PennState
Huck Institutes of the Life Sciences

Intercollege Graduate Degree Program

in

Bioinformatics and Genomics (BG)

Degree Requirements Booklet

Fall 2024

BG Program: www.huck.psu.edu/graduate-programs/bioinformatics-and-genomics
Information for current students: https://gradschool.psu.edu/student-support/student-support-faqs
J. Jeffrey and Ann Marie Fox Graduate School policies: https://gradschool.psu.edu/graduate-education-policies

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Bioinformatics and Genomics (BG) Program Objectives

Bioinformatics and Genomics (BG) is an interdisciplinary graduate program that integrates three focal areas of research: Computational, evolutionary, and functional genomics. Students will be trained in bioinformatics, computation, statistics, genomics, and systems biology. The main 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 results to a broad audience.
- Enhance collaborative environment to facilitate productive interactions and creative efforts in genomics and bioinformatics research.

These objectives will be met in part by offering a set of required and elective courses, which are designed to provide opportunities to develop knowledge in the following and other areas:

- Foundations of genomics, i.e. molecular genetics
- Sequencing technologies, genome assembly, alignments, read mapping
- Basic bioinformatics programming and scripting
- Algorithm development in bioinformatics
- Statistical methods in genomics and bioinformatics; competence in R or equivalent
- Identification and analysis of functionally important components of the genome
- Transcriptomics techniques (microarray, RNA-seq) and analysis
- Genome variation, phenotypic trait mapping (e.g. genome-wide association studies)
- Comparative genomics, molecular evolution, signatures of negative and positive selection

The following courses are required for all Ph.D., M.D./Ph.D., and M.S. students:

- BGEN 541 Critical Analysis in Bioinformatics and Genomics Research Topics (3)
- BGEN/MCIBS 551 Genomics (3)
- MCIBS 554 Foundations in Data Driven Life Sciences (3)
- BGEN 590 Colloquium in Bioinformatics and Genomics (1)
- MCIBS 591 Ethics, Rigor, Reproducibility and Conduct in the Life Sciences (2)
- STAT 555 Statistical Analysis of Genomics Data (3)
- BMMB 852 Applied Bioinformatics (2)

Additional courses for Ph.D. and M.D./Ph.D. students:

All Ph.D. and M.D./Ph.D. students must complete one evolutionary genomics course (3 credits), selected from the below options or another course with prior approval from the program chair:

- BIOL 405 Molecular Evolution (3)
- BIOL 428 Population Genetics (3)
- ANTH or BIOL 460 Human Genetics (3)

If a Ph.D. or M.D./Ph.D. student has not previously completed a statistics or probability course, they will also be required to complete one of STAT 500 (3), STAT 501 (3), or STAT 502 (3).

Additional courses for Ph.D. students only:

Bioinformatics and Genomics Ph.D. students are required to complete at least three laboratory rotations in the first year of study, with registration in the following class each of the fall and spring semesters.

- BGEN 596 Independent Studies (1 credit x 2 semesters)

Bioinformatics and Genomics Ph.D. students may be required to complete (or may choose to take) a pedagogy course at least one semester prior to serving as a Teaching Assistant (TA) to meet the BG program's teaching requirement (see below), depending on stipulations of the department offering the course. For example, the Biology department requires all TAs to complete BIOL 893 before teaching.

- BIOL 893 Experiential Teaching in Biology (1)

An internship is optional for Ph.D. students.

- BGEN 595 Internship (1)

Additional courses for M.S. students only:

- One of STAT 500 (3), STAT 501 (3), or STAT 502 (3)
- BIOL 405 Molecular Evolution (3)

MS students will work with the program chair to determine whether they will be required to complete either a thesis or an internship as part of their MS training. Approval of the thesis option is contingent on a BG faculty member agreeing to serve as the thesis advisor.

Thesis option students (required credits and culminating experience):

- BGEN 600 Thesis Research (6)
- Acceptance by advisors/committee members of a thesis and pass a thesis defense

Internship option students (required credits and culminating experience):

- BGEN 596 Non-Thesis Research (4)
- BGEN 595 Internship (2)
- Acceptance by the program chair of a paper reporting results from an original research project. The internship is separate from the research project and data from the internship are not required for the scholarly paper.

