

Genomics and Computational Biology

Graduate Group Handbook

2011



Training Mission

The Genomics and Computational Biology Graduate Group identifies outstanding Ph.D. candidates, recruits them to the University of Pennsylvania, and trains them to be productive scientists in both the academic and industry arenas. The overall mission of our training program is to provide students with mentorship and help them develop the skills they need to become independent and interdisciplinary research scientists in genome sciences and computational biology. The goal of the program is to produce accomplished biomedical scientists regardless of particular approaches. However, because our graduates also pursue careers other than research, our training program is designed also to prepare students for non-academic careers (or opportunities). Pursuant to this overall mission, GCB seeks to provide each trainee with a comprehensive understanding of the foundation of genomics and computational biology. The students learn the application and importance of both theoretical and experimental approaches to biomedical problems. They are expected to learn the contemporary and historical views associated with the study of genomics and computational biology.

GCB accomplishes its training goals by:

- a) providing trainees with a foundation of knowledge through coursework, seminars, journal clubs, and interactions with visiting scientists;
- b) training students to evaluate the current literature and develop questions into testable hypotheses;
- c) providing trainees with an intensive basic research experience.

History of the GCB Program:

In 2001, Penn created a new Graduate Group, Genomics and Computational Biology (GCB). At Penn, PhD programs are called “Graduate Groups.” These groups are sometimes aligned with departments (e.g., Biology), but others (e.g., GCB) include faculty based in several departments. GCB is an interdisciplinary Ph.D. program, administered by Biomedical Graduate Studies (BGS – the Ph.D. division of the School of Medicine), but constituted of faculty from many different departments. The program is a cooperative undertaking by the schools of Medicine, Arts and Sciences, Engineering and Applied Science, Wharton, Veterinary Medicine, and the Penn-associated Wistar Institute and Children’s Hospital of Pennsylvania (CHOP). Faculty can, and do, participate in multiple Graduate Groups. The former chairs of GCB are Drs. Richard Spielman (2001-2004) and Warren Ewens (2004-2007). The current chair of the graduate group is Dr. Maja Bucan.

As mentioned above, the GCB graduate program brings together the experimental approaches of high-throughput genetics and molecular biology with the ability to manage and interpret the very large collections of data that result from such experiments. Applicants to the program are expected to have a strong background in one or more relevant fields, such as molecular biology, computer science, or genetics. Building on these, the graduate program provides advanced education in various aspects of bioinformatics and genomics, including as appropriate genetics, computer science, mathematics and statistics, and molecular and cell biology. While it is not expected that any one student will become an expert in all these areas, a student who specializes in computational biology, for example, is expected to receive substantial training in areas such as genomics and in particular to obtain laboratory experience in such areas. Similarly, a student who specializes in experimental genomics is not expected to become expert in computer algorithm theory but is expected to understand the theory behind the techniques,

tools, and algorithms used in practice and to be competent in the development and use of such tools if the need arises.

The structure of the GCB course requirements and candidacy exam reflects our aim to have students achieve excellence in either biology or quantitative sciences with solid competence in the other, and in addition gain the ability to solve problems that require understanding of both fields in order to remain in good standing. Based on feedback from students who have attained PhDs from our program, it seems that this emphasis on computational and experimental research presents a major advantage in their career planning.

Faculty Membership

GCB faculty are drawn from across the university, bringing diverse expertise to a quickly developing field. The graduate program benefits from the highly dynamic and collaborative atmosphere of the Penn genomics and computational biology community. By any measure, we have a large number of highly qualified faculty from a wide variety of research fields and an enormous breadth in their research interests in genomics and computational biology:

Genetic variation and genomics of human disease (Bucan, Cappola, Cheung, Chodosh, Emanuel, Ewens, FitzGerald, Hakonarson, Li M., Li H., Maris, Master, Minn, Pack, Riethman, Tishkoff, Ungar, Wang)

Population genetics and evolutionary biology (Ewens, Feng, Li M., Li H., Kim, Plotkin, Roos, Sneigowski, Tishkoff, Wang)

