PennState
Huck Institutes of the Life Sciences

Intercollege Graduate Degree Program

in

Bioinformatics and Genomics (BG)

Degree Requirements Booklet

Fall 2018

BG Program: www.huck.psu.edu/graduate-programs/bioinformatics-and-genomics
Information for current students: www.gradschool.psu.edu/current-students
Graduate school policies: http://www.gradschool.psu.edu/current-students/student/

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Bioinformatics and Genomics (BG)

Course Objectives

Bioinformatics and Genomics (BG) graduate program is an interdisciplinary program that integrates three focal areas of research: computational, evolutionary and functional genomics. Students will be trained in the areas of Bioinformatics, Computation, Statistics, Genomics and Systems Biology. The main course objectives are to:

- Provide students with comprehensive training in the use and development of advanced bioinformatics, computational and statistical approaches to collect, process, analyze, integrate and interpret complex, large-scale genomic data.
- Provide students with an in-depth understanding of the potential application of these approaches to basic and applied research and the skills to communicate approaches to a broad audience.
- Enhance collaborative environment to facilitate productive interactions and creative efforts in genomics and bioinformatics research.

These objectives will be met by offering a set of required and elective courses, which are designed to provide following knowledge modules;

- Foundations of genomics: molecular genetics
- Sequencing technologies, genome assembly, alignments, read mapping
- Basic programming and scripting used in bioinformatics
- Algorithm development in bioinformatics
- Statistical methods in genomics and bioinformatics; competence in R or equivalent.
- Transcriptomes: Techniques (microarray, RNA-seq), analysis
- Comparative genomics, molecular evolution: function inferred from signatures of negative and positive selection
- Finding and functional analysis of protein-coding genes
- Genome variation, mutagenesis, connection to phenotype
- Genome mapping (Mendelian inheritance of genes and DNA markers).

The following courses are required. Students are advised to complete these courses during the first 18 months of study. The schedule of courses will be determined in consultation with the program chair.

- MCIBS 541 Critical Analysis in Bioinformatics and Genomics Research Topics (2)
- MCIBS 551 Genomics (3)
- MCIBS 554 Foundations in Data Driven Life Sciences (3)
- MCIBS 589 Colloquium in Bioinformatics and Genomics (2)
- MCIBS 591 Ethics (1)
- MCIBS 596 Independent Studies (2)
- STAT 555 Statistical Analysis of Genomics Data (3)

Besides these required courses, following are the recommended electives. Students may choose to register for these courses in consultation with the doctoral advisory committee and/or program co-chairs.

- BIOL 405 Molecular Evolution (3)*
- BIOL 428 Population Genetics (3)
- BMB 484 Functional Genomics (3)
- BMB 497 Introduction to Bioinformatics (3)
- BMMB 533 Protein Evolution (3)
- BMMB 852 Applied Bioinformatics (2)*
- BMMB 566 Algorithms and Data Structures in Bioinformatics (3)
- CHE 512 Optimization and Biological Networks (3)
- IST 597 Machine Learning and Big Data Analytics (3)
- MCIBS 556 Computation, Bioinformatics and Statistics Practicum (3)
- PHYS 580 Elements of Network Science and Its Applications (3)
- STAT 500 Applied Statistics (3)*
- STAT 501 Regression Methods (3).
- STAT 505 Applied Multivariate Analysis (3)
- STAT 512 Design and Analysis of Experiments (3)
- STAT 557 Data Mining (3)

*Students will be tested for their knowledge in these courses. Those found deficient will be advised to register for these courses during the first 18 months period. Students may also refer to a longer list of electives, which are provided in the General information section.

Options in Bioinformatics and Genomics

Students may pursue the doctoral program with no options or select an available option in Algorithms and Computation; or Statistical Genomics.

Students are admitted to the option after successfully completing the following:

- The first year curriculum of the Bioinformatics and Genomics program
- Three research rotations, of which at least two must be with the faculty affiliated with the option
- The qualifying examination

Option in Algorithms and Computation

The objective of the Option in Algorithms and Computation is to provide students in the Intercollege Graduate Degree Program (IGDP) in Bioinformatics and Genomics (BG) the opportunity to focus their graduate curriculum and research on the principles and applications of advanced computational techniques, from specialized data structure and algorithms to the use of novel software and hardware frameworks. The Algorithms and Computation Option will offer the specialized training and background needed for students to become leaders and contributors to the development of novel computational techniques. The option will also expose students to forefront developments in modern computer science and give them an opportunity to translate those advances for use in bioinformatics and genomics. Students in this option will take a foundational computer science course covering fundamental algorithm analysis and design techniques and their applications in bioinformatics and genomics.

The following courses are required

- BMMB/CSE 566 Algorithms and Data Structures in Bioinformatics (3)
- CMPSC 465 Data Structures and Algorithms OR CSE 565 Algorithm Design and Analysis (4)

In addition, students are required to complete at least two of the following courses:

- CMPSC 431 Database Management Systems (3)
- CMPSC 450 Concurrent Scientific Programming (3)
- CSE 562 Probablistic Algorithms (3)
- CMPSC 464 Introduction to the Theory of Computation (3)
- CSE 583 Pattern Recognition-Principles and Applications (3)
- CMPEN 454 Fundamentals of Computer Vision
- CHE 512 Optimization in Biological Networks (3)

Option in Statistical Genomics

The objective of the Option in Statistical Genomics is to provide students in the Intercollege Graduate Degree Program (IGDP) in Bioinformatics and Genomics (BG) the opportunity to focus their graduate curriculum and research on the principles and applications of advanced statistical techniques, from experimental design, to data processing, to statistical inference, visualization, and the use of statistical programming tools. The Statistical Genomics Option will offer the specialized training and background needed for students to become leaders and contributors to the development of novel data analysis and inference methods. The option will also expose students to forefront developments in modern statistics and give them an opportunity to translate those advances for use in bioinformatics and genomics.