Notes on courses for all students:

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.

The program chair may approve waivers for one or more of the above courses depending on the assessment. M.S. students should keep in mind that they may need to immediately replace any waived courses with electives in order to meet the 30-credit requirement during their relatively short time in the program.

Besides the above required courses, the following are potential electives for BG students. Students may choose to register for these (or other) courses in consultation with their doctoral advisory committee and/or program chair.

- BIOL 428 Population Genetics (3)
- BIOL 460 Human Genetics (3)
- BMB 484 Functional Genomics (3)
- BMB 497 Introduction to Bioinformatics (3)
- BMMB 533 Protein Evolution (3)
- BMMB 566 Algorithms and Data Structures in Bioinformatics (3)
- CHE 512 Optimization and Biological Networks (3)
- CSE 520 Science of Computer Programming
- CSE 541 Database Systems I
- CSE 560 Theory of Graphs and Networks
- CSE 562 Probabilistic Algorithms
- CSE 565 Algorithm Design and Analysis
- 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 501 Regression Methods (3)
- STAT 502 Analysis of Variance and Design of Experiments (3)
- STAT 504 Analysis of Discrete Data (3)
- STAT 505 Applied Multivariate Analysis (3)
- STAT 508 Applied Data Mining & Statistical Learning (3)
- STAT 557 Data Mining (3)

General Information

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 Huck Institutes Graduate Education Office (101 HLSB or email fqh5144@psu.edu).

After completing four years in the program, Ph.D. and M.D./Ph.D. 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 Huck Institutes Graduate Education Office (101 HLSB or email fqh5144@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 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.

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 (https://gradschool.psu.edu/graduate-education-policies/gcac/gcac-800/gcac-803-procedures-termination-unsatisfactory-scholarship/).

Annual Graduate Student Activity Report:
Annual Evaluations are an integral part of the student's professional development. The Ph.D. 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. For M.S. students, their thesis advisors will be provided a link to a separate form for evaluation. You may contact the Huck Graduate Programs Office to ensure that your Ph.D. advisor has received the form.

A link to the online Annual Graduate Student Activity Report (GSAR) will be sent to all Huck graduate students each spring semester from the Huck Institutes Graduate Education 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. https://grad-activity.science.psu.edu/

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 Institutes 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, Acting Director for Graduate Education in the Huck.

Applying for Graduation:
At the beginning of the semester that a student wishes to graduate:

. Access LionPATH at www.lionpath.psu.edu and navigate to "academics" to choose "apply to graduate"
. If not currently in the PSU system call 814-865-1795 to reach Graduate Enrollment Services.

Dissertation or Thesis submission:
Students must present their thesis or dissertation in accordance with the Penn State University guidelines as described in the Thesis and Dissertation Guide "Requirements and Guidelines for the Preparation of Master's Thesis and Doctoral Dissertations".
Web site: https://gradschool.psu.edu/academics/theses-and-dissertations/submission-procedure

Doctoral Minor

Doctoral students who are not already part of the BG program may elect to complete a minor with the permission of their 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.

To earn a graduate minor in Bioinformatics and Genomics, students may take a subset of the following courses to reach the 15 total required credits:

BGEN 541 Critical Analysis of Bioinformatics and Genomics Research Topics (3)
BMMB 852 Applied Bioinformatics (2)
BGEN/MCIBS 551 Genomics (3)
MCIBS 554 Foundations in Data Driven Life Sciences (3)
STAT 555 Statistical Analysis of Genomics Data (3)
Max one of the following: BIOL 405 Molecular Evolution (3), BIOL 428 Population Genetics (3), BIOL 460 Human Genetics (3)

Masters (M.S.) Degree

BG has some specific program requirements for conferral of the M.S. degree in addition to those described in the Fox Graduate School Policy GCAC-631 (http://gradschool.psu.edu/graduate-education-policies/gcac/gcac-600/gcac-631-degree-requirements-research-masters/).