Functional genomics (Bucan, Bushman, Carstens, Cherry, Cheung, Chodosh, Davies, Diamond, Davuluri, Eberwine, Emanuel, Fitzgerald, Gregory, Hogenesch, Huang, Kaestner, Kim, Maris, Master, Murray, Pack, Wagner)

Chromatin Remodeling (Kaestner, Berger, Lazar)

Structural biology and proteomics (Greenbaum, Master, Radhakrishnan, Sarkar, Saven, Sharp, Speicher)

Databases (Davidson, Davuluri, Roos, Stoeckert, Wang, White)

Algorithms and machine learning (Kannan, Kim, Roos, Ungar, Wang)

Statistics and Applied Math (Cheung, Davuluri, Epstein, Ewens, Jensen, Kim, Li M., Li H., Ungar)

Systems Biology (Diamond, Goulian, Hogenesch, Kim, Kumar, Murray, Plotkin, Raj, Roos, Rubin)

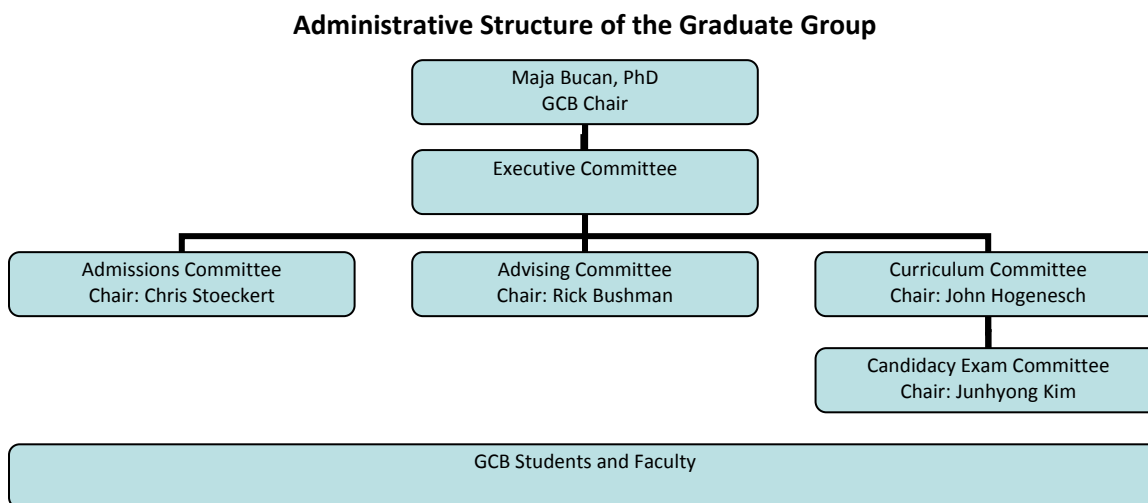
Requirements for Graduate Group Membership

Faculty membership in GCB will be approved by the executive committee on the basis of a CV and letter of request from the candidate, or a nomination letter from a current GCB faculty member. Candidates for membership in the graduate group are asked to give a chalk talk prior to joining the group, to introduce themselves and their research to GCB students and faculty. To remain in GCB, faculty are expected to contribute to the group in a substantive way, which may include teaching, serving on an administrative committee, serving on thesis committees, or other service work. Mentoring a GCB

student in a rotation or on their thesis project is not considered adequate in and of itself to maintain membership in GCB. Faculty that are not deemed to be contributing will be invited to contribute (in some cases, to a specific activity) in order to retain their good standing. If they prefer not to contribute, they will be removed from the GCB faculty but are welcome to rejoin the GCB program at a later date.

Governance of the Graduate Group

The Graduate Group is overseen by the Chair and the Executive Committee with additional Advising, Curriculum, Admissions, and Candidacy Exam (formerly Prelim Exam) Committees. Two student representatives serve on each committee.



Chairperson

The Chairperson is the individual responsible for governance of GCB. The GCB Chair oversees all committees of the GCB and selects Course Directors for all courses. The Chair convenes meetings of the Executive Committee and sets the agenda for these meetings. The Chair sets the agenda and presides over annual Faculty Meetings.