The following are required courses:

- STAT 501 Regression Methods (3) or STAT 511 Regression Analysis and Modeling (3)
- STAT 557 Data Mining (3)

In addition, students are required to complete two courses from the following:

- STAT 414 Introduction to Probability Theory (3)
- STAT 415 Introduction to Mathematical Statistics (3)
- STAT 416 Stochastic Modeling (3)
- STAT 502 Analysis of Variance (3)
- STAT 504 Analysis of Discrete Data (3)
- STAT 505 Applied Multivariate Analysis (3)
- STAT 540 Statistical Computing (3)

Safety Training
Within the first semester of residence, all students are required to take/pass safety and chemical waste disposal training sessions offered at the respective campus. For information and links regarding the Environmental Health & Safety office: http://ehs.psu.edu/laboratory-and-research-safety

Responsible Conduct of Research Training Requirement:
First year students should complete the online CITI RCR course during or before the Orientation. To register, go to the Penn State CITI website http://citi.psu.edu/ where you will find instructions. Select your campus, then select Pennsylvania State University Courses and register for the Biomedical Responsible Conduct of Research Course. Students must work on their own to complete the course modules and pass the on-line quizzes. All modules must be completed before 12:00 noon on the first day of class of the fall semester, and a copy of the student's Completion Report must be submitted to the Program administrative office (101 HLSB or email jep32@psu.edu).

After completing four years in the program, students are required to re-take the online CITI RCR course and participate in two sessions of ethics discussions in MCIBS 591 course or equivalent. A copy of the student's Completion Report must be submitted to the Program administrative office (101 HLSB or email jep32@psu.edu).

Academic Integrity
Academic dishonesty, cheating, and plagiarism are not tolerated by the University. Students should not "engage in or tolerate acts of falsification, misrepresentation or deception. Acts of dishonesty violate the ethical principles of the University community and compromise the worth of work completed by others". Plagiarism (taking Academic integrity violations will result in disciplinary sanctions including dismissal from the BG Graduate program. University Policies for handling student misconduct are available at: http://undergrad.psu.edu/aappm/G-9-academic-integrity.html and at: http://gradschool.psu.edu/graduate-education-policies/. Academic integrity violations will result in disciplinary sanctions and can result in a student's dismissal from the Graduate Program.

Rotations/Mentor Selection:
Students will be required to be associated with research laboratories as a part of Independent Studies (MCIBS 596). Students will participate in three lab rotations beginning in their first semester. The choice of rotation laboratories will be made in consultation with the co-chairs of the BG program. Each lab rotation will be of 8 weeks duration as specified by the program co-chair. Students are required to finalize their rotation plan a week

before the start date and communicate their choices to the program co-chair. During this period, students are expected to participate in a research project and other activities typical of a research laboratory. Rotating students will meet as a group every week in a forum with the program co-chair to discuss issues related to graduate research and present rotation projects. At the completion of each lab rotation, a report must be submitted to the program co-chair describing this research project. The purpose of these rotations is to identify a primary thesis advisor, typically by April 1st. The selection of primary advisor will be based on the preferences of both the student and mentor and will take into consideration shared research interests and available position. Additional lab rotations may be permitted at the discretion of program co-chairs.

Qualifying Exam:
The candidacy exam will be administered after completion of the towards the end of the Spring semester of the first year. The goal of the qualifying examination is to evaluate the student's ability to solve problems in the three major areas (computational, evolutionary and functional genomics) including the ability to think in an integrated manner to determine if the student has the potential to successfully complete the Ph.D. program. Based on this evaluation, the qualifying exam committee may recommend the student to take remedial actions to address any areas of deficiency.

The qualifying exam will have both written and oral components. The student will be given a choice of three papers selected by the program chair in consultation with rotation mentors and course instructors. The student will write a synopsis that will identify a problem within the topic area, discuss how the problem could be resolved, and will propose future research within that problem area. The synopsis should be written in a research paper format in 11-point font, with single spacing, of about five to ten pages length, including references. The paper may also include original graphics and tables. All aspects of the document should be directly and clearly relevant to the question being addressed. This document will serve as the basis for the oral portion of the qualifying exam. The oral exam will consist of a 15-20 minute presentation by the student followed by a question-answer session, which may last for 2 hours.

The student qualifying exam committee will include three faculty members, representing the three major areas (computational, evolutionary and functional genomics). The composition of the student candidacy exam committee and choice of research topic for examination must be approved by program co-chair. The timetable for completion of the written and oral portions of the examination will be determined by the program chair.

A doctoral advisory committee will be formed at the conclusion of the Qualifying Exam (See p17 for details). Students wishing to pursue a minor field of study must communicate to the program co-chair at this time after obtaining approval from the doctoral advisory committee.