Specifically, for the 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 and there must be at least 12 credits in the major at the 400-, 500-, 800-level. Required courses for master's degree are detailed in the Program Objectives section of this handbook. BGEN 600 Thesis Research may be counted towards the 30 credit minimum. BGEN 595 Internship and electives also count towards the minimum 30 credit requirement. Program Options are not offered for the M.S. degree.

MS students will work with the program chair to determine whether they will be required to complete either a thesis or an internship as part of their MS training. Approval of the thesis option is contingent on a BG faculty member agreeing to serve as the thesis advisor. The thesis option requires acceptance of a thesis by advisors/committee members and the passing of a thesis defense. The internship option requires the completion of a paper reporting results from an original research project (conducted apart from the thesis) with acceptance by the program chair.

M.D./Ph.D. Degree

Required courses for the M.D./Ph.D. degree are detailed in the Program Objectives section of this handbook.

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 (http://gradschool.psu.edu/graduate-education-policies/gcac/gcac-600/gcac-602-phd-committee-formation/). The committee must include at least two members of the BG program graduate faculty and one M.D./Ph.D. steering committee member.

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 paper must be accepted before they return to the third year of medical school. A dissertation must be prepared and defended by each M.D./Ph.D. candidate.

Unless described otherwise in this section (i.e., the paragraphs immediately above this one) and excepting the rotation, BG program qualifying exam (the requirement which is otherwise filled by passing the USMLE Medical Exam, BMS 506A, and BMS 506B), and teaching requirements, the requirements for the Ph.D. Degree described below are also applicable to M.D./PhD. students.

Ph.D. Degree

Students in the BG Ph.D. program must complete the coursework detailed in the Program Objectives section of this handbook. In addition, in consultation with the program chair, and based on the background and needs of the student, specific courses may be waived or additional courses required.

Rotations/Mentor Selection:
Ph.D. students will be required to be associated with research laboratories as a part of Independent Studies (BGEN 596). Students will participate in at least three lab rotations beginning in their first semester. The choice of rotation laboratories will be made in consultation with the chair of the BG program. Each lab rotation will be of 8 weeks duration. Students should aim to finalize the plan for their first rotation in the month prior to the start date and communicate their choice and ongoing decision process for subsequent rotations to the program chair. During the rotations, students are expected to participate in a research project and other activities typical of a research laboratory.

These rotations are very important because i) they are excellent training opportunities in and of themselves, ii) they give students the opportunity to develop a deeper sense of what their PhD research in each labs would be like, and iii) for satisfactory progress in the BG program students must, via strong rotation project performance, demonstrate that they would be a good and productive member of a lab group to a PI who then acknowledges this by agreeing to serve as Ph.D. advisor. Thus, it is important for students to conduct their rotations in labs that 1) they could envision potentially ultimately joining *and* 2) confidently have the ability to accept a new student at the end of the year, assuming strong performance during the rotation. At the culmination of the first three rotations (by April 1), students may join one of these labs based on a mutually-positive rotation experience/performance and sufficiently overlapping research interests, for the remainder of the PhD training period. Fourth and fifth rotations are not necessary but may either be necessary or desired (for example, see below discussion re: College of Medicine rotations).

<u>Rotation schedule:</u>

- First rotation: Sep 1st-Oct 30th
- Second rotation: Nov 1st to Jan 15th
- Third rotation: Jan 15th to March 15th
- Invitation to mutually finalize lab/advisor selection: April 1st
- Fourth rotation (if necessary): March 15th to May 15th
- Summer rotation (if necessary): May 15th to July 15th

Regarding rotation projects with Medical College faculty located at the Hershey campus: In the past there has been a program to provide funding for accommodation in Hershey for interested students to conduct a rotation with Medical College faculty taking place in the summer after your first year of classes at University Park, which could be investigated together with the program chair if desired. However, in practice, BG students especially interested in a Hershey lab typically prefer to conduct that rotation as one of the first three rotations, so that the decision on their permanent home can be set prior to the end of the spring semester. Doing so involves some

discussion with your rotation advisor, but a rotation project that is largely remotely advised via zoom meetings and online updates but with perhaps a bi-weekly or at most weekly visit for in-person interactions with the PI and lab, is often the solution. There is a shuttle between the two campuses. Students who ultimately select a lab at the College of Medicine will need to work with staff at the College of Medicine as well as the Huck Grad Programs Office to change their campus and complete any onboarding steps required by the College of Medicine.

