro to Pathology & Pathophysiology of Disease
ENG EC 533: Advanced Discrete Mathematics
ENG EC 534: Discrete Stochastic Models
ENG EC 730: Information-Theoretical Design of Algorithms
ENG EC 761: Information Theory and Coding

† The core, elective and research/seminar courses are grouped by department.

Colleges:
ENG = College of Engineering **GRS** = Graduate School of Arts and Sciences **CAS** = College of Arts and Sciences
SPH = School of Public Health GMS = Graduate Medical Sciences

Departments:
BE = Biomedical Engineering **BF** = Bioinformatics **BI** = Biology **BS** = Biostatistics
CH = Chemistry **CS** = Computer Science **EC** = Electrical and Computer Engineering **MA** = Mathematics
MB = Molecular Biology, Cell Biology and Biochemistry (MCBB) **PA** = Pathology **PY** = Physics

Teaching Requirement

Starting in fall 2012, one semester of teaching has been added as a curriculum requirement for the Ph.D. program. Students must complete the teaching requirement by the end of their third year of study. The Bioinformatics Program currently offers several different opportunities for our students to gain experience and develop teaching skills. These opportunities include:

BF 527: Applications in Bioinformatics

Bioinformatics Program students have an opportunity to teach BF 527: Applications in Bioinformatics. The course is offered annually and is co-taught by two advanced-level PhD students (3rd year or higher). The Director of Graduate Studies and are responsible for all aspects of the course including: defining and developing course content and materials; preparing and delivering bi-weekly lectures; overseeing bi-weekly computer lab sessions; and designing and grading homework assignments and exams. They also consult during office hours with students taking the course.

Teaching Fellowships for Bioinformatics Core Courses

Students also have the opportunity to serve as Teaching Fellows in two Bioinformatics core courses: BE768: Biological Database Systems and BF778: Physical Chemistry for Systems Biology. The courses are both offered annually. Duties include: teaching labs; creating and grading homework assignments; grading exams; and developing and presenting tutorials to supplement material being taught by the course instructor.

Teaching Fellowships for Courses Outside of the Bioinformatics Program
Additionally, students may have opportunities to serve as Teaching Fellows for courses offered by other programs outside of Bioinformatics. The courses are typically introductory courses at the undergraduate level offered by the Biology, Chemistry and Computer Science departments. The duties include, but are not limited to: overseeing discussions and lab sections; grading homework assignments and exams; and serving as an additional resource to registered students.

To assist our students in identifying teaching opportunities, each semester we will notify relevant departments (Biology, Chemistry, Computer Science, Math and Statistics, etc.) that our students are available to teach and have funding through the Bioinformatics Program. We will then compile and distribute to eligible Bioinformatics students a list of courses that have available teaching opportunities.

Lab Rotation Requirements:
Three lab rotations (BF810) are required during a Ph.D. student's first year. One rotation must be experimental, one computational, and the third can be either. At least two must be at Boston University, on either the Charles River campus or the Medical School campus. A rotation completed with a Boston University adjunct faculty member at a laboratory located off-campus (including the NIH) is not considered a rotation done at BU. Only rotations done in laboratories located on-campus fulfill the rotation residency requirement.

Students in the NIH-sponsored Graduate Partnership Program (GPP) have a modified rotation requirement. They still must take three rotations, but two of these may be done at NIH, preferably in the summer preceding and/or following their first year of graduate school. The third rotation must be taken at Boston University (on either Charles River or the Medical School campus). It is recommended (but not required) that this be an experimental, not computational, rotation.

Students that are awarded an IGERT Fellowship will receive credit toward one of the required rotations for the training they complete during the summer prior to their first semester.

In order to select a lab, students should visit faculty websites and narrow their choices to about 6 labs, then make appointments with faculty members to discuss their research. It is also recommended that students meet with other employees of the lab to discuss their experience there. Selection of laboratories is aided by enrolling in BF820, which is completed by mid-November of the first year. In this course, faculty with projects available for bioinformatics graduate students introduce their research topics. Also, a list of lab openings is sent around periodically. You may also request this list from the Graduate Program Coordinator.

Rotations typically last for a minimum of nine weeks and it is expected that the student will participate in the lab full time except for time spent on classes and class work. Students report on each rotation by completing a **Lab Rotation Approval Form** before the start of the rotation and a **Lab Rotation Report Form** at the end of the rotation. The report form must include a report of work completed; be signed by the immediate laboratory supervisor and academic advisor; and submitted to the Graduate Program Coordinator. Students are required to begin their first rotation by October 15th and submit the first rotation report by December 15th. The second report must be submitted by March 15th and the third by May 15th. Rotations will only be credited if reports are received by the due dates. Rotation forms can be found on the Bioinformatics website http://www.bu.edu/bioinformatics/student-services.

II. Ph.D. Advising System

Academic Advisor
Upon entry into the Bioinformatics Program, each student will be appointed an Academic Advisor from the Bioinformatics faculty. The advisor will act as the student's primary academic advisor until the student selects a research advisor(s) (see below).

Research Advisor(s)
The Ph.D. thesis is expected to have both computational and experimental components and will ideally, involve collaboration between experimental and computational labs. Therefore, the Bioinformatics Program strongly encourages the selection of two research advisors, one primarily computational and one primarily experimental. However, the nature of the Ph.D. thesis may be such that only a single advisor is appropriate. In this case, the advisor should be primarily computational. In either case, **one research advisor must be a faculty member of the Boston University Program in Bioinformatics.** If two advisors are selected and one is from outside Boston University, the other advisor must be a member of the Bioinformatics computational core faculty[1]. Students typically identify potential research advisers based upon published research, academic advising, teaching, research lab meetings and laboratory rotations. Research advisors are selected by mutual agreement with the student and replace the academic advisor. Students must identify their research advisor(s) at the end of their first year in the program (by June 1st). Once identified, students must submit a Research Advisor Election/Change Form to the Graduate Program Coordinator.

After research advisors have been selected, the student will submit to the Graduate Program Coordinator usually no later than October 1st of the second year, a 1-2 page description of the proposed research project, signed by the research advisor(s). Thereafter, the student will submit, annually, by October 1st, a 1-2 page summary of progress, including research problems, results, and a list of accepted and submitted research papers and posters.

III. Requirements for Admission to Ph.D. Candidacy

With successful completion of all course requirements and the qualifying examination, the student is admitted to Ph.D. candidacy. The student will receive formal notification of Ph.D. candidacy from the Bioinformatics Graduate Program Office. Once entered, Ph.D. candidacy will expire on its third anniversary. In unusual circumstances, the student may petition the Director of Graduate Studies (DGS) for an extension. The DGS will review the petition and the student will be advised in writing of the outcome. No student will be allowed to defend a completed Ph.D. dissertation if he/she is not a Ph.D. candidate.