Comprehensive Exam:
The comprehensive exam will test the ability of the student to articulate a testable hypothesis and present a rational approach to support this hypothesis. The comprehensive examination will be administered by a committee composed of the three advisors plus an outside faculty member who is not in the primary advisor's home department. Student's primary dissertation advisor will chair the comprehensive exam committee. The comprehensive exam will be an oral defense of a written proposal for the planned dissertation research. Experience in writing research proposals is an invaluable part of graduate training. Thus, students in the BG program will develop the proposal for their comprehensive exam to fit the format and guidelines for an NSF or NIH doctoral dissertation improvement proposal. It is expected that the proposal will be submitted to the agency at the time of or soon after the comprehensive examination. The comprehensive exam will begin with a 15 – 20 minute overview of the proposal and of any preliminary data that the student has obtained to support the proposal. The comprehensive exam should be taken after the second academic year upon the student's successful completion of the core courses, and the qualifying exam, and any additional courses required by the advisory committee. The proposal should be submitted to the examination committee at least two weeks prior to the exam.

Thesis Requirement:

Submission of a written dissertation and its defense before the dissertation committee are the program's final requirements. The dissertation must be approved in writing by the dissertation committee and the co-Director on that campus. Students must follow the thesis guidelines outlined by the Graduate School. The final approved dissertation must be deposited with the Graduate School and the Huck Institutes of the Life Sciences in advance of graduation.

Post-Comprehensive Progress Reports:
Subsequent to the Comprehensive Examination, all BG students will be required to provide his/her Doctoral Committee with a yearly progress report to be delivered prior to the anniversary date of the comprehensive exam. The report is to consist of a 5 to 12 page summary of progress made during the last year and a prospectus of upcoming work. This report is to be discussed with the committee members, preferably at an annual meeting of the entire committee. Students must submit copies of their reports as well as a signature page documenting the fact that they have discussed the report with all members of their committee to the BG graduate program office and co- director(s) within three weeks of the anniversary date of their comprehensive exam.

Teaching Requirement:
A minimum of one semester of teaching is required of all BG students. Students should register for on-line training at the Schreyer Institute: http://www.schreyerinstitute.psu.edu/NIO/. It is preferred that students serve as a teaching assistant and enroll for credit in the required Supervised Experience in College Teaching course (MCIBS 602) or other equivalent course offered by other departments before performing TA duties. Teaching requirement should be completed before appearing for the Comprehensive Examination. An English competency requirement must be satisfied by non-native English speakers before any teaching duties are assigned. The Supervised Experience in College Teaching booklet lists many of the courses available and the teaching duties. . Interested students could obtain a Teaching Certificate by completing the requirements listed at: http://www.gradschool.psu.edu/current-students/tacert/

Internship (optional):
Students may spend up to one semester in an internship at a medical center, government laboratory or in an industrial environment. Non-traditional settings are also available. The internship should be discussed with the Program Chair. The Huck Graduate Programs Office may provide assistance in securing a suitable internship. Typically students who wish to participate in an internship do so during the summer of their first year. Internships can be conducted later, with the agreement of their advisors, but students must arrange for their own financial support. Students will register for one credit of MCIBS 595 while conducting the internship. At the end of the internship, the student must submit a summary report to the advisor and the program chair.

Topics for Discussion Prior to Joining a Laboratory

1. Time Commitment Expected in the Lab
2. Funding Source and Grade Level
3. Vacation and Leave Policy
4. Possibility of Internship and/or TA
5. Access to Advisor
6. Possibility (expectations) for publications and conference presentations

Student-Faculty Compact

(Adapted from the Recommendation of The Committee on Graduate Student and Faculty Issues, The Graduate Council, The Pennsylvania State University, 2009 and The Document approved by the Penn State Hershey Graduate Program Directors May 6, 2006 and updated April 22, 2010)

Purpose:

Student-Faculty Compacts are useful to encourage good communications and to enhance the working environment in student-advisor/mentor relationships. Compacts provide a basis for discussion between students and advisors/mentors regarding mutual responsibilities and future plans.

"The compact serves as both a pledge and a reminder to advisors and their graduate students that their conduct in fulfilling their commitments to one another should reflect the highest professional standards and mutual respect."

Items that should be discussed by students and potential mentors prior to choosing a permanent laboratory situation.

Expectations of the Advisor towards Graduate Students in a Laboratory

1. Professionalism/Honesty/Ethics
    a. The Graduate Student will:
        i. Perform research and other educational activities conscientiously, maintain good research records and catalog and maintain all tangible research materials that result from the project.
        ii. Respect all ethical standards when conducting research including compliance with all institutional and federal regulations.
        iii. Show respect for and work collegially with my co-workers, support staff and other individuals with whom I interact.
        iv. Do your best to satisfy all project deadlines outlined by the advisor.
2. Communication
        i. Outline a defined program of research with the advisor that will include well defined goals and timelines. Organize time to meet these deadlines.
        ii. Have open and timely discussions with the advisor on a regular basis regarding the status of the research.
        iii. Seek regular feedback on performance and expect annual performance evaluations.
        iv. Understand that you have a responsibility with the advisor to write up, in a timely manner, research findings for publication and presentation at professional meetings.

Expectations of the Graduate Students in a Laboratory of the Advisor

1. Training and Education
    a. The Advisor will:
        i. Set a mutually agreed upon set of expectations and goals at the beginning of the outset of the student's admission to the laboratory. These will be reviewed and revised periodically as the student progresses through the program.
        ii. Acknowledge that the purpose of the training that graduate students receive is to prepare them to become independent professionals.

iii. Work to prepare students for required program examinations and committee selections.
iv. Read the student's dissertation and other writing thoroughly and carefully and in a timely manner.
v. Provide the student with the required guidance and mentoring as needed.
vi. Encourage the interaction of the student with other students and faculty, both intra and extramurally and encourage attendance at professional meetings to network and to present research findings.