In addition to these responsibilities, the Chair also:

- Supervises day-to-day operations of the GCB
- Serves on all GCB Committees
- Attends to the funding of all GCB students
- Helps Training Grant principal investigators identify students appropriate for their training programs
- Serves on the Biomedical Graduate Studies Advisory Committee
- Meets with students on a regular basis
- Oversees the Graduate Group Coordinator
- Oversees the Faculty composition of the Program (i.e., committees)
- Approves rotation and thesis laboratories and assures regular thesis committee meetings
- Gives final approval of the Dissertation of each student
- Prepares the Resource Document for Graduate Group Reviews

The Chair serves a three-year renewable term. In the Spring semester of the third year of a term, the Executive Committee requests nominations for the Chair and then contacts the nominees to determine if they would agree to serve. After the first three-year term, the Executive Committee may reappoint the chair through a committee vote, and a member of the committee should inform the faculty and students. Nominations must be of senior level (Associate or Full Professor) individuals from the Standing Faculty of the University. The Chair is expected to be experienced in training Ph.D. level students.

Executive committee:

The Executive committee consists of the chairs of the other committees as well as other GCB faculty that wish to serve. It is responsible for:

- Changes and exceptions to GCB policy
- Overall administration of the GCB program
- Admission of new faculty to the program
- Removal of non-contributing faculty from the program
- Advancement to Ph.D. candidacy of the students

The Executive Committee functions as an advisory committee to the Chair. It is composed of the GCB Chair and other faculty selected from senior membership of the GCB. The membership will represent the concerns of the Advising, Curriculum, and Admissions Committees. Its responsibilities are to maintain integration of the various graduate group programs and to review significant changes in policy, direction, or intent as recommended by GCB Committees or members, prior to final approval by the membership at large. Like the Advising Committee, the membership should always broadly represent each aspect of the students' training program. The Chair of the Executive Committee is the GCB Chair, who is responsible for leading meetings and organizing the agenda.

The Executive Committee also evaluates faculty applications for membership in GCB. This committee reviews applications and votes for nomination and election to membership. This Committee also solicits nominations for GCB Chair and tabulates votes from the membership.

Curriculum committee:

The Curriculum Committee is primarily composed of course co-directors for GCB courses (GCB 531, GCB 535, GCB 537, and GCB 752). This committee reviews the existing curriculum and evaluates how the students' needs are met by the available courses. Modifications to the existing curriculum are initiated by this Committee and approved by the Executive Committee and then by the membership of the GCB. Two GCB students will serve on this Committee

The Chair of this committee prepares the agenda and runs committee meetings and sits on the GCB Executive Committee. The Chair of the committee, along with the graduate group Chair, attends BGS Curriculum Committee meetings. The Curriculum Committee reviews the existing curriculum and evaluates how the students' needs are met by the available courses. Modifications to the existing curriculum are initiated by this Committee and approved by the Executive Committee and then by the GCB faculty body. The Chair of this committee prepares the agenda and runs committee meetings and sits on the Executive Committee.

Admissions committee:

Responsible for:

- Reviewing all applications
- Classifying students into 3 categories:
 - Invite for interview
 - Reject
 - May be invited later
- Selecting faculty interviewers for the candidates
- Participating in student interviews
- Reviewing interview evaluations and recommending acceptance

The Chair of the Admissions Committee sits on the BGS Admissions Committee and represents GCB. He or she also serves as a member of the GCB Executive Committee, and works with the graduate group coordinator to prepare admissions materials and reports for committee meetings.

Advising committee:

This committee consists of 5 members who meet with first and second year students at the beginning of each semester to advise and approve of each student's course and rotation choices. If some members are unable to attend the meeting, special effort is made to have representatives from different areas of the curriculum (biology, statistics, computer science, etc.). Members of the Advising committee also meet with first year students at the end of their second semester or in the summer prior to the second year to review the students' progress, rotations, and plans for the coming year. In addition, the Advising Committee is responsible for monitoring the progress of students via their thesis committees. Student members of the advising committee will offer their advice but not be privy to their colleagues' transcripts (with grades) and other formal evaluations. Student representation should include a 2nd and 3rd year student to provide recent feedback on courses.