Qualifying Examination

All Boston University graduate students must pass a qualifying exam in order to advance to the level of PhD Candidacy. In the Bioinformatics Program, this exam takes the form of an oral qualifying exam. The goal of the exam is for the student to demonstrate his or her general proficiency in bioinformatics, as well as command of the area(s) in which he or she intends to conduct research. Each student in the Bioinformatics Program will select a Qualifying Committee (QC) of 4 faculty members in the program (including his or her primary adviser), typically by sometime during the first semester of their second year. It is strongly encouraged that the QC

[1] Core Computational Faculty: Gary Benson, James Collins, Charles DeLisi, Simon Kasif, Paola Sebastiani, Daniel Segrè, Temple Smith, Sandor Vajda, Yu (Brandon) Xia, Charles Cantor, John Straub, Doug Densmore, Luis Carvalho, Eric Kolaczyk, Mark Kon, Calin Belta, Pankaj Mehta, H. Eugene Stanley.

include both faculty members with biological/experimental expertise and faculty members with computational expertise. The Director of Graduate Studies (DGS) must approve the committee membership and will be an ex officio member of the committee. In order to help avoid issues with committee membership students are required to submit the name of 6 potential committee members and the topic of their research project by December 1st of their second year. Students must schedule their Qualifying Exam by March 31 of their second year, and must take the exam by June 30. Students who fail to pass the exam on their first try are allowed a second attempt, to be scheduled and completed by the end of the first semester of their third year.

The oral qualifying exam will generally last approximately 2 hours, during which time members of the QC will ask questions focused on topics relating to the general topic area(s) chosen from the list below. At least one topic area should be agreed upon by the student and his/her QC prior to scheduling the exam. At that time, the student will also work with the QC to identify a list of specific representative resources (e.g., books, chapters, articles, etc.) around which the oral exam questioning can be expected largely to focus. Questions should probe the student's knowledge of both biological and computational aspects of the chosen topic areas. Ideally, the examination questions will not only test general background knowledge, but also those aspects that pertain specifically to the student's intended area of research. Towards this end, students are expected to make a brief (20-30 min) oral presentation on their current research to the committee at the start of the exam. At least 2 weeks prior to the exam, the committee should be supplied with a brief written description (no more than 10 pages) of the student's current and planned research, organized in the manner of a grant proposal.

Approved general topic areas (each with a sample of illustrative sub-topic areas) are given below. Approval for a topic area(s) outside of those listed must be obtained from the Bioinformatics Curriculum Committee.

- **Biochemistry and Molecular Biology**
  Enzyme catalysis; regulation; metabolomics; macromolecular metabolism; biochemical pathways; molecular evolution.
- **Databases and Computing**
  Algorithms and complexity; database design; SQL; query optimization; web interface design; visualization.
- **Genetics and Genomics**
  Gene expression analysis; transcriptional regulation; epigenetics; proteomics; sequence analysis.
- **Statistics and Machine Learning**
  Data mining; learning algorithms; probabilistic modeling; statistical methods and modeling; statistical genetics.
- **Structural Biology and Biophysics**
  Methods of macromolecular structure determination; spectroscopic probes; energy transduction; bioenergetics.
- **Systems Biology / Synthetic Biology**
  Network modeling (metabolic, regulatory, etc.); non-linear dynamics; reverse engineering.

Following successful completion of the Qualifying Exam, and filing of the appropriate paperwork with the Bioinformatics Program office (which transmits it to the Graduate School of Arts and Sciences), the student passes to PhD Candidacy.

Immediately following the examination, the Report of Examinations form must be submitted to the Graduate Program Coordinator along with a copy of the oral proposal.

<u>Examination Committee</u>
The Qualifying Examination Committee consists of the student's research advisor(s) and two or three additional scientists, for a total of four members. At least two members should serve on the faculty of the Bioinformatics Program at Boston University. At least one member of the committee

must be from the Bioinformatics computational core faculty[2]. Inclusion of scientists (Ph.D.-level) from outside academic institutions or companies is encouraged. Outside members require a special service appointment (this does not apply to adjunct faculty). A "Special Service Appointment Form" along with the C.V. of the outside member should be submitted to the Graduate Program Coordinator. The chair of the committee, who must be a Bioinformatics faculty member and not a research advisor, will submit the Report of Examinations Form which documents the student's performance, to the Graduate Program Office immediately after the examination. The student's Qualifying Examination Committee is responsible for grading the exam. It is left to the committee's discretion how to remedy any unsatisfactory performance. A student who fails the examination has one opportunity to re-take it after three months have elapsed. Failure on the second attempt constitutes grounds for automatic dismissal from the Ph.D. program and loss of any further financial aid. In such an event, the student may still be eligible for the M.S. degree provided the degree requirements have been met. Upon successful completion of the examination, the Qualifying Examination Committee generally continues to serve as a student's Thesis Committee.

Students must have their examination committee as well as the date/time of their examination approved via a Committee Approval Form. This form must be submitted to the Graduate Program Coordinator at least one month in advance of the oral examination. The oral examination **cannot** be scheduled any less than a month from when the Committee Approval Form is submitted.

IV. Preparation and Submission of a Ph.D. Dissertation

Some of the forms mentioned below require the signature of the Director. In these cases, the forms should be submitted to the Graduate Program Coordinator who will obtain the signatures. Once the forms are complete, students will be contacted so they may hand the forms in at the GRS Records Office in person.

1. Thesis Advisory Committee. A student must have a Thesis Advisory Committee, which is normally the same as the student's Qualifying Examination Committee (see above). The composition criteria of both committees are the same. The Thesis Advisory Committee meets annually to review the Ph.D. candidate's progress and make suggestions. At the conclusion of the annual Thesis Advisory Committee meeting, the committee chair is responsible for completing the Thesis Advisory Committee Report form. This form provides a written evaluation of the student's research progress and summarizes the feedback/recommendations given the committee. The Thesis Advisory Committee Report form is to be signed by the committee chair, research advisor(s) and student. The form must be returned to the Graduate Program Coordinator. A copy will be provided to the student.

2. Thesis/Dissertation Committee. The Thesis/Dissertation Committee is very similar to the Thesis Advisory Committee and consists of the student's research advisor(s) and three or four additional scientists, for a total of **five members**. At least three members must be Boston University faculty and of those, two members should serve on the faculty of the Bioinformatics Program. At least one member of the committee must be from the Bioinformatics computational core faculty[2]. Inclusion of scientists (Ph.D.-level) from outside academic institutions or companies is encouraged. Outside members require a special service appointment (this does not apply to adjunct faculty). A "Special Service Appointment Form" along with the C.V. of the outside member should be submitted to the Graduate Program Coordinator.

Two members of the committee are designated the First and Second Readers of the thesis. If the student has one research advisor, that member will be the First Reader. If the student has two

[2] Core Computational Faculty: Gary Benson, James Collins, Charles DeLisi, Simon Kasif, Paola Sebastiani, Daniel Segrè, Temple Smith, Sandor Vajda, Yu (Brandon) Xia, Charles Cantor, John Straub, Doug Densmore, Luis Carvalho, Eric Kolaczyk, Mark Kon, Calin Belta, Pankaj Mehta, H. Eugene Stanley.

research advisors, one will be the First Reader and the other the Second Reader. A third member of the committee, who must be a Bioinformatics faculty member, will serve as Chairman of the Dissertation Defense. A student cannot change the members of the dissertation committee after submission of the dissertation prospectus to the Graduate School of Arts and Sciences. All members must attend the Dissertation Defense.