2. Communication
   i. Meet with the student periodically over the course of each academic semester and no less than once per semester to review goals and progress.
   ii. Acknowledge contributions to the development of any intellectual property and define future access to tangible research materials according to institutional policy.
   iii. Discuss, in advance, appropriate authorship and co-authorship roles on all relevant publications and presentations

Exiting a Student-Faculty Relation

"Student-faculty relations are sustainable in large measure because of a compatible fit between the student and the faculty member. On occasion, the fit may be less than either a student or a faculty advisor initially anticipated, resulting in one or the other seeking to end the relation, even though the student is making satisfactory progress based on the perspectives of all concerned. Neither party should view these situations negatively; rather they represent mid-course corrections intended to improve the student's academic and professional mentoring by faculty.

The party wishing to leave the student-faculty relation should request a meeting with the other party, and possibly the student's committee, to discuss his/her concerns and recommendations. If an alternative advisor has not been identified prior to this meeting, consideration of possible options would be appropriate. In the end, advancing the student's academic program should be the prime objective for changing advisors."

Representative Course Schedule

Students should consult with program co-chairs or primary advisors before scheduling courses.

Year 1 - Fall Semester

- BMMB 852 Applied Bioinformatics (2)
- MCIBS 541. Critical Analysis in Bioinformatics and Genomics Research Topics (1)
- MCIBS 551. Genomics (3)
- MCIBS 596. Independent Studies, Lab Rotations (1)
- MCIBS 589 Colloquium in Bioinformatics and Genomics (2)
- STAT 500 Applied Statistics (3)
- Submit CITI RCR Course Completion Report to Program Office

Spring Semester

- BIOL 405 Molecular Evolution (3)
- MCIBS 541. Critical Analysis in Bioinformatics and Genomics Research Topics (1)
- MCIBS 554 Foundations in Data Driven Life Sciences, (3)
- STAT 555 Statistical Analysis of Genomics Data (3)
- MCIBS 591 Ethics in Life Sciences (1)
- MCIBS 596. Independent Studies, Lab Rotations (1)
- MCIBS 589 Colloquium in Bioinformatics and Genomics (2)
- Qualifying Examination

Summer

- MCIBS 595. Internship (1) (optional)

Year 2 - Fall Semester

- MCIBS 600. Thesis Research (variable credits)
- MCIBS 602. Supervised Experience in College Teaching (1)
- BG Electives (0-6 credits)

Spring Semester

- MCIBS 600. Thesis Research (variable credits)
- BG Electives (optional; 0-6 credits)

Year 3

- MCIBS 600. Thesis Research (9)
- Comprehensive Examination

Years 4-5

- MCIBS 601. Thesis Preparation (0)

A brief description of BG required courses:

MCIBS 541. CRITICAL ANALYSIS IN BIOINFORMATICS AND GENOMICS RESEARCH TOPICS (1**)** This course provides a review of current literature related to the areas of bioinformatics and genomics. Students will critically evaluate selected articles in terms of the objectives of the study, significance of the question, the experimental design, and author's conclusions. The goals of the course are to cultivate habit of reading current literature and to develop critical oral and written presentation skills.

MCIBS 551. GENOMICS (3) Students are introduced to the structure and function of genomes including the use of some of the web-based tools and resources for studies and research in genomics. A team of BG faculty active in genomics research teaches the course from both University Park and Hershey campuses. By taking this graduate course in Genomics, trainees should learn current information about the structure and function of genomes, develop facility in the many web-based tools and resources for further studies and research in genomics, and appreciate the power and limitations of current resources and knowledge.

MCIBS 554. FOUNDATIONS IN DATA DRIVEN LIFE SCIENCES (3) MCIBS/BMMB 551 will deal with the structure and function of genomes including the use of some current web-based tools and resources for studies and research in genomics. The overall objective is to learn current information about the structure and function of genomes, to develop facility in the many web-based tools and resources for further studies and research in genomics, and to appreciate the power and limitations of current resources and knowledge. This course is designed as a basic course for any student in the life sciences who needs to exploit the developments and tools in genomics in their own research and who wants to broaden their understanding of the current knowledge and research in the life sciences that are increasingly drawing on genomics advances.

MCIBS 589. Colloquium in Bioinformatics and Genomics (2) The course builds on continuing seminars by Faculty, Students and outside speakers on topics of interest in the area of bioinformatics, computation, statistics and genomics. The course is designed to train students to develop understanding of broad research topics and enhance their ability to comprehend, analyze and participate in public seminars. Students will attend 'Weekly Wartik Genomics Seminars' and talks by faculty in Bioinformatics and Genomics program. Students will submit one-page summary of the talks and participate in a discussion about seminars and offer their critiques on various topics presented.

MCIBS 591. ETHICS IN THE LIFE SCIENCES (1) Students examine integrity and misconduct in life sciences research, including issues of data collection, publication, authorship, and peer review. Students receive A-F quality grades.

MCIBS 595. INTERNSHIP (1, optional) For students interested in exploring academic, government, medical, law, or business corporate approaches to research. This is an external work assignment relevant to individual research or career goals. Students receive an R (satisfactory/passing) or U (unsatisfactory/failing). Only R credits are counted for credit totals. Students typically participate in an internship the summer of their first year. Contacts, positions, applications, course registration, course requirements, and grading are processed through the Eberly College of Science Cooperative Education Program (814-865-5000). Additional credits of MCIBS 595 are at the expense of the student. Interested Huck Institutes' graduate students are to discuss the opportunity with their graduate program chair and/or their faculty advisor to help determine the best timing for this experience.