Candidacy Exam Committee:

Responsible for:

- Setting the dates for the exam
- Collecting the questions from GCB faculty
- Collating the exam
- Proctoring the exam and coordinating the grading process
- Evaluating the exam and recommending pass/fail/conditional pass

The Candidacy Exam Committee consists of faculty members who remain on the committee for several years, as well as a rotating group of advisors of third year students. The committee works closely with the Curriculum and Advising Committees to ensure that the exam tests candidates' knowledge in the areas of experimental and computational sciences, as well as statistical methods. After the exam is administered, the Committee meets to discuss individual scores and recommend whether a student should advance to full candidacy in the PhD program.

Current GCB Committee Membership**GCB Executive Committee**

Maja Bucan	Graduate Group Chair
Frederic Bushman	
Warren Ewens	
Susan Davidson	
John Hogenesch	
Junhyong Kim	
Harold Riethman	
David Roos	
Chris Stoeckert	
Lyle Ungar	
Ellen Tsai	Student Representative

GCB Advising Committee

Frederic Bushman	Chair, Advising Committee
Brian Gregory	
Mark Goulian	
Shane Jensen	
Lyle Ungar	
Serena Dollive	Student Representative
Brett Hannigan	Student Representative
Maja Bucan	Ex-officio

GCB Admissions Committee

Chris Stoeckert	Chair, Admissions Committee
Li-San Wang	Co-chair, Admissions Committee
Vivian Cheung	Chair, MD/PhD Admissions
Maja Bucan	Ex-officio
Hongzhe Li	
Klaus Kaestner	
Arjun Raj	
David Roos	
Sarah Tishkoff	
Nate Berkowitz	Student Representative
Fan Li	Student Representative

GCB Candidacy Exam Committee

Junhyong Kim	Chair, Exam Committee
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GCB Curriculum Committee

John Hogenesch	Chair, Curriculum Committee
Warren Ewens	
Junhyong Kim	
Stephen Master	
Harold Riethman	
Li-San Wang	
Scott Sherrill-Mix	Student Representative

GCB Curriculum

Training in Genomics and Computational Biology involves coursework, seminars, interactions with outside scientists, and research. These activities will impart a comprehensive knowledge of genomics and computational biology and teach the skills necessary for a career in biomedical science.

GCB-Directed Courses

GCB currently directs three courses (GCB 531, 537, and 752), all led by GCB faculty, which are tailored to GCB students. In addition, GCB 530 and 530 cover topics relevant to computational biology in a format more appropriate for other BGS students and those in related programs across the university.

General Requirements of the Doctoral Program: Upon matriculating, students will meet with the Advising Committee to design a course of study that encompasses their academic interests and fulfills the curriculum requirements of the GCB program.

When the thesis committee is formed, it will consist of at least one faculty member from another discipline (for example, students in biology would have a thesis member from Computer Science, students in computer science would have a thesis committee member from Biology or the School of Medicine). This will ensure that the student gets input from experts across the disciplines that most influence today's research in Genomics and Computational Biology. When possible, students are encouraged to have thesis co-advisors from within GCB with expertise in complementary disciplines.

Students in GCB take courses as described below, do lab rotations with GCB faculty, and attend the research seminars sponsored by Penn Genome Frontiers Institute (PGFI), Penn Center for Bioinformatics (PCBI), and seminar series of their host department, as well as weekly student-faculty "chalk talks" (see page 14).

The GCB curriculum combines several required courses specifically designed for the GCB program and other courses available in other programs. In general, the core courses are taken during the first year, although one can be switched to the second year if necessary. For example, students sometimes take BIOM 600 or 555 during their second year. In the first year, students generally take three courses each semester and participate in one lab rotation. During the second year, the lab rotation is replaced by pre-dissertation research in the student's thesis lab under the direction of their mentor.