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

Qualifying Exam:

The qualifying exam will be administered to Ph.D. students towards the end of the Spring semester of their first academic year in the program. The qualifying exam has both written and oral components. The goal of the qualifying exam is to determine whether the student has the potential to successfully complete the Ph.D. program, based on evaluation of the student's ability to critically read relevant literature in bioinformatics and genomics ***and*** to think more broadly about research in this field in an integrated manner. Based on their evaluation, the qualifying exam committee may decide to pass the student with or without recommended remedial actions to address any areas of deficiency, to fail the student with an opportunity to retake the exam, or to fail the student without the opportunity to retake the exam.

For the written component of the exam, each student will be provided with a choice of three published articles; they will select one of these articles on which to base a 5-10 page exam paper with 11-point font, single-line spacing, and 1-inch margins. These 5-10 pages should include a list of references cited, and may include original figures to help illustrate key concepts or results, although figures are not required. It is not permissible to simply copy existing figures from the article or from elsewhere. Each student is required to submit their written exam to the program chair within 104 hours (i.e. 9 am Monday to 5 pm Friday) of receiving the three articles.

The expectations for the written qualifying exam extend beyond the ability to clearly and concisely describe the research article. Specifically, the exam paper should demonstrate: **i)** the student's knowledge of background information needed to understand the article (or at least the major aspects of the article around which the student is constructing their discussion) *including with different or broader perspectives than those presented by the authors in the article*, **ii)** a clear understanding of the authors' likely purpose for conducting the study and/or the hypothesis driving the research and/or the methodological improvement, **iii)** the student's ability to succinctly and objectively present the experimental and methodological approach, and **iv)** the student's ability to critically assess the results and the methods that were used to derive them (or a major subset of results, as per above) of the article in context of the purpose/ hypothesis. **Very importantly**, the exam paper should also **v)** synthesize the major results of this study in a broader and/or different context than presented by the authors in their discussion. This goal could potentially be accomplished by recognizing and detailing novel cross-field impacts of the results, by describing the student's ideas for future experiments (in vitro or in silico) that were inspired by this study with an explanation of why the results of those experiments would be particularly insightful, or in other manners.

Our program emphasizes the importance of scholarly integrity and research ethics, including in-class and out of class training and discussion about plagiarism and how to avoid it. Students should ensure that they are writing everything in the paper fully from scratch – they are advised to avoid, for example, writing explanations of the published article's method while reading the authors' text, which risks the author's phrasing being incorporated into the written exam. If such plagiarism occurs, this can result in exam failure. To reiterate: We advise students to separate the reading and writing processes as completely as possible.

The written exam paper will serve as the basis for the oral portion of the qualifying exam, which will take place a minimum of one week following the completion of the written exam. The oral exam will consist of a 15-20 minutes presentation by the student followed by an extended question-answer session with the exam committee, which may last for up to 2 hours. The qualifying exam committee will include three Bioinformatics and Genomics faculty members. The composition of the student qualifying exam committee must be approved by the program chair.

Doctoral Dissertation Committee Composition:
According to the Graduate Education Policies published by the Fox Graduate School (https://gradschool.psu.edu/graduate-education-policies/gcac/gcac-600/gcac-602-phd-committee-formation/), the dissertation committee must meet the following guidelines:

- A minimum of 4 approved PSU Graduate Faculty.
- At least 2 committee members must be designated as inside the major. One member should be designated as outside the major field, and one member, the outside unit member, must hold a primary appointment in a department that differs from the primary appointment of the advisor and committee chair.
- For intercollege graduate programs (i.e. Bioinformatics and Genomics) the outside field and outside unit members may be inside the major (i.e. Bioinformatics and Genomics program faculty members) 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. All major and outside members of the committee must be approved PSU Graduate Faculty members.
- 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 program chair and approval of the graduate dean.
- The committee chair or one of the co-chairs must be a member of the approved PSU Graduate Faculty. Typically this is the faculty advisor or someone in the graduate program.
- Committee exam attendance expectations: May be held fully in-person, fully remote, or hybrid with some individuals participating in-person while others participate remotely.
- Approval of 2/3 of the committee members is needed for passing comprehensive and dissertation defense examinations.
- **The committee must be formed (and paperwork filed) within one year of passing the qualifying exam. Moreover, there is additional paperwork that must be filed at least 3-4 weeks prior to your scheduled comprehensive exam and dissertation defense dates. Please contact:** Freya Heryla, fqh5144@psu.edu, 101 Life Sciences Bldg.

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 the student's doctoral dissertation committee (see above). Typically, the student's primary dissertation advisor will chair the comprehensive exam committee. The comprehensive exam should be taken either during or 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 comprehensive exam will be an oral defense of a submitted written proposal for the planned dissertation research. Experience in writing research proposals is an

invaluable part of graduate training. Thus, Ph.D. students in the BG program will develop the proposal for their comprehensive exam to fit the format and guidelines for an NSF doctoral dissertation improvement or an NIH pre-doctoral fellowship proposal. Ideally, the proposal will be submitted to the agency at the time of or soon after the comprehensive examination. The proposal must be submitted to the examination committee at least two weeks prior to the exam. The comprehensive exam itself will begin with a 20–25 minute overview by the student of the proposal and of any preliminary data they have obtained to support it, followed by questions by members of the committee, answers by the student, and discussion lasting for a total of up to two hours. The evaluation criteria are as follows. The student must demonstrate: i) the use of good scholarship in completing the written proposal, ii) the ability to formulate a set of interconnected projects that could form the basis for a Bioinformatics and Genomics dissertation when completed, iii) the ability to detail and justify study designs and analytical and (as applicable) data collection methods, iv) the ability to articulate the significance of the project, and v) the ability to respond in real-time to questions from the committee about the proposal and how uncertainties could be addressed as the proposed work proceeds. A favorable vote of at least two-thirds of the members of the Ph.D. committee is required for passing the comprehensive exam. If a student fails the comprehensive exam they are allowed to retake the exam a maximum of one additional time, only if such a plan is approved by the majority of the committee and by the program chair, and following the completion of any conditions specified by the Ph.D. committee and/or program chair. The required timeframe for any such conditions to be met must be specified by the committee and program chair within one month following the exam. If a student fails the final attempt of the comprehensive exam (or fails to complete any conditions within the specified timeframe requirements) they may be allowed to change to the MS degree if they would like to work towards meeting those requirements.

Post-Comprehensive Progress Reports:
Subsequent to the Comprehensive Examination, all BG Ph.D. and M.D./Ph.D. students will be required to provide their 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 1-2 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 program chair and Huck Institutes Graduate Education Office within three weeks of the anniversary date of their comprehensive exam.

Dissertation 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 program chair or co-chair on that campus. Students must follow the dissertation guidelines outlined by the Fox Graduate School. A final, complete draft of the written dissertation must be submitted to the full committee for review a minimum of two weeks prior to the scheduled defense. The final oral examination shall consist of a public oral presentation of the dissertation for 30-50 minutes followed by a closed discussion between the student and the student's Ph.D. committee lasting for a total of up to three hours. The evaluation criteria are as follows. The student must demonstrate: i) the report of high-quality research and the use of good scholarship in completing the written dissertation, ii) the ability to articulate the significance of the project as well as how it fits into the broader scientific context, and iii) the ability to respond in real-time to questions from the committee about the work and its constituent components, including justification of the methods and in-depth explanations of results. A favorable vote of at least two-thirds of the members of the Ph.D. committee is required for passing the dissertation defense. If a student fails the dissertation defense they are allowed to schedule a maximum of one additional defense, only if such a plan is approved by the majority of the committee and by the program chair, and following the completion of any conditions specified by the Ph.D. committee and/or program chair. The required timeframe for any such conditions to be met must be specified by the committee and program chair within one month following the dissertation defense. If a student fails the final attempt of the dissertation defense (or fails to complete any conditions within the specified timeframe requirements) they may be allowed to change to the MS

degree if they would like to work towards meeting those requirements. The final approved dissertation must be deposited electronically with the Fox Graduate School in advance of graduation.