MCIBS 596. INDEPENDENT STUDIES: LABORATORY ROTATIONS (1-3 per semester pending graduate program) For students exploring potential Ph.D. projects and faculty advisors. Students receive an R (satisfactory/passing) or F (unsatisfactory/failing). Only R credits are counted for credit totals.

MCIBS 600. THESIS RESEARCH (1-9 per semester pending graduate program) For students who have been matched with a faculty advisor AND have not taken/passed their comprehensive exams. Students may receive A-F grades or R/F grades at any time. By the time students pass their comprehensive exams, up to 12 credits worth of MCIBS 600 may have the A-F quality grade.

MCIBS 601. THESIS PREPARATION (0 per semester) For those students who passed their comprehensive exams. This course appears on the transcript but does not have any grade or credit associated with it.

MCIBS 602. SUPERVISED EXPERIENCE IN COLLEGE TEACHING (1) Students receive either a lecture, lab, or recitation class to help teach. Students also participate in the Huck Institutes teaching assistant training sessions and receive A-F grades on their transcripts from their faculty course supervisors. Please note that these grades are not computed in with the overall GPA. International graduate students must pass an English proficiency exam before any teaching duties are assigned.

STAT 555. STATISTICAL ANALYSIS OF GENOMIC DATA (3) Students are introduced to statistical analysis and experimental design for high-throughput "omics" data. Topics include an introduction to the biology of gene and protein expression, experimental design for high throughput measurement platforms, data pre-processing, differential expression analysis, peak finding, clustering and classification, and data reduction techniques. Trainees will become familiar with statistical and bioinformatics software.

Additional List of Suggested Electives

This list is representative. Students are encouraged to check for other available courses listed by various departments and programs.

BIOL 427 Evolution (3) Selected topics on the evolution of life.

BIOL 460H Human Genetics (4) Gene mapping in humans; molecular basis of genetic disease; genomic structure; immunogenetics; and genetic evidence for human evolutionary history.

BMMB 400 Molecular Biology of the Gene (3) Biochemistry of genetic phenomena, including the structure, replication and dynamics of genes and chromosomes, their expression and regulation.

BMMB 533 Protein Evolution (2) Protein Evolution will treat the changes observed in proteins at the level of comparisons of sequences of related proteins, how sequence changes are reflected in structure changes, and how proteins develop novel functions.

CSE 520 Science of Computer Programming (4) Weakest preconditions, nondeterminism, terminating constructs, formal derivation of some often used algorithms, correctness of programs, formal specification of large systems.

CSE 541 Database Systems I (3) Data models and relational database design; database integrity and concurrency control; distributed database design and concurrency control; query optimization.

CSE 550 (MATH 550) Numerical Linear Algebra (3) Solution of linear systems, sparse matrix techniques, linear least squares, singular value decomposition, numerical computation of eigenvalues and eigenvectors.

CSE 551 (MATH 551) Numerical Solution of Ordinary Differential Equations (3) Methods for initial value and boundary value problems. Convergence and stability analysis, automatic error control, stiff systems, boundary value problems.

CSE 552 (MATH 552) Numerical Solution of Partial Differential Equations (3) Finite difference methods for elliptic, parabolic, and hyperbolic differential equations; solutions techniques for discretized systems; finite element methods for elliptic problems.

CSE 553 (MATH 553) Introduction to Approximation Theory (3) Interpolation; remainder theory; approximation of functions; error analysis; orthogonal polynomials; approximation of linear functionals; functional analysis applied to numerical analysis.

CSE 554 (EE 564) Error Correcting Codes for Computers and Communication (3) Block, cyclic, and convolutional codes. Circuits and algorithms for decoding. Application to reliable communication and fault-tolerant computing.

CSE 555 (MATH 555) Numerical Optimization Techniques (3) Unconstrained and constrained optimization methods, linear and quadratic programming, software issues, ellipsoid and Karmarkar's algorithm, global optimization, parallelism in optimization.

CSE 556 (MATH 556) Finite Element Methods (3) Sobolev spaces, variational formulations of boundary value problems; piecewise polynomial approximation theory, convergence and stability, special methods and applications.

CSE 557 Concurrent Matrix Computation (3) This course discusses matrix computations on architectures that exploit concurrency. It will draw upon recent research in the field.

CSE 560 Theory of Graphs and Networks (3) Theory and applications of graphs, including structure of graphs, network analysis, and algorithms for computer solution of graph-theoretic problems.

CSE 562 Probabilistic Algorithms (3) Design and analysis of probabilistic algorithms, reliability problems, probabilistic complexity classes, lower bounds.

CSE 564 Complexity of Combinatorial Problems (3) NP-completeness theory; approximation and heuristic techniques; discrete scheduling; additional complexity classes.

CSE 565 Algorithm Design and Analysis (4) An introduction to algorithmic design and analysis.

MCIBS 556 Computation, Bioinformatics and Statistics Practicum (3)

STAT 464 Applied Nonparametric Statistics (3) Tests based on nominal and ordinal data for both related and independent samples. Chi-square tests, correlation.

STAT 502 Analysis of Variance and Design of Experiments (3) Analysis of variance and design concepts; factorial, nested, and unbalanced data; ANCOVA; blocked, Latin square, split-plot, repeated measures designs.