3. Dissertation Prospectus (Dissertation Prospectus Approval Page). Approximately nine months prior to the proposed graduation date, a formal Dissertation Prospectus must be submitted to Martha Khan in the GRS Records Office along with the Dissertation Prospectus Approval Page. The dissertation prospectus should be prepared in consultation, and with approval of, the student's research advisors (First and Second Readers). An additional requirement for the Bioinformatics Program is that each member of the student's Thesis Defense Committee must review and approve the prospectus. Committee approval is documented by completion of the *Bioinformatics Dissertation Prospectus Approval* form (this is in addition to the approval form required by GRS). The Director of Graduate Studies and the Director of the Bioinformatics Program must also approve the prospectus. The Dissertation Prospectus generally provides an outline of the major chapters and subheadings to be included in the Ph.D. thesis.

4. Statement of Progress. The Bioinformatics Program expects its PhD students to finish their dissertation and defense within five years of joining the program or shortly thereafter. To help ensure that students are on track to complete within that timeframe, a Statement of Progress is required by September 1st of the 5th year in the PhD program. This statement should include an estimate of the dissertation defense date (month and year), the status of the selection of a defense committee, the titles and completion status of the major sections of the dissertation, and a summary of publications based on the dissertation research, broken down into the categories (a) already published, (b) submitted, and (c) in preparation or planned. Students are required to complete this statement in consultation with their research advisors and to jointly sign the statement.

5. Diploma Application. At least three months prior to the proposed graduation date, a Diploma Application must be completed and submitted to Martha Khan in the GRS Records Office. The application is available at the same office.

6. Ph.D. Dissertation Defense Abstract. At least three weeks prior to the defense of dissertation, this abstract must be submitted to Martha Khan in the GRS Records Office. This abstract must be read and approved by the student's research advisors (First and Second Readers), the Director of Graduate Studies, and the Director of the Bioinformatics Program before being submitted to the Graduate School of Arts and Sciences.

7. Distribution of Dissertation. At least two weeks prior to the defense of the dissertation, the student will distribute a copy of the dissertation to the members of the Thesis/Dissertation committee. The student must anticipate that the committee will make numerous suggestions and required changes in the proposed thesis. In some cases the committee may require additional data analyses or even additional experimental work, which must be completed prior to scheduling the final thesis defense.

8. Distribution of Announcement. At least two weeks prior to the defense of the dissertation, a public announcement of the dissertation defense, abstract, and a brief C.V. of the candidate must be submitted to the Graduate Program Coordinator to distribute to all Bioinformatics students and faculty members.

9. Ph.D. Thesis/Dissertation Defense.
It is expected of all Ph.D. students to defend significance, originality and methodologies employed in their thesis research. This defense consists of two parts.

A. The first is the public seminar open to the University community and based on the work by the student. Generally in consultation with the student's thesis committee, the time and date for this seminar will be submitted to the Graduate School of Arts and Sciences for publication.

B. The second is an oral defense of the work, which usually follows the public seminar, and is done privately before the student's Thesis Committee. The committee members ensure that the research is complete and understood by the candidate. At this time they can voice any concerns over the data or the preparation of the dissertation document. Depending on how well the thesis experiments are designed, performed, and defended, and how well the thesis is prepared, the committee will vote whether or not the thesis is complete and satisfactory. More than one committee member voting negatively will require either another Dissertation Defense or a decision about whether the Ph.D. degree is offered. Because the signatures of both Readers are required on the thesis, a Reader who votes negatively automatically necessitates another Dissertation Defense. A positive vote on the Dissertation Defense usually involves several suggested modifications of the thesis. An agreement is reached, in consultation with the Readers, for the incorporation of any written comments from committee members for the final version of the thesis, which is the version submitted to the Graduate School of Arts and Sciences. **Students must pay attention to published deadlines for submission of this final version of the signed thesis. These are hard deadlines and late submission <u>will</u> delay graduation.** Upon satisfactory completion of revisions, the First and Second Readers approve and sign several copies of a final version of the thesis. Two copies of the final thesis on appropriate bond paper are submitted to Martha Khan in the GRS Records Office by the required dates prior to graduation. The student must give final copies to the First and Second Readers (and when requested, other members of the thesis committee), and should retain at least one final copy for him/herself.

A set of rules/guidelines concerning page sizes, page numbering etc. for the thesis is available at the Graduate School Records Office in a pamphlet entitled <u>Guide for the Writers of Theses and Dissertations</u>. The Graduate School rules must be strictly followed. It is advisable for the student to schedule a meeting with the Graduate School Records Officer (Martha Kahn, 617-353-2964) when the dissertation is beginning to take shape to ensure that specific stylistic guidelines are being followed.

The Bioinformatics M.S. Program

I. Degree Requirements

The master's degree requires a total of 32 credits. The emphasis of the M.S. program is preparation for mid-level industrial positions in bioinformatics, and the M.S. degree constitutes a "Pre-professional M.S." Credits earned in the M.S. program may be applicable to the Ph.D. program, but the M.S. program is not intended to be a stepping-stone towards a Ph.D. (M.S. candidates wishing to enter the Ph.D. program must apply for admission to that program via the normal application process.) In order to receive a master's degree (by the end of the second year of full-time study) students must demonstrate mastery of the core subject matter (no lower than a 'B' in all core courses). They must also demonstrate a working knowledge of computational methods available to the modern bioinformatician by completing an internship as part of their degree requirements. Upon completion of the internship, the student is required to submit a written on the internship experience (see guidelines below). This report serves in lieu of an M.S. thesis. A brief written report from the intern's supervisor is also required. Internships credit is obtained by registering for BF 541, Bioinformatics Internship, or BF 501/502, Bioinformatics Master's Project. The required credit hours may vary.

Core Course Requirements:

The following courses are required (**20+** credits)

Course #	Course Name	Credits	Offered
BI 552[1]	Molecular Biology I	4	Fall
BE 562[2]	Computational Biology: Genomes, Networks, Evolution	4	Fall
BF 778	Physical Chemistry for Systems Biology	4	Spring
BE 768	Biological Database Systems	4	Spring
BF 821	Bioinformatics Graduate Seminar	2+2	Spring & Fall
BF 541	Bionformatics Internship	Var	Spring, Fall, Summer

[1] Students may take BI 553, Molecular Biology II if approved by their advisor(s).

[2] Students with no prior experience or exposure to bioinformatics application should take BF 527, Bioinformatics Applications, before taking BE 562.

Fulfillment of core course **equivalents** will be determined based on documented previous academic and/or work experience. The students and his or her advisor will petition the curriculum committee for such equivalencies. When either past work or an alternate course has been accepted as a core equivalent, the student's advisor will recommend other courses to fulfill the **20** core credit hours. **Advanced elective courses should be taken in place of any waived course requirements**.