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 BGEN 601 (post-comprehensive exam). Assistantship appointments typically originate with the department of the faculty advisor. If no faculty advisor has yet been identified, as is likely for first year Ph.D. students, students should contact the Huck Institutes Graduate Education Office.

Teaching Requirement:
Ph.D. students in the program are required to fulfill a teaching experience requirement. There are several options for doing so, reflecting the diversity of student opportunities and interest that exist across our program. First, the requirement may be met by serving as a teaching assistant for a minimum of one semester. It is preferred (and sometimes required, depending on the department sponsoring the TA opportunity) that students enroll for credit in a pedagogical training course (BIOL 893 or other equivalent) at least one semester prior to the TA assignment. An English competency requirement must be satisfied by non-native English speakers before any teaching assistant duties are assigned. Interested students could potentially obtain a Teaching Certificate; for details see: https://gradschool.psu.edu/student-support/professional-development/penn-state-cirtl-teaching-certificate. Alternatively, a student may i) develop the content and deliver a workshop to other students, as long as the workshop is widely advertised and attended, ii) serve as a teaching assistant for the annual Bioinformatics Data Reproducibility workshop, or iii) complete another pedagogical/teaching experience. Any of these alternative (i.e. other than serving as a teaching assistant for a typical university course) requires prior discussion with and approval from the program chair. The teaching requirement should be completed before appearing for the Comprehensive Examination.

Internship (optional):
Ph.D. students may participate in an internship with a private company, medical center, or government laboratory. Non-traditional settings are also available. The internship should be discussed with the Program Chair. 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 the program chair and advisor, but students must arrange for their own financial support. Students will register for one credit of BGEN 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.

Options in Bioinformatics and Genomics:
Students may pursue the doctoral program with no options or select an option in Algorithms and Computation or in 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 Probabilistic 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)

Representative Course Schedule for Bioinformatics & Genomics PhD Students

Students should consult with program chair or primary advisor before scheduling courses. Any student on an assistantship, please note that the maximum amount of credits you can take are 12 credits so please check with the program chair/Huck staff if you find yourselves over-enrolled.

Year 1 - Fall Semester

- BMMB 852 Applied Bioinformatics (2)
- BGEN 541 Critical Analysis in Bioinformatics and Genomics Research Topics (3)
- BGEN/MCIBS 551 Genomics (3)
- BGEN 596 Independent Studies, Lab Rotations (1)
- Submit CITI RCR Course Completion Report to Huck Institutes Graduate Education Office

Spring Semester

- MCIBS 554 Foundations in Data Driven Life Sciences (3)
- STAT 555 Statistical Analysis of Genomics Data (3)
- BGEN 590 Colloquium in Bioinformatics and Genomics (1)
- MCIBS 591 Ethics, Rigor, Reproducibility and Conduct in the Life Sciences (2)
- BGEN 596 Independent Studies, Lab Rotations (1)
- BIOL 405 or 428*
- Qualifying Examination

(*BIOL 460 is typically offered in the fall semester; BIOL 405 and 428 are typically offered in the spring semester)

Year 2 - Fall Semester

- BGEN 600 Thesis Research (variable credits)
- BIOL 893 (1) or equivalent, if required
- BGEN 556 Computation, Bioinformatics, and Statistics Practicum (3)
- BG Electives (0-6 credits)

Spring Semester

- BGEN 600 Thesis Research (variable credits)
- BG Electives (optional; 0-6 credits)
- Comprehensive Examination (students will ideally have passed the Comprehensive Examination by the end of their second year in the program, but the timing can vary depending on research area and circumstances; discuss with the thesis advisor and program chair)