STAT 503 Design of Experiments (3) Design principles; optimality; confounding in split-plot, repeated measures, fractional factorial, response surface, and balanced/partially balanced incomplete block designs.

STAT 504 Analysis of Discrete Data (3) Models for frequency arrays; goodness-of-fit tests; two-, three-, and higher- way tables; latent and logistic models.

STAT 510 Applied Time Series Analysis (3) Identification of models for empirical data collected over time. Use of models in forecasting.

STAT 511 Regression Analysis and Modeling (3) Multiple regression methodology using matrix notation; linear, polynomial, and nonlinear models; indicator variables; AOV models; piece-wise regression, autocorrelation; residual analyses.

STAT 513 Theory of Statistics I (3) Probability models, random variables, expectation, generating functions, distribution theory, limit theorems, parametric families, exponential families, sampling distributions.

STAT 514 Theory of Statistics II (3) Sufficiency, completeness, likelihood, estimation, testing, decision theory, Bayesian inference, sequential procedures, multivariate distributions and inference, nonparametric inference.

STAT 540 Statistical Computing (3) Computational foundations of statistics; algorithms for linear and nonlinear models, discrete algorithms in statistics, graphics, missing data, Monte Carlo techniques.

STAT 544 Categorical Data Analysis I (3) Two-way tables; generalized linear models; logistic and conditional logistic models; loglinear models; fitting strategies; model selection; residual analysis.

English Requirement for International Students

The English Requirement for International students is that prescribed by the Graduate School. Depending on the graduate program, all entering international students, whether or not they hold a Teaching Assistantship, will be required to take the American English Oral Communicative Proficiency Test (AEOCPT) which is administered by the University's Department of Applied Linguistics.

Given at the beginning of fall and spring semesters, international students are required to pre-register for the AEOCPT. The test scores from the AEOCPT are posted on the University's Administrative Information System (AIS) computer. Below is the course of action for the various AEOCPT score ranges.

NR = No Restrictions. This person should be allowed to teach with no restrictions based on ability to communicate in English.
(Penn State AEOCPT Score of 250-300)

WR = Take ESL 118G. This person should not be allowed to teach before completing and receiving a grade of "A" in ESL 118G - "American Oral English for ITA's III."
(Penn State AEOCPT Score of 230-249)

TC = Take ESL 117G. This person should not be allowed to teach before completing and receiving a grade of "A" in both ESL 117G -"American Oral English for ITA's II"
and ESL 118G - "American Oral English for ITA's III."
(Penn State AEOCPT Score of 200-229)

SL = Speaking/Listening. This person should enroll in ESL 115G - "American Oral English for ITA's I" and receive a grade of "A" before taking ESL 117G and ESL 118G.
(Penn State AEOCPT Score below 200)
Students, who are required to enroll in ESL courses, must complete the ESL requirement by the end of the second semester of residency. Students who fail to satisfy this requirement may be terminated from the respective graduate program, at the discretion of the graduate program chair.

Grade Point Average
Credit hours are earned only for the grades A, B, and C. However, all A and F grades are included in the computation of the grade point average. Grade points are assigned as follows:

A = 4 (above average graduate work)
B = 3 (average graduate work)
C = 2 (below average graduate work)
D = 1 (failing graduate work)
F = 0 (failing graduate work)

Grades D and F are not acceptable for graduate credit. If a course is repeated, then both grades are used in computing the cumulative grade point average

Unsatisfactory Scholarship
Students are required to have a minimum grade-point average of 3.0 for the doctoral qualifying examination, admission to the comprehensive examination, dissertation defense, and graduation. One or more failing grades, a cumulative grade-point average below 3.0, or failing any of the examinations may be considered evidence of unsatisfactory scholarship and be grounds for dismissal from the University (http://gradschool.psu.edu/graduate-education-policies/gcac/gcac-800/procedures-termination-unsatisfactory-scholarship/).

Assistantships and Student Status
Students with teaching or research graduate assistantships must be registered as full time students to maintain stipend eligibility. Full time status is considered either a minimum of nine credits each fall and spring semester (pre-comprehensive exam) or XXX 601 (0 credits, post-comprehensive exam). The assistantship appointments typically originate with the department of the faculty advisor. If no faculty advisor has been identified, as likely the situation with first year doctoral students, students should consult with their respective Graduate Program Chair.

Annual Graduate Student Activity Report
Annual Evaluations are an integral part of the student's professional development. The thesis advisor (or the Program Chair for students not yet settled in a lab) should conduct annual evaluations of the student's progress and overall performance and provide guidance with regard to future goals. While students and their advisors should meet regularly over the course of a year, the annual evaluations ensure that at least one meeting has been held to specifically look at the student's progress and performance. Continued financial support of each student will be dependent on satisfactory progress as stated in admission offer letters.

A link to the online Annual Graduate Student Activity Report (GSAR), https://apps.science.psu.edu/grad_activity/, will be sent to all Huck graduate students at the end of each spring semester from the Huck Institutes Graduate Programs Office. This online evaluation must be completed and approved by August 15 each year. Earlier deadlines will be assigned for each component of the report.

Each student, in consultation with their advisor, will describe their research progress and plans according to the prompts that appear on the online form under the section "Progress and Future Plans":

1) Please provide a brief description of the current status of your research project.
2) Please describe your research accomplishments over the past year.
3) Please provide a description of your research plans for the upcoming year.