Suggested Curriculum:

A. First Year:

FALL SEMESTER
1) BI 552 Molecular Biology I (4cr)
2) BE 562 Computational Biology: Genomes, Networks, Evolution (4cr)

SPRING SEMESTER
1) BF 778 Physical Chemistry for Systems Biology (4cr)
2) BE 768 Biological Database Systems (4cr)
3) BF 821 Bioinformatics Graduate Student Seminar (2cr each semester)

SUMMER: Students may begin the internship

B. Second Year:

FALL SEMESTER
1) BF 821 Bioinformatics Graduate Student Seminar (2cr)
2) BE 562 Computational Biology: Genomes, Networks, Evolution (4cr) if not taken in first year

ELECTIVES
1) BE 777 Computational Genomics (4cr)

SPRING SEMESTER
1) BF 541 Bioinformatics Internship, or BF 501/502 Bioinformatics Master's Project

Background enhancement: Typically students enrolling in the Bioinformatics M.S. Program have strength in either the computational area or in biochemistry/molecular biology, but not both. In consultation with their academic adviser, they may decide to take or audit some introductory courses to strengthen areas where their background has deficiencies. Examples of such courses (which do *not* carry graduate credit) are CS113 *Introduction to Computer Science and C++),* CH 172 *Life Science Chemistry II* (organic chemistry), CH 273 *Principles of Biochemistry,* BI 203 *Cell Biology*, and BI 206 *Genetics*

II. Master's Advising System

Academic Advisor

The Graduate Program Director serves as the student's primary academic advisor. Students should consult with the director to tailor their coursework to meet specific curricular needs in the transition into an interdisciplinary program. The director will also be available to advise them with regard to internship placements that will satisfy degree requirements.

III. Internship Program

Guidelines

Internships provide the bridge between classroom/laboratory study and "real-world" employment. Each student must complete an internship with a minimum of 400 hours of on-the-job experience (*e.g.,* 10 weeks full-time work in the summer). The format is very flexible, and part-time internships running concurrently with classes or employment are acceptable. Students whose regular, full-time job includes a strong bioinformatics component over at least a 6-month period can request that this be considered an internship. Students must consult with their academic advisor to assess the suitability of a proposed internship. For this purpose, "bioinformatics" means extensive use of computational tools to analyze, display and/or archive biological information (usually at the molecular level). The project supervisor must be familiar with the tools employed, and if possible, the position should involve regular interaction with "wet-bench" scientists. While most internships will take place in industrial settings, suitable projects can be completed in non-profit or academic research laboratories. In every case the student must obtain final approval from the Program Director *before* commencing an internship. *For full-time students the internship should begin no later than the third semester after beginning the M.S. program.*

Finding an Internship

Students have the final responsibility for finding an internship. The Bioinformatics Program Office maintains a list of past internship placements. These can serve as potential leads for current students. From time to time the office will solicit additions to this list through the Program's industrial advisers. Numerous job fairs in the biotechnology area occur here in Boston and students should attend these whenever possible. Not only do they help make connections with potential internship sponsors, but they also give an opportunity to learn about current trends in the industry. Another opportunity to contact potential sponsors is the Annual Biomedical Engineering Senior Project Conference (at the end of second semester). Websites may also be useful. And, of course, the network of bioinformatics students should provide many useful suggestions.

Internship Report

At the conclusion of the internship the student must submit a report that summarizes (a) the project he/she worked on (in general terms), (b) work accomplished (with very specific emphasis on the student's contribution), and (c) description of the impact of the experience on the student's professional development. Reports need not be more than two double-spaced text pages in length, though longer reports are acceptable. Append any detailed material that supports the narrative (tables, figures, publications, progress reports etc.). In cases where confidentiality agreements restrict release of pertinent project details, the report can describe the work in terms sufficiently general so as to be acceptable to the company in which the work was done.

Supervisor's Evaluation

The supervisor must provide a brief written evaluation of the intern and his/her work. A letter or an email will suffice. The quality of the intern's technical work and his/her ability to function as part of a research team should comprise the bulk of the evaluation. Communication skills and ability to work independently are also important points.

IV. Masters Program in Clinical Bioinformatics (MD Track)

Background The past 50 years have witnessed a scientific revolution of the first magnitude, a revolution which has transformed our knowledge of the cell from next to nothing, to nearly everything. With the complete sequence of the human and other genomes now elucidated, we will soon a have a complete parts list of the human cell-the precise location and base sequence of every gene in a reference genome. The reference allows us to rapidly characterize polymorphisms across the human population, and it also enables molecular fingerprinting technologies that permit identification of the precursors and consequences of normal and pathological changes in gene expression.

These changes are driving, and coupled to, advances in monitoring and understanding the collective properties of proteins and metabolites, and their modifications under various forms of stress. The full armamentarium of tools and information is profoundly altering biomedical research and the culture of science, and it is destined--during the next 10-20 years--stimulate an explosive growth in diagnostics, prognostics and therapeutics, profoundly altering the practice of medicine. But with this bewildering explosion of information and tools, comes subtle and complex dilemmas of choice, which must be faced collectively by society, and individually by patients and health care professionals. The need for clinically trained leaders, who understand these changes, their origin and their course, and who will play a proactive role in guiding their development, is crucial if the world's population is to benefit by these remarkable scientific advances.

Goal To train physician-scientists who will be leaders in applying and stimulating the development of post-genomic technologies to clinical research and the practice of medicine.

Program Content The Boston University Graduate Program in Bioinformatics consists of more than 50 faculty from the Colleges of Arts and Science, Medicine and Dentistry, Engineering and Public Health. The doctoral program which was approved by the Board of Trustees in 1999, and currently includes students co-mentored by a combination of advisors—experimental, clinical, and computational. Multidisciplinary laboratories with trainees form diverse backgrounds (mathematics, biology, chemistry etc) and levels (form undergraduate through post-doctoral) common. Collaborations between laboratories is also common, with joint seminars, research papers and grant proposals central to the Program.

Requirements The master's degree requires a total of 32 credits. MS candidates must demonstrate mastery of the core subject matter (no lower than a "B" in core courses) and complete a masters research project with a written and oral report which will serve as a Masters Thesis. Candidates will be expected to develop their ideas to the point of publication.

Contact Information For additional information, please contact Dr. Avrum Spira, Co-Director, at 617-638-4860

Core Courses

ENG BF527: Applications in Bioinformatics This course explores the use of bioinformatics databases and software as research tools. Students will use data mining tools to extract DNA and protein sequences from primary and secondary databases. Software tools will be used to compare and analyze these sequences and construct gene and protein models for solving research problems related to molecular evolution, drug discovery, and genetic bases for development and diseases. (4 credits)

ENG BE 562: Computational Biology: Genomes, Networks, Evolution
Prereq: Fundamentals of programming and algorithm design (EK 127 or equivalent), basic molecular biology (BE 209 or equivalent), statistics and probability (BE 200 or equivalent), or consent of instructor. The algorithmic and machine learning foundations of computational biology, combining theory with practice are covered. Principles of algorithm design and core methods in computational biology, and an introduction of important problems in computational biology. Hands on experience analyzing large-scale biological data sets. 4 cr.