In view of the highly varied academic backgrounds of students in GCB, members of the Advisory Committee meet with each student individually once per semester (Year 1 and 2) and plan courses and rotations. Under the GCB curriculum, students are required to complete a minimum of twelve classes, as specified below. The advising committee helps design a course schedule for each student that matches his/her needs and interests.

Required Courses:**1. Introduction to Genome Science (GCB 531) (J. Hogenesch and J. Murray)**

This course serves as an introduction to the main laboratory and theoretical aspects of genomics and computational biology. The main topics discussed center around the analysis of sequences (annotation, alignment, homology, gene finding, variation between sequences, phylogeny reconstruction/estimation), and the functional analysis of genes (expression levels, proteomics, screens for mutants), together with a discussion of gene mapping, linkage disequilibrium, genetics of complex diseases, and integrative genomics.

2. Advanced Computational Biology (GCB 537) (L. Wang)

GCB537 is a course geared towards GCB students, who are expected to have exposure to basic computational biology techniques and general familiarity with modern biology. This course is designed to (1) broaden the students' knowledge in more advanced computational techniques applied to a wide variety of biological problems, and (2) provide a forum for the improvement of the students' presentation skills. Papers are selected to cover a wide variety of areas not covered to the same degree in any of the other lecture-based courses.

3. Genomics Seminar (GCB 752) (H. Riethman)

Recent papers from the primary genomics literature form the core material for the course. Each 3-hr seminar features a major topic in genomics, with student presentations centered on papers selected within the topic area. The "presenting" student will give a 10-15 minute introduction to the paper and will show powerpoint slides of the data in the paper. All students in the class are expected to have read and to be prepared to discuss the papers presented. For example, following the introduction, non-presenting students will be called upon to explain a particular table or figure, or to discuss a point raised in the paper.

Strongly recommended courses:**1. BIOM 600: Cell Biology**

BIOM 600 is an intermediate level graduate course designed to introduce students to the molecular components and physiological mechanisms that underlie the structure and function of cells. The course is designed as an in-depth survey to cover general concepts central to the field of biochemistry and cell biology and to emphasize these concepts within the context of current scientific research questions and technical approaches. Lectures will focus on recent discoveries in contemporary cell biology involving (i) basic cellular biochemistry; (ii) mechanisms of membrane transport and excitability; (iii) intracellular compartmentalization and protein/vesicle targeting, organelle biogenesis; (iv) cytoskeletal architecture, cell motility and adhesion; and (v) molecular mechanisms of signal transduction. Efforts will be made to familiarize students with recent technical advances in molecular, biochemical, microscopic, spectroscopic, and electrophysiologic techniques.

2. Either**a. BIOM 555: Control of Gene Expression**

Regulation of gene expression including chromatin structure, transcription, DNA modification, RNA processing, translation, control of gene expression via microRNAs and post-translational processing.

b. CAMB 550: Genetic Principles

This is a combined lecture and discussion course that surveys major concepts and approaches used in experimental and human genetics. Discussions are problem-based and emphasize practical aspects of generating and interpreting genetic data.

3. STAT 510: Probability and 511: Statistics, or equivalent. Students are expected to obtain graduate-level knowledge of probability and inference techniques. Other statistics courses students often take include STAT 512: Mathematical Statistics, STAT 542: Bayesian Data Analysis. Students with little statistical background may want to take BIOL 446: Statistics for Biologists, and BIOL 556: Advanced Statistics.
4. At least one "core" computer science course (usually CIS 520: Machine Learning, CIS 550: Database and Information Systems, CIS 502: Analysis of Algorithms, or CIT 591 and 594: Programming Language and Tech)

Other courses offered by GCB:

GCB 530: Systems in Ecology and Molecular Biology (J. Kim)

The goal of this seminar course is to draw connections between empirical and theoretical studies of biological dynamics and assemblies at all scales from whole organisms to cells to molecules. We will review the primary literature and draw parallels between organismal systems and cell-molecular systems. We will also study the more recent systems biology literature and find connections to concepts in ecology, evolution, and economics. We will hold didactic lessons to understand the underlying mathematical and statistical concepts. Primary literature will be selected each week and read as a group with weekly presentations by the students. The presentations will also include discussions of the mathematics and statistical techniques and concepts. One of the goals of the course will be to write a review paper as a group for submission to a review journal

GCB 535: Introduction to Bioinformatics (S. Master)

This course provides a broad overview of bioinformatics and computational biology as applied to biomedical research. Course material will be geared towards answering specific biological questions ranging from detailed analysis of a single gene through whole-genome analysis, transcriptional profiling, and systems biology. The relevant principles underlying these methods will be addressed at a level appropriate for biologists without a background in computational sciences. This course should enable students to integrate modern bioinformatics tools into their research program.