In addition to this information, each student should provide all of the requested information such as publications, meetings attended, etc. The online system is self-explanatory but the Huck Graduate Education Office will be

happy to assist as necessary. Completed student reports will be reviewed by the Program Chair and, when appropriate, by Troy Ott, Associate Director for Graduate Education in the Huck.

Vacation Guidelines
The following are general policy guidelines concerning vacation time for graduate students:

In addition to designated University holidays, 10 days (2 weeks) of discretionary vacation per year is standard. Days spent attending scientific meetings or training conferences will not count as vacation time. Students may take more than the regularly allocated vacation time in any given calendar year for special travel or activities if they have the **consent of their research advisor** and they take correspondingly fewer vacation days in the preceding and/or following years. Compensatory vacation time can be granted at the discretion of the research advisor when a student works one or more of the designated University holidays.

Students **must inform their research advisor (or the Graduate Student Administrator if a research advisor has not yet been assigned)** of their vacation plans no fewer than 15 days prior to the first day of their planned vacation. It is recommended that the students submit their vacation request to their advisor in writing and also to obtain written approval of the vacation time (an email will suffice). Students should also provide contact information for the days they are to be absent to their advisor (or the Graduate Student Administrator, if appropriate) at the time the vacation/absence request is made. While it is expected that the advisor/Administrator will approve most reasonable requests, the advisor/Administrator has the right to deny the requested absence if there are particular circumstances that warrant such a denial. Such denials should not, however, become an ongoing impediment to any given student being able to use all of their annual vacation time in a reasonable and satisfactory fashion.

These recommended guidelines are advisory and reflect those suggested by government agencies such as National Science Foundation and National Institutes of Health for training grant fellows. **Students should consult with their research advisor regarding any specific policies relating to vacation or laboratory absences that apply to research group members of the particular advisor. Common sense policies and procedures should apply.**

Dissertation Submission and Exit Interview
Upon completion of the degree, students are to provide the Graduate Program with an electronic copy of their dissertation. Students also participate in both the University and Huck Institutes' Exit Interview Process. For the latter, students may meet with the Graduate Program Chair or appropriate representative.

Applying to Graduate
Students must present their dissertation in accordance with the Penn State University guidelines as described in the THESIS GUIDE "Requirements and Guidelines for the Preparation of Master's and Doctoral Dissertations". Current copies can be obtained from the Thesis Office:

115 Kern Building
University Park, PA 16802
Phone: 814/865-5448

Web site: http://www.gradschool.psu.edu/current-students/etd/

At the beginning of the semester that students wish to graduate, they are to either:

(1) Access LionPATH via www.lionpath.psu.edu, if in the PSU computer system; navigate to "academics" and choose "apply to graduate"

or

(2) call Graduate Enrollment at 814-865-1795, if not in the PSU computer system

Doctoral Dissertation Committee Composition
According to the Graduate Degree Programs Bulletin published by the Graduate School regarding Doctoral Committees: (http://gradschool.psu.edu/graduate-education-policies/gcac/gcac-600/doctoral-dissertation-committee-formation/), the dissertation committee must meet the following guidelines:

- 4 person minimum of approved PSU Graduate Faculty.

- 2 members must be inside the major and 1 member must be outside the major. Note - the outside member must be member of the approved PSU Graduate Faculty. The outside member for intercollege graduate programs may be inside the major but committee membership must have representation from more than one department. The outside field member represents a field outside the student's major field of study and is expected to provide a broader range of disciplinary perspective and expertise.

- A person not affiliated with PSU may be added as a special member (beyond the 4 members of the approved PSU Graduate Faculty) upon recommendation of the head of the program and approval of the graduate dean. A memo plus the individual's C.V. must be drafted with approval signature spaces for the Graduate Program Chair plus Ms. Lori Anne Stania (Director, Graduate Enrollment Services).

- Have committee chair or one of the co-chairs be a member of the approved PSU Graduate Faculty. Typically this is the faculty advisor or someone in the graduate program.

- The doctoral student and three committee members must be physically present for the comprehensive exam and defense. No more than one person may be present via telephone. Telephone or video conference arrangements must be approved by the Dean of the Graduate School. A form letter is available for this special request.

- Need approval of 2/3 of the committee members for passing comprehensive exam and defense dissertation.

- **Need to submit paperwork 3-4 weeks prior to your scheduled comprehensive exam and defense. Please contact the appropriate staff member:**
  University Park: Jean Pierce 101 Life Sciences Bldg.; 814-867-0371; jep32@psu.edu
  Hershey Campus: Kathy Shuey H133 HMC; 717-531-8982; kes6@psu.edu

  Please note- Graduate Programs may have additional committee composition criteria.

Masters (M.S.) Degree

Requirements listed here are in addition to requirements stated in the DEGREE REQUIREMENTS section of the *Graduate Bulletin*.

For master's degree, a minimum of 30 graduate credits and a 3.0 overall GPA are required. At least 18 credits at the 500-level or above must be included in the program. Required courses for master's degree are: MCIBS 551 Genomics (3), MCIBS 554 Foundations in Data Driven Life Sciences (3), STAT 555, Statistical Analysis of Genomics Data (3), BMMB 852 Applied Bioinformatics (2), BIOL 405 Molecular Evolution (3), MCIBS 541 Critical Analysis of Bioinformatics and Genomics Research Topics (1 credit per semester, maximum of 2 credits), MCIBS 597 Colloquium in Bioinformatics and Genomics (3), MCIBS 591 Ethics in Life Sciences (1), MCIBS 596 Individual Studies (1-6), and MCIBS 600 Thesis Research (6). No more than 6 credits of Thesis Research may be counted toward 30 credit minimum. MCIBS 595 Internship and electives also count towards the minimum 30 credit requirement. Options are not offered for the M.S. degree.