***ENG BE768: Biological Database* Analysis** Describes relational data models and database management systems. Teaches the theories and techniques of constructing relational databases with emphasis on those aspects needed for various biological data, including sequences, structures, genetic linkages and maps, and signal pathways. Introduces relational database query language SQL and the ORACLE database management system, with an emphasis on answering biologically important questions. Summarizes currently existing biological databases. Describes Web based programming tools to make databases accessible. Addresses questions in data integration and security. The future directions for biological database development are also discussed. (4 credits)

SPH BS830: Design and Analysis of Microarray Data The purpose of this course is to present some of the methods for the analysis of gene expression data measured through microarrays. The course will start with a review of the basic biology of gene expression and an overview of microarray technology. The course will then describe the statistical techniques currently used to compare gene expression across different conditions and it will progress to describe the analysis of more complex experiments designed to identify genes with similar functions and to build models for molecular classification. The statistical techniques described in this course will include regression, discriminant analysis, clustering, classification, and simple graphical models. Methods for computational and biological validation will be discussed. Students will apply these methods in homework assignments and a final project. (4 credits)

GRS BF821: Bioinformatics Graduate Seminar In this course the students present advanced papers in Computational Biology and Bioinformatics. The papers are chosen to cover recent breakthroughs in genomics, computational biology, high-throughput biology, analysis methods, computational modeling, databases, theory and bioinformatics. Students are required to take the seminar course twice. (2 credits each time for a total of 4 credits)

ENG BF501: Bioinformatics Research Participation in a research project under the direction of a faculty advisor. Variable credits (6-10 credits)

Electives

ENG BE777: Computational Genomics A case-study approach to current topics in computational genomics. Mathematical and engineering tools for analyzing genomic data are reviewed. The relationships between sequence, structure, and function in complex biological networks are studied using quantitative modeling. Whole genome analysis is performed. Completion of a series of projects emphasizing real-life data, integrated approaches, practical applications, hands-on analysis, and collaboration. Course projects aim at improving current approaches and involve C and/or PERL programming to interface with existing software packages. The course will be offered in a computer laboratory equipped with one laptop per student. (4 credits)

GMS GE 701: Principles of Genetics & Genomics This course will serve as a foundation for understanding the heritable basis of numerous biological traits, the relationships among genes, and the regulation of their expression. We will focus on the ability to use genetic systems to probe these problems, and therefore will heavily explore the experimental aspects of these

investigations. In addition, we will discuss the impact of the genome sequences on the practice of modern science. Moreover, we will use a case study approach to investigate the rich variety of scientific insights gained through genetic studies.(4 credits)

SPH EB703: Biostatistics Topics include confidence intervals and hypothesis testing; sample size and power considerations; analysis of variance and multiple comparisons; correlation and regression; multiple regression and statistical control of confounding; logistic regression; and survival analysis. This course gives students the skills to perform, present, and interpret basic statistical analyses. For the more advanced topics, the focus is on interpretative skills and critically reading the literature.(4 credits)

GMS GE702: Advanced Topics in Genetics & Genomics The Advanced Topics course will focus on the mechanisms of biological processes that influence the inheritance and regulation of genes. In particular, the molecular details of genetic, epigenetic, and genomic processes will be discussed. Both genetic and genomic experimental approaches to these processes will be explored. In addition, we will discuss the possibilities of utilizing these technologies in medical treatments (4 credits)

GMS GE705: Critical Thinking in Genetics and Genomics This class is designed to chronologically follow the development of a field of study, the cell cycle, to allow students to explore the logical evolution of a coherent line of scientific inquiry. The individual meetings build on the background studies discussed in previous meetings, examine apparent discrepancies in experimental results, critique the approaches employed by the authors, and consider the logical follow-through experiments for the results at hand.(4 credits)

GMS BI793: Mass Spectrometry, Proteomics, and Functional Genomics This course will give investigators the background necessary to effectively design mass spectrometric experiments and interpret data. The instrumentation will be described at a level appropriate to graduate students in biochemistry and the structure of biological macromolecules will be described as it applies to mass spectrometry. Students will leave the course with a full understanding and effective use of mass spectrometric data in their research. Lectures will be devoted to instrumentation, ionization methods, and applications to proteins, lipids, carbohydrates, glycoconjugates, and nucleic acids. The uses of the technology in proteomics, biotechnology and medicine will be covered in detail. (4 credits)

Highlights of the Bioinformatics Program

Seminar Series

The Bioinformatics Program invites seminar speakers both from academic and industrial settings to discuss an aspect of their research. Bioinformatics students are encouraged to attend all seminars and are expected to attend the Bioinformatics-related seminars. Students are asked to join the guest speaker at an informal luncheon following the speaker's presentations. Formal dinners may be planned as well. Students will be notified of these seminars as they are scheduled.

Facilities

The program in Bioinformatics spans the Colleges of Arts and Sciences, Engineering, Dentistry, Medicine, and Law. Research areas are numerous and include biological information management, genomic sequence mining, drug design and targeting, protein and nucleic acid structure, and cellular regulatory networks. Students in the program have access to state-of-the-art computational facilities, including a Biowolf Linux cluster, a 332 processor Regatta supercomputer, at least 30 PCs and 10 high-end graphics workstations. The experimental facilities include pulse-field apparatus, high-speed sequencers, for microarrays an Axon 400B scanner with GenePixPro, a MALDI mass spectrometer, and various NMR spectrometers, fluorescence-activated cell cytometer and sorter, real-time quantitative PCR instrument, oligonucleotide synthesizer and automated DNA sequencing facility, confocal and electron microscopes, arrayed for generation of microarrays, two-dimensional fluorescence imager and robot spot picker.

With sixty faculty currently contributing to the program, the resources in centers and labs and students is comparable to the number of faculty participating. The University also has a number of libraries and offices that are available to the students. You can review the faculty pages at our web site (http://www.bu.edu/bioinformatics) to learn more about these facilities and what projects they are currently involved in.

The following are some of the on-campus resources:

Biomedical Data-Acquisition Laboratory
Biomolecular Engineering Research Center
Cellular and Subcellular Mechanics Laboratories
Computer Modeling and Simulation Laboratory
Biomolecular System Laboratory
DNA Sequencing Core Facility
Center for Biodynamic
Center for Advanced Biotechnology
Center for Computational Science
Science and Engineering Library

Graduate School of Arts and Sciences General Guidelines

Time Limits
The MS program shall be completed within three years after the first registration for study leading to the master's degree. The post-bachelor's Ph.D. program must be completed within seven years after the first registration for doctoral study. The post-master's Ph.D. program must be completed within five years after the first registration for the doctoral program.