Sample Course Schedules

Undergraduate Background	Fall-Year1	Spring-Year1	Fall-Year2	Spring-Year2
Biology	GCB 531	GCB 537	BIOL/STAT/CIS Elective	GCB 752
	STAT 510	STAT 512/STAT 542	CIT 591	BIOM 555
	BIOM 600	Elective (for dissertation)	Elective (for dissertation)	CIT 594
Bioinformatics	GCB 531	GCB 537	BIOM 600	GCB 752
	STAT 510	STAT 512	CIS 502/CIS 520/CIS 550	BIOM 555
	Biology Seminar Elective	Genetics course (i.e. CAMB 550)	Elective (for dissertation)	Elective (for dissertation)

Undergraduate Background	Fall-Year1	Spring-Year1	Fall-Year2	Spring-Year2
Computer Science (no statistics background)	GCB 531 BIOL 421 STAT 510/STAT 511/STAT 520	GCB 537 STAT 511/STAT 512/STAT 520 Genetics course (i.e. CAMB 550)	BIOM 600 CIS 502/CIS 520/CIS 550 Elective (for dissertation)	GCB 752 BIOM 555 Elective (for dissertation)
Math/Statistics	GCB 531 BIOL 421 CIS 502/CIS 550	GCB 537 STAT 512/STAT 542 Genetics course (i.e. CAMB 550)	BIOM 600 BIOL/STAT/CIS Elective Elective (for dissertation)	GCB 752 BIOM 555 Elective (for dissertation)
Other: i.e. Engineering (BE/EE)	GCB 531 BIOL 421/Biology Seminar Elective STAT/CIS Elective	GCB 537 STAT course (i.e. 510/512/520) Genetics course (i.e. CAMB 550)	BIOM 600 CIS 502/CIS 520/CIS 550 Elective (for dissertation)	GCB 752 BIOM 555 Elective (for dissertation)

Lab Rotations (GCB 699)

Because it is essential that candidates have a firm training in biology and experimental techniques, a crucial component of the GCB curriculum is research rotations in the laboratories of the associated faculty. Students in this program are required to do three lab rotations as part of their training. The definition of a lab rotation is flexible and includes the possibility of some rotations in a computer science lab (for example, the application of data mining techniques to biological information sources) or a course of directed reading and research in mathematics/statistics, but students should expect to spend at least 25 hours per week in their rotation lab. At least one rotation must be a wet-lab project.

Students will be evaluated and graded on each rotation by the supervising faculty member. The dissertation laboratory is usually chosen from one of these rotation labs, although this is not required. To ensure breadth of the training experience, all laboratory assignments must be approved in advance by the GCB chair or the Chair of the Advising Committee.

Pre-dissertation Research (GCB 899)

Starting in the fall of their second year, students begin graded lab work in their chosen dissertation laboratory. These lab projects serve as a foundation to the more formal dissertation research that follows the Candidacy Exam.