Year 3

- BGEN 600 Thesis Research (9 credits per semester until Comprehensive Exam has been passed)
- BGEN 601 Ph.D. Dissertation Full-Time (full-time enrollment after Comprehensive Exam has been passed)

Summer (recommended for after the Comprehensive Exam has been passed, with ideal timing reviewed with the committee)

- BGEN 595 Internship (1) (optional)

Years 4-5

- BGEN 601 Ph.D. Dissertation Full-Time

Brief Descriptions of BG Courses

BGEN 541. CRITICAL ANALYSIS IN BIOINFORMATICS AND GENOMICS RESEARCH TOPICS (3) 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.

BGEN/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) Expanded overview of current developments and technique in computational biology and genomics. BMMB/MCIBS 554 Foundations in Data Driven Life Sciences (3) The successful progression of data-driven biomedical research is obscured by wide-range of logistical problems related to data handling and processing, a widespread disconnect between developers and consumers of biomedical analysis software, and lack of accessible, well-developed curricula and active learning opportunities necessary for the development of key data analysis skills in the next generation of researcher and clinicians. This course aims a filling these gaps. Topics include fundamental concepts that underpin analysis of sequence data, design of complex experiments, research transparency and reproducibility, as well as result disseminations practices relevant to presentations and publications.

BGEN 556. Computation, Bioinformatics, and Statistics Practicum (3) In this course, we will identify, plan and implement actual research projects involving high dimensional, complex "omics" data that are relevant to the biomedical sciences, and of direct interest to the students enrolled and their mentors. We will form teams and work on these projects throughout the semester – fostering interdisciplinary exchanges, the ability to work collaboratively in teams, and excellence in oral and written scientific communication (through presentations and reports; see "Assessment" below). Various types of computational tools and statistical techniques will be discussed, utilized and compared, based on the students' background and choice of research projects.

BGEN 590. COLLOQUIUM IN BIOINFORMATICS AND GENOMICS (1) 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.

MCIBS 591. ETHICS, RIGOR, REPRODUCIBILITY AND CONDUCT OR RESEARCH IN THE LIFE SCIENCES (2) Students examine integrity and misconduct in life sciences research, including issues of data collection, publication, authorship, and peer review.

BGEN 596. INDEPENDENT STUDIES (1 X 2 semesters) Laboratory rotations 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.

BGEN 600. THESIS RESEARCH (1-9 per semester) 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 BGEN 600 may have the A-F quality grade.

BGEN 601. THESIS PREPARATION (0) For those students who passed their comprehensive exams. This course appears on the transcript but has no credit and only an R grade associated with it.

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.

English Proficiency Requirement

The University requires that all students whose first language is not English and who plan to be teaching assistants take the Penn State 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, 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) secure website. Below is the course of action for the various AEOCPT score ranges.

AEOCPT SCORE	REQUIRED COURSE	PROGNOSIS
250 - 300	None	Student may teach with no restrictions.
200 - 249	ESL 118G	Must pass the Interactive Performance Test (IPT) before teaching.
150 – 199	ESL 117G followed by ESL 118G	Two semesters of ESL, then IPT before teaching.
<150	ESL 115G, then ESL 117G, then ESL 118G	Three semesters of ESL, then IPT before teaching.

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.

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 before choosing a permanent laboratory:

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 co-workers, support staff and other individuals with whom the student interact.
        iv. Do the 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 the student has 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
    a. The Advisor will:
        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 Advising Relationship:
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 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.

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.*

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/huck-graduate-student-advisory-committee

Career Development Resources Website:
The HGSAC maintains a Career Development Resources web site that can be reached from the Huck Institutes Graduate Program home page (https://www.huck.psu.edu/resources/students/graduate-students/professional-development/professional-development-overview). 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 encouraged 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
- Articles and resources to guide you through the process

Huck Institutes Graduate Network on LinkedIn:
BG students are encouraged to join the Penn State Huck Institutes Graduate Network on LinkedIn: https://www.linkedin.com/groups/8278299/. This LinkedIn group is a great resource for students interested in careers in both industry and academia to network and connect with program alumni.