Residency Requirement
Each student must satisfy a residency requirement of a minimum of two consecutive regular semesters of full-time graduate study at Boston University. Full-time study in this context is full-time commitment to the discipline as determined by the department. Without necessarily implying full-time course enrollment, this commitment permits access to libraries, laboratories, instructional staff, and other academic facilities of the University, including the department of concentration.
Doctoral students holding appointments as teaching fellows or research assistants are considered full-time students for purposes of the residency requirement provided that the time beyond that required by their appointments is devoted fully to their graduate program. In order to graduate, students must be registered part- or full time in the semester or summer term in which they complete degree requirements, as well as in the preceding semester.

Transfer of Credit
Graduate-level courses in other accredited graduate schools or in other Schools or Colleges of Boston University not used toward the awarding of any other degree may be transferred on recommendation of the major advisor and the Director of the department with the approval of the Graduate School. Credit for work to be taken concurrently with studies in the Graduate School of Arts and Sciences must be approved before registration for such courses; all such courses must have been taken for a letter grade (not pass/fail). No transfer of credit for courses taken before the senior year of college or from correspondence or extension schools will be accepted. Petitions for credits for transfer are available in the GRS Records Office.

Registration
An officially registered student is one who has selected courses by telephone registration (TelReg) or submitted course selections, web registration (WebReg), on a registration form and who has paid or settled all charges.

Candidates for admission may not register until they receive a formal statement of acceptance. Registration is conducted under the direction of the Office of the University Registrar. Graduate students should consult the GRS Records Office, for detailed instruction concerning the procedure to be followed during the announced registration period. Students must be registered for any regular semester or Summer Term during which a degree requirement is completed or University facilities are used.

A student who, in any semester, fails to register and has not been granted an official leave of absence will be considered a continuing student and will be charged the usual fee for such status. Failure to register for two consecutive regular semesters without having been granted an authorized leave of absence may result in termination of degree status.

Registration Deadlines
A student in the Graduate School of Arts and Sciences should complete the course selection process by May for the fall semester and December for the spring semester. The deadline for payment/settlement of a student's account appears in The Guide published by the Office of Student Accounting Services. A new graduate student usually completes registration during the week prior to the beginning of classes. Late fees are charged to students who do not register or settle their tuition account during the official period. Students may not register later than one week

after the start of classes without written approval from their School or College. Students who are not registered by the deadline will have their financial assistance offers revoked.

Adding or Dropping a Course
Students wishing to change their courses must complete a Class Adjustment Form, obtain their advisor's signature, and return the completed form to the Graduate Program Coordinator. A request for late registration in courses cannot ordinarily be granted after the first full week of classes.

No course may be added after the first two weeks of class. A course dropped during the first five weeks of class will not appear on the student's permanent record. After the first five weeks, a dropped course will appear on the student's record as W, and the student will be charged for the course. No course may be dropped after the eighth week of class. Graduate School financial aid will not cover the cost of a course from which a student has officially withdrawn. Students who register for any course are held responsible for its completion unless they officially withdraw by the deadline date or change to the status of auditor within the first five weeks of class.

Full-Time Students
By enrollment— A student enrolled in three to four-and-a-half courses (12 to 18 credits) will be considered full-time and will be charged full tuition and fees. A student may register for more than four courses (16 credits) only with approval of the Graduate School's Committee on Academic Standards.

By certification— a student registered for fewer than three courses or 12 credits (a minimum of one course must be taken until all coursework requirements have been completed) but engaged otherwise in full-time study, research, or teaching pertinent to the completion of degree requirements or to gaining competence in the field of study, may be certified as a full-time student. Such a student must pay tuition on a per-course basis and full-time fees. A student desiring full-time certification must submit to the Graduate Program Coordinator, during the official registration period, a completed full-time certification form approved by the advisor.

As teaching fellows and research assistants— Students holding regular appointments as teaching fellows or research assistants are considered full-time if they are enrolled in two or more courses. Teaching fellows or research assistants taking fewer than two courses may, if appropriate, be designated as full-time by certification.

Part-Time Students
All part-time students who are candidates for degrees must register each regular semester for no less than one semester course until all departmental course requirements are completed. Continuing students (see below) may register for less than one 4-credit course.

Continuing Student Status
M.S. and Ph.D. candidates who have completed all departmental course requirements must register each subsequent regular semester for continuing student status until all requirements for the degree have been completed. Payment of the Continuing Student Fee each semester entitles the student to appropriate access to and use of the libraries, research laboratories, academic staff, and other academic facilities of the University for the purpose of completing such requirements as examinations, research, and thesis or dissertation work. Continuing students who are Ph.D. candidates are entitled to officially audit one course each semester without further tuition charge. Graduate courses at the 900 level, language and physical education courses, studio courses and courses with laboratories may not be audited.

Registering and payment of regular tuition and fees for at least one course exempts the student from the Continuing Student Fee. Continuing students may also qualify as full time according to the above regulations.

Incomplete Coursework and Grade Changes
When the work of a course has not been completed within the semester of registration, the grade of I is used. This automatically becomes a permanent I (unsatisfactory grade) unless the coursework is completed within the following calendar year. Grades of I and C+ or lower are interpreted as failures. A student receiving such grades in more than two semester courses (or more than a total of 8 credit hours) is terminated. Grades, including incompletes, may not be changed after a period of one year from the time the original grade is recorded.

Graduation
MA degrees are awarded in September, January, and May. PhD degrees are awarded in January and May. Commencement exercises are held in May only. Students planning to receive their degrees at the May commencement must submit diploma applications by February 1. Students must submit diploma applications by July 1 for September graduation and by November 1 for January graduation. Students in approved dual degree programs must file separate diploma applications with each School. The diploma application is valid only for the graduation date specified; a new application must be filed if the student does not graduate as planned. Diploma applications and copies of the Graduate School of Arts and Sciences regulations on the preparation of theses and dissertations are available in the GRS Records Office.

Transcripts
Requests for official transcripts must be made in writing, either by letter or by completing a Transcript Request form available online at Office of the University Registrar or at the Office of the University Registrar. Please include the following information: full name, including any former names; signature; Boston University ID number or Social Security number; Schools attended and dates; degrees awarded; and complete address of transcript destinations. The transcript fee is $5 per copy, and payment must accompany the request. Processing time for transcript requests received by mail is three to five business days. The Registrar's Office does not accept faxed transcript requests. Transcripts can be sent by DHL for an additional $11 per destination to locations within the continental United States. For other destinations, please contact the Transcript Department for the cost. Unofficial transcripts can be obtained in person at the Registrar's Office during regular business hours. There is no charge for unofficial transcripts. A valid photo ID is required to obtain unofficial and official transcripts if the request is done in person at the Registrar's Office. Please note that the Registrar's Office does not mail unofficial transcripts.

Suspension or Dismissal
Boston University, through its various faculties or appropriate committees, may suspend or dismiss any student from the University for reasons of scholarship, aptitude, or conduct.