Example Elective Courses:

BE 519: Cellular-Level Neural Simulation and Modeling
 BE 567: Modeling Biological Systems
 BE 630/EE 630: Elements of Neural Computation, Complexity, and Learning
 BIOL 419: Evolutionary Genetics
 BIOL 421/CAMB 421: Molecular Genetics
 BIOL 480/CAMB 480: Advanced Cell Biology
 BIOL 488/INSC 578: Advanced Topics in Behavioral Genetics
 BIOL 513/GCB 513/CAMB 513: Evolution in Cancer
 BIOL 527/GCB 527: Advanced Molecular Biology and Genetics
 BIOL 539/CAMB 539: Prokaryotic Molecular Genetics
 BIOL 556: Advanced Statistics
 BIOM 600: Cell Biology and Biochemistry
 BMB 508: Macromolecular Biophysics
 BMB 585: Cell Cycle Checkpoints and Cancer
 BMB 614: Membrane Biochemistry (1/2 credit)
 BMB 615: Understanding Peptides and Proteins from the Ground up (1/2 credit)
 BMB 619: Protein Folding (1/2 credit)
 BSTA 621/STAT 512: Statistical Inference I
 BSTA 630: Statistical Methods and Data Analysis
 BSTA 657: Multivariate Data Analysis
 BSTA 670: Statistical Computing
 BSTA 785: Statistical Methods for Genomic Data Analysis
 BSTA 787: Methods for Statistical Genetics in Complex Human Disease
 CAMB 512: Cancer Genetics and Biology
 CAMB 421: Molecular Genetics
 CAMB 530: Cell Cycle and Cancer Seminar
 CAMB 550: Genetic Principles
 CAMB 541: Genetic Systems
 CAMB 608: Regulation of Eukaryotic Gene Expression
 CAMB 625: Microbial Genomics
 CIS 502: Analysis of Algorithms
 CIS 511: Theory of Computation
 CIS 520: Machine Learning
 CIS 521: Introduction to Artificial Intelligence
 CIS 534: Introduction to Parallel Computing
 CIS 550: Database and Information Systems
 CIS 558: Computer Analysis and Modeling of

Biological Signals and Systems
 CIS 620: Advanced Topics in Artificial Intelligence
 CIS 650: Advanced Topics in Databases
 CIS 677: Advanced Topics in Algorithms and Complexity
 CIS 700: Machine Learning in Bioinformatics
 INSC 587: Neurobiology of Disease
 INSC 594/BE 520: Computational Neuroscience
 STAT 431: Statistical Inference
 STAT 550: Mathematical Statistics
 STAT 925: Multivariate Analysis

Seminars

Students are required to attend the monthly Penn Bioinformatics Forum (PBF) seminar series, the monthly PGFI genomics seminars, departmental seminars, and GCB Chalk Talks. All GCB students are invited for a lunch meeting with seminar speakers in the listed seminar series (PBF, PGFI, departmental seminars and genomics faculty applicants in several schools across the campus). GCB students and students also organize two PBF seminars per year (i.e. they select speakers, send the invitations, organize the schedule and meet with speakers on an individual basis, while Penn faculty meet the speaker for lunch and dinner as a group).

GCB Chalk Talks

Chalk Talks offer students an opportunity to present their research to other GCB students and faculty. Each chalk talk includes student and faculty speakers, and students are typically paired with their faculty advisor, with each covering topics related to the student's research. GCB Chalk Talks also provide the opportunity for GCB faculty candidates to present their research, and for students to learn more about potential lab rotations. Below is a schedule of the past year's Chalk Talks.

The Candidacy Exam

At the end of the second year, students are required to take the Candidacy Exam (formerly the Prelim Exam) given by an ad hoc committee of three to five faculty members drawn from multiple disciplines within GCB. This exam determines whether a student has attained a satisfactory degree of scientific knowledge as well as a sufficient independence of thought to enter candidacy for the PhD degree. The exam consists of a written exam that focuses on both the experimental and computational portions of the curriculum, as well as a written literature review on a specified topic. The literature review portion of the exam now takes place within GCB 752.

The goal of the GCB Candidacy Exam is to ensure that students engaged in dissertation research have the appropriate fundamental knowledge covering the basic areas relevant to Genomics and Computational Biology and to assess the students' skills in critical reading and synthesis of primary literature. The exam is administered by the GCB Candidacy Exam committee. The committee will determine the test material and the content of the test with input from other GCB faculty members. The exam will consist of a written exam covering the basic knowledge set. It is expected that the students will have knowledge equivalent to passing a graduate level class covering topics in the biological sciences, computer science, and statistics.