Students must complete original laboratory research and internship that culminates in a thesis. The thesis must be accepted by the advisers and/or committee members, the head of the graduate program, and the Graduate School, and the student must pass a thesis defense.

Activate Intent to Graduate
At the beginning of the semester that a student wishes to graduate . . . . .
. If in PSU's computer system: access LionPATH at www.lionpath.psu.edu
. If not: call 814-865-1795 to reach Graduate Enrollment

M.D./Ph.D. Degree

Students in the M.D./Ph.D. program in BG must complete the following coursework: MCIBS 541, MCIBS 551, MCIBS 554, MCIBS 589, MCIBS 591, and STAT 555. In addition, based on the background and needs of the student, the following elective course will also be taken: BIOL 405, STAT 500, and BMMB 852.

The dissertation committee of an M.D./Ph.D. student is formed upon entry into the dissertation laboratory and must comply with all Graduate Council requirements. The committee must include at least two members of the BG program graduate faculty and one M.D./Ph.D. steering committee member.

The M.D./Ph.D. student prepares a written comprehensive examination in the format of a grant application and gives an oral presentation of this proposal to their dissertation committee.

M.D./Ph.D. candidates are required to have at least one paper submitted for publication in a major peer-reviewed scientific journal prior to the final doctoral examination, and this must be accepted before they return to the third year of medical school. Aa dissertation must prepared and defended by each M.D./Ph.D. candidate.

Doctoral Minor

A student may elect to choose a minor with the permission of his or her doctoral committee. A minor consists of no fewer than 15 graduate credits of integrated or articulated work in one field related to, but different from, that of the major. A minor normally may be taken only in one of the approved graduate degree programs offered at Penn State, or in a formal graduate minor program that has been approved by the Graduate Council. The minor field chosen must have the approval of the departments or committees responsible for both the major program and the minor field. At least one faculty from the minor field must be on the candidate's doctoral committee. Students may take following courses for the minor

MCIBS 551 Genomics (3)
MCIBS 554 Foundations in Data Driven Life Sciences (3)
MCIBS 541 Critical Analysis of Bioinformatics and Genomics Research Topics (1 X 2)
BMMB 852 Applied Bioinformatics (2)
STAT 500 Applied Statistics (3) or BIOL 405 Molecular Evolution (3)
STAT 555 Statistical Analysis of Genomics Data (3)

Appendix 1: Huck Institutes Resources

The Huck Institutes Travel Award

The Huck Institutes of the Life Sciences provide Travel Awards to Ph.D. students enrolled in any of the graduate programs administered by the Huck Institutes who will give poster and/or oral presentations at domestic or international conferences. To apply for this travel award, submit a request form at https://wiki.vpr.psu.edu/display/HUCKGPA/Graduate+travel+award+requests. The application will be sent to the Program Chair for review and approval. The maximum award for domestic travel is $750, and the maximum award for international travel is $1,500. These funds may be used for transportation, lodging, and meeting registration fees; meals and per diem charges are not allowed. Students are eligible to receive this award twice during their study at Penn State (for 2 domestic or 1 domestic and 1 international meeting).

Huck Institutes Graduate Advisory Committee (HGSAC)

HGSAC is made up of graduate student representatives from each of the six PhD programs administrated by the Huck Institutes of the Life Sciences as well as from the Biochemistry, Microbiology, and Molecular Biology (BMMB) graduate program in the Eberly College of Science. The committee has a maximum size of 15 students, including the Chair and two representatives from each graduate program. The committee organizes career development, networking, and social events, serves as a liaison between graduate students, faculty and administrators. **Contact:** PSU.HGSAC@gmail.com

This Graduate Student Advisory Committee represents all graduate students in the Huck Institutes of the Life Sciences. Its mission is to promote graduate student interests, facilitate communication among students and faculty, and help guide students in their career plans. More information is available at: https://www.huck.psu.edu/resources/students/graduate-students/graduate-student-involvement/student-leadership/huck-graduate-student-advisory-committee

Career Development Resources Website

The HGSAC maintains a Career Development Resources web site (https://www.huck.psu.edu/resources/students/graduate-students/professional-development/professional-development-overview) that can be reached from the Huck Institutes Graduate Program home page. It provides a wide variety of articles on professional development and career exploration for life science students and postdocs, as well as links to seminars, conferences and workshops of interest.

Individual Development Plan:

Students are required to register at myIDP site (http://myidp.sciencecareers.org/) and utilize resources for setting goals for their career. myIDP provides:

- Exercises to help you examine your skills, interests, and values
- A list of 20 scientific career paths with a prediction of which ones best fit your skills and interests
- A tool for setting strategic goals for the coming year, with optional reminders to keep you on track
- A tool for setting strategic goals for the coming year, with optional reminders to keep you on track
- Articles and resources to guide you through the process

Huck Institutes Graduate Network on LinkedIn

BG students, especially those who may be interested in jobs in industry are encouraged to join the Penn State Huck Institutes Graduate Network on LinkedIn: https://www.linkedin.com/groups/8278299/. LinkedIn is no longer just a place for business- and marketing-oriented networking – scientists in both industry and academia are beginning to catch on to the benefits of on-line networking.