Leave of Absence and Withdrawal
Normally, students must register for each regular semester until completion of all degree requirements. Upon written request to the Graduate School of Arts and Sciences, a student will be allowed up to two semesters of leave of absence without committee consideration. Leaves of absence beyond two semesters may be granted in cases of substantiated illness, one-semester maternity or paternity leave, or military service. In exceptional cases, the student should petition the Associate Dean of the Graduate School of Arts and Sciences with approval of the chairman of the department or division of concentration.

A student who files for a leave of absence from the University before classes start is eligible to receive full credit of tuition and fees. Students should refer to "Withdrawals and Refunds" in the GRS Bulletin for the refund schedule after the beginning of classes. A student who is on leave and who has borrowed federal and/or private loans may be required to begin repayment while on leave. If leave is granted, a certificate of authorized leave of absence is issued and a copy included in the student's record.

The period of authorized leave of absence is counted as a part of the time allowed for completion of degree requirements. Students may not complete any degree requirements in a semester for which they have been granted leave of absence. Students must be registered in the semester in which the degree requirements are completed, as well as in the preceding semester.

Students who wish to withdraw or take a leave of absence from the University must submit their requests in writing to the GRS Records Office, Suite 112, 705 Commonwealth Avenue, Boston, MA 02215. The Graduate School will be responsible for notifying the student's major department. A request for a withdrawal or leave of absence is effective on the day it is received in the appropriate office; charges are canceled in accordance with the University's published refund schedule, based on the effective date of the student's leave of absence or withdrawal. Mere absence from class does not reduce financial obligations or guarantee that final grades will not be recorded.

Readmission to a Degree Program
Students applying for readmission to the Graduate School of Arts and Sciences will be subject to the following regulations: a minimum of two years must elapse from the time of withdrawal or termination until enrollment; reapplication must be accompanied by an application fee; if readmitted, the student may be asked to retake examinations or demonstrate knowledge in current issues in the field of specialization; readmitted students will be subject to the rules and regulations set forth in the Graduate School of Arts and Sciences Bulletin at the time of readmission; students who have outstanding financial obligations to the University at the time of withdrawal or termination will be required to meet those obligations as a condition of readmission; at the time of readmission, the student must provide a detailed schedule of plans for completing the remaining degree requirements within specific time limits.

Identification Cards and Numbers
Terrier cards are issued by the Terrier Card Office and the Office of the University Registrar. Students are assigned an ID number by the University.

A student is entitled to a new card only when there are changes to the information on the card. A fee is charged for replacing a lost card. Replacement cards are issued at the Terrier Card Office and the Office of the University Registrar.

** For more information about the GRS General Guidelines please see their bulletin either in print format or online at http://www.bu.edu/bulletins/grs.

Course Descriptions

CORE COURSES

CAS BI 552: Molecular Biology I
Prereq: BI 203-Cell Biology, BI 206-Genetics. Synthesis, structure, and function of biologically important macromolecules (DNA, RNA, and proteins). Regulation and control of the synthesis of RNA and proteins. Introduction to molecular biology of eukaryotes. Discussion of molecular biological techniques, including genetics and recombinant DNA techniques. Three hours lecture, one hour discussion. 4 cr. *Professor Leochler*.

ENG BF 751: Molecular Biology and Biochemistry: Molecules and Processes
This course consists of two modules (a) "Molecules" – an introduction to the molecular make-up of living organisms, including the mechanisms of action of key players in metabolism and other dynamic functions of cells, and (b) "Processes" – a survey of selected biochemical and cellular functions viewed from the systems-biology level. Each week during the first of two, two-hour classes we will present and discuss fundamental information about the make-up and properties of relevant biological components at the molecular (and sometimes supramolecular) level. The second class will involve presentations by training faculty or guest lecturers about exemplary systems cognate with the material presented earlier that week followed by extensive discussion. Whenever possible, the presentations will involving the presenter's own research. In most cases these they will start at the level of physiological function and "drill down" to the molecular details (to the extent that those are known). The "Processes" module will include introductions to metabolic and signaling networks, sub-networks and control processes. 4 cr. *Professor Mohr*

ENG BE 562: Computational Biology: Genomes, Networks, Evolution
Prereq: Fundamentals of programming and algorithm design (EK 127 or equivalent), basic molecular biology (BE 209 or equivalent), statistics and probability (BE 200 or equivalent), or consent of instructor. The algorithmic and machine learning foundations of computational biology, combining theory with practice are covered. Principles of algorithm design and core methods in computational biology, and an introduction of important problems in computational biology. Hands on experience analyzing large-scale biological data sets. 4 cr. *Professor Galagan*

ENG BE 768: Biological Database Analysis
Prereq: CS 112 or CS 113, graduate standing, or consent of instructor. Background knowledge of biochemistry and genetics. Describes relational data models and database management systems. Teaches the theories and techniques of constructing relational databases with emphasis on those aspects needed for various biological data, including sequences, structures, genetic linkages and maps, and signal pathways. Introduces relational database query language SQL. Summarizes currently existing biological databases and the Web-based programming tools for their access. Object-oriented modeling is introduced primarily as a design aid for dealing with the particular complexities of biological information in standard RDB design. Emphasis will be on those problems associated with dealing with data whose nomenclature and interrelationships are undergoing rapid change. 4 cr. *Professor Benson*

ENG BE 777: Computational Genomics
Formerly BE 700
Prereq: BE 561 or consent of instructor. A case-study approach to current topics in computational genomics. Mathematical and engineering tools for analyzing genomic data are reviewed. The relationships between sequence, structure, and function in complex biological networks are studied using quantitative modeling. Whole genome analysis is performed. Completion of a series of projects emphasizing real-life data, integrated approaches, practical applications, hands-on analysis, and collaboration. Course projects aim at improving current approaches and involve C and/or PERL programming to interface with existing software packages. The course will be offered in a computer laboratory equipped with one laptop per student. 4 cr. *Professor Xia*

ENG BF 778: Physical Chemistry for Systems Biology
This course introduces students to quantitative modeling in bioinformatics and systems biology. We begin with basic principles of statistical thermodynamics, chemical kinetics, with selected applications in biomolecular systems. Next we describe molecular driving forces in biology, and computation with biomolecular structures. Finally we discuss quantitative models of biomolecular networks, and design principles of biological circuits. 4 cr. *Professor Xia*

ENG BF 690: Bioinformatics Challenge Project
The Challenge Project consists of complex open-ended biological problems which can best be addressed by a combination of bioinformatics and wet-lab approaches. The Project will extend over both semesters in the first year. The problems involve bioinformatics as a key element, typically requiring the use of large data sets and computational analyses to make predictions about molecular function, molecular interactions, regulation, networks, etc. *Professor Benson*

ENG BF 810: PhD Laboratory Rotation System
This course is for Ph.D. students to take part in a laboratory rotation system. Students will become familiar with research activity in Bioinformatics labs. These rotations will help students identify the laboratory in which they will perform their Dissertation research. Post-Bachelor Ph.D. students must complete one 9-week rotation in their first semester of matriculation and two in their second semester. Ph.D. standing, 1 cr. per rotation; 3 total.