At the end of May, when all the scores are in, the faculty advisors of the students taking the exam meet with the Exam Committee to review the test scores, as well as class and rotation grades, and make the final recommendation for the student's evaluation. The student may receive the following evaluations: "Pass," "Qualified Pass," "Retake," or "Fail." A "Qualified Pass" signifies that the student must remedy some deficiency in background. This may entail, for example, taking an additional course, or conducting an independent research project. Students who fail part or all of the exam by a small margin may be re-examined on the appropriate section(s). Students who do not pass the exam on the second occasion face dismissal from the program after review by the Candidacy Exam Committee.

Master's Degree

Students who leave the PhD program after the Candidacy Exam but before their PhD research is complete may receive a Master's Degree if they complete sufficient original research and write a thesis of approximately 20 pages. The thesis work is overseen by the student's mentor, and if the final paper receives approval from a two-member committee (one member of the GCB Executive Committee and one other faculty member), the graduate group Chair will request a Master's Degree be awarded by the Biomedical Graduate Studies Program.

Thesis Research and PhD Mentorship

The GCB program is designed to provide mentorship and develop skills that will produce independent research scientist in the field of genomics and computational biology.

It is the responsibility of the advisor and the thesis committee to evaluate the scientific quality and importance of the student's work and to decide at which point the student will receive permission to write the thesis. It is expected that the body of work accomplished is relevant and important to the scientific community. This criterion can be met by having at least two first author papers published or "in press" in peer-reviewed scientific journals. Our program is highly interdisciplinary and it is expected that while some students will gain a balanced training in experimental, computational, and statistical areas, others may master a specific field (in genomic or computational biology) but, at the same time, develop competence in the other areas. In other words, a student with a strong background in one area (genomics or computational biology) should develop skills that will facilitate productive interactions with investigators in other fields.

Thesis Committee:

After passing the Candidacy Exam, students assemble a "Thesis Advisory Committee". This committee, which is selected by the student in consultation with the thesis supervisor and approved by the Chair, includes the student's supervisor and at least four other faculty members (one to serve as "Chair," and one from outside the University of Pennsylvania/CHOP) experienced in the research area(s) involved. The Thesis Committee, like the Candidacy Exam Committee, will have a balance among biologists, computer scientists, and statisticians. All members of the thesis committee are encouraged to attend the student's chalk talks.

Prior to the first meeting, students are required to prepare a written proposal for the thesis project (approximately 7 pages, in NRSA grant format; with Specific Aims and Research Strategy), and submit it to the committee for evaluation. Each student is required to meet with this advisory committee at least once a year. Following each meeting, the committee chair submits a written report on the student's progress to the graduate group coordinator. In addition, students are encouraged to communicate informally, as often as is necessary, with members of their dissertation committee so that this committee is informed about results, changes in strategy, or problems that arise. While our goal is for students to complete their study in about five years, we recognize that some will require additional time.

Thesis Defense:

When a suitable body of research has been completed, the Thesis Advisory Committee is convened. If the committee approves, the dissertation writing is begun. When the dissertation has been written, the

student is advised to distribute a penultimate draft to the Thesis Committee two weeks before the scheduled defense. Thus, before the final draft is submitted, each committee member can identify necessary revisions and suggest improvements. After the student has had the opportunity to meet the criticisms and incorporate the suggestions of the committee in a final draft, a thesis defense is scheduled. This defense includes a formal “public” seminar followed by a private session with the Advisory Committee. Following this private session, the Thesis Committee renders its recommendation on granting the degree.

Financial Resources Available to Students and Faculty

Training Grants

In addition to support from faculty mentors’ labs, fellowships, and research grants, GCB students may also receive financial support for tuition and stipend from one of Penn’s NIH training grants. On the next page is a list of training grant funding available to BGS students. The grants in this list all have GCB faculty members as trainers (i.e., researchers whose labs train students in fields relevant to the specific grant).

Individual Fellowships

In addition to NIH training grants, students may apply for individual fellowships from a variety of organizations. GCB students have been supported by the following fellowship sources: Penn Genome Frontiers Institute, United States Department of Energy, NSF, NIH, and the United States Army.