ENG BF 820: Research Opportunities in Bioinformatics
Required for entering Bioinformatics Ph.D. students. The course will consist of a series of presentations by Bioinformatics faculty that focuses on research projects being investigated in their laboratories. Emphasis is placed on the description of collaborative projects involving experimental and computational approaches to Bioinformatics research problems. 1 cr. *Professor Kepler*

ENG BF 821: Bioinformatics Graduate Seminar
In this course the students present advanced papers in Computational Biology and Bioinformatics. The papers are chosen to cover recent breakthroughs in genomics, computational biology, high-throughput biology, analysis methods, computational modeling, databases, theory and bioinformatics. 2 cr. *Professor Xia*

BIOINFORMATICS COURSES

ENG BF 527: Applications in Bioinformatics
Prereq: CAS BI/CH 421 or CAS BI 203 and BI 206 and consent of instructor; CAS MA 121, MA 123 or MA 127 or equivalent. The material will be presented in a case-based format, using real-world examples to investigate the most widely used bioinformatics applications, e.g., BLAST, Clustal, GRAIL, INSIGHT II, or RASMOL. We will address a broad range of biological questions currently addressed via genomic data, including sequence alignment, pattern recognition and identification, extrapolation of sequence to structure, and intermolecular interactions. 4 cr.

ENG BF 541, 542: Internship in Bioinformatics
This course allows M.S. and Ph.D. students in bioinformatics to take part in an industrial internship. Students will be required to present a report on their training and/or make a presentation and poster as a part of participating in the University's Science Day program (annual in March). Variable credits

ENG BF 501, 502: Master's Project
For MS students in bioinformatics. Participation in a research project under the direction of two faculty advisors. Variable credits

ENG BF 752: Directed Study
Detailed analysis of special topics in the theory and research in bioinformatics. The topics are determined by the instructor depending upon interest and expertise. Staff. 2 cr/4 cr.

ENG BF 900: Pre-candidacy Research in Bioinformatics
For Ph.D. students prior to candidacy. Participation in a research project under the direction of two faculty advisors. Requires the development of a brief document outlining the proposed research leading to either a Ph.D. prospectus (for Ph.D. students). Variable credits

ENG BF 901, 902: Post-candidacy Thesis/Research in Bioinformatics
For Ph.D. students post-candidacy. Participation in a research project under the direction of two faculty advisors. Variable credits

Please visit the links below to view…

BIOMEDICAL ENGINEERING COURSES

http://www.bu.edu/academics/eng/programs/biomedical-engineering/

BIOLOGY COURSES

http://www.bu.edu/bulletins/grs/item14.html#anchor05

CHEMISTRY COURSES

http://www.bu.edu/bulletins/grs/item17.html#anchor04

COMPUTER ENGINEERING COURSES

http://www.bu.edu/academics/eng/programs/computer-engineering/

COMPUTER SCIENCE

http://www.bu.edu/bulletins/grs/item20.html#anchor04

ELECTRICAL ENGINEERING COURSES

http://www.bu.edu/academics/eng/programs/electrical-engineering/

MATHEMATICS AND STATISTICS COURSES

http://www.bu.edu/bulletins/grs/item29.html#anchor06

MOLECULAR BIOLOGY, CELL BIOLOGY & BIOCHEMISTRY COURSES (MCBB)

http://www.bu.edu/academics/grs/programs/molecular-biology-cell-biology-biochemistry/

Appendix

A. Graduate School of Arts and Sciences 2012-13 Graduation Calendar

A candidate must be registered for the semester or summer term in which degree requirements are completed and during the preceding semester. Please bring all paperwork to GRS in person.

Ph. D. Degree Candidates

	Jan. 25, 2013 Award	May 19, 2013 Award
Dissertation Prospectus due in the Graduate School Office (GRS)	April 6, 2012	October 5, 2012
Diploma Application due in GRS *	November 1, 2012	February 1, 2013
First draft of dissertation (submitted to readers)	October 5, 2012	February 1, 2013
Dissertation abstract (max. 350 words) approved by dept. – due in GRS Office for review and approval by the Dean	At least three weeks prior to Final Oral Exam	At least three weeks prior to Final Oral Exam
Schedule of Final Oral Examination (to be arranged by department) due in GRS with fourteen copies of approved abstract	Two weeks prior to Final Oral Exam	Two weeks prior to Final Oral Exam
Last date to hold Final Oral Exam N.B. The deadline for submission of the dissertation is the same date (see item below)	December 14, 2012	April 12, 2013
Approved and signed dissertation (2 copies due in GRS on or before this date) **	December 14, 2012	April 12, 2013

**Prior to the dissertation defense, the candidate must schedule an appointment with the Records Officer for review of the dissertation format. All Ph.D. degree requirements are complete only when both copies of the dissertation have been certified as meeting the standards of the Graduate School or Arts and Sciences and of the Mugar Memorial Library.

M.S. Degree Candidates

	Jan 25, 2013 Award	May 19, 2013 Award	Sept. 25, 2013 Award
Diploma Application due in GRS *	November 1, 2012	February 1, 2013	July 1, 2013

* The diploma application is only valid for the graduation date specified; a new application must be filed if the student does not graduate as planned.

B. Academic Calendar 2012-2013

FALL 2012

Instruction Begins	Tuesday, September 4, 2012
Holiday, Classes Suspended	Monday, October 8, 2012
Substitute Monday Schedule of Classes	Tuesday, October 9, 2012
Parents Weekend	Friday, October 19 - Sunday, October 21, 2012
Fall Recess Begins	Wednesday, November 21, 2012
Instruction Resumes	Monday, November 26, 2012
Last Day of Instruction	Wednesday, December 12, 2012
Study Period	Thursday, December 13, - Sunday, December 16, 2012
Final Exams Begin	Monday, December 17, 2012
Final Exams End	Friday, December 21, 2012

SPRING 2013

Instruction Begins	Wednesday, January 16, 2013
Holiday, Classes Suspended	Monday, January 21, 2013
Holiday, Classes Suspended	Monday, February 18, 2013
Substitute Monday Schedule of Classes	Wednesday, February 20, 2013
Spring Recess	Saturday, March 9 - Sunday, March 17, 2013
Instruction Resumes	Monday, March 18, 2013
Holiday, Classes Suspended	Monday, April 15, 2013
Substitute Monday Schedule of Classes	Thursday, April 18, 2013
Last Day of Instruction	Thursday, May 2, 2013
Study Period	Friday, May 3 - Monday, May 6, 2013
Final Exams Begin	Tuesday, May 7, 2013
Final Exams End	Saturday, May 11, 20
COMMENCEMENT	**Friday, May 17 - Sunday, May 19, 2013**

NOTES

- Classes will be held on Veterans Day, Friday, November 12, 2012.
- The University, in scheduling classes on religious holidays and observances, intends that students observing those traditions be given ample opportunity to make up work. Faculty members who wish to observe religious holidays will arrange for another faculty member to meet their classes or for canceled classes to be rescheduled.