BIOINFORMATICS AND GENOMICS

Graduate Program Head	David Koslicki
Program Code	BGEN
Campus(es)	Hershey (Ph.D., M.S.) University Park (Ph.D., M.S.)
Degrees Conferred	Doctor of Philosophy (Ph.D.) Master of Science (M.S.) Joint M.D./Ph.D. with the College of Medicine
The Graduate Faculty	View (https://secure.gradsch.psu.edu/gpms/?searchType=fac&prog=BGEN)

The IGDP in BG is an interdepartmental program that engages faculty members from six colleges on two campuses. This broad-reaching program provides students a wide range of understanding of multiple disciplines with specific expertise in a chosen area, and encourages interdisciplinary research that is truly changing biological research as well as health and lifestyles.

Admission Requirements

Applicants apply for admission to the program via the Graduate School application for admission (https://gradschool.psu.edu/graduate-admissions/how-to-apply/). Requirements listed here are in addition to Graduate Council policies listed under GCAC-300 Admissions Policies (https://gradschool.psu.edu/graduate-education-policies/).

- Fully completed, official online Penn State Graduate Application (http://gradschool.psu.edu/prospective-students/how-to-apply/).
- Paid, nonrefundable application fee (see Requirements for Graduate Admission (http://www.gradschool.psu.edu/prospective-students/how-to-apply/new-applicants/application-fees/) for current fee).
- Official transcripts from all post-secondary institutions attended (http://www.gradschool.psu.edu/prospective-students/how-to-apply/new-applicants/requirements-for-graduate-admission/).
- Completed BG-specific questions on the Graduate Application.
- Application for a U.S. visa (international applicants only).
- Names and contact information, including business email addresses, for three references.
- Successful applicants generally will have a minimum 3.5 on a 4.0 scale junior/senior undergraduate grade point average, and will have completed course work in both quantitative and life science subjects.

The language of instruction at Penn State is English. English proficiency test scores (TOEFL/IELTS) may be required for international applicants. See GCAC-305 Admission Requirements for International Students (https://gradschool.psu.edu/graduate-education-policies/gcac/gcac-300/gcac-305-admission-requirements-international-students/) for more information.

Applicants to the BG program must have a minimum TOEFL total score of 90 with a 19 on the speaking section for the Internet-based test (iBT). Successful applicants generally have a minimum score of 100 (including 23 on the speaking component) on the Internet-based test.

Degree Requirements

Master of Science (M.S.)

Requirements listed here are in addition to Graduate Council policies listed under GCAC-600 Research Degree Policies. (https://gradschool.psu.edu/graduate-education-policies/)

For master's degree, a minimum of 30 credits at the 400, 500, 600, or 800 level and a 3.0 overall GPA are required. At least 18 credits in the 500 and 600 series combined (thesis option) or 500 series alone (internship plus scholarly paper option) must be included in the program. As part of the application to the graduate program, students will indicate their preference for completing either a thesis or an internship plus a scholarly paper as part of their M.S. training. Approval of the thesis option is contingent on a BG faculty member agreeing to serve as the thesis adviser.

Required courses for all BG master's degree students are:

Code	Title	Credits
Required Courses		
BGEN 551	Genomics	3
MCIBS 554	Foundations in Data Driven Life Sciences	3
Choose one of the following:		3
STAT 500	Applied Statistics	
STAT 501	Regression Methods	
STAT 502	Analysis of Variance and Design of Experiments	
STAT 555	Statistical Analysis of Genomics Data	3
BMMB 852	Applied Bioinformatics	2
BIOL 405	Molecular Evolution	3
BGEN 541	Critical Analysis of Bioinformatics and Genomics Research Topics	3
BGEN 590	Colloquium	1
MCIBS 591	Ethics, Rigor, Reproducibility and Conduct of Research in the Life Sciences	2
Electives		
At least one elective credit must be chosen from a list of approved classes maintained by the graduate program office.		1
Culminating Experience		
Students choosing the M.S. with thesis option must complete original laboratory research (a minimum of 6 credits of BGEN 600) 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.		
BGEN 600		6
Students choosing the M.S. with internship plus scholarly paper option must complete independent study (non-thesis research, BGEN 596) and an internship (BGEN 595). Acceptance by the program chair of a scholarly paper reporting results from an original research project is required to fulfill the culminating experience. The internship is separate from the research project and data from the internship are not required for the scholarly paper.		
BGEN 596	Individual Studies	4
BGEN 595	Internship	2
Total Credits		**30**

Program Options described below for the Ph.D. degree are not offered for the M.S. degree.

Doctor of Philosophy (Ph.D.)

Requirements listed here are in addition to Graduate Council policies listed under GCAC-600 Research Degree Policies. (https://gradschool.psu.edu/graduate-education-policies/)

For the Ph.D., a minimum of 35 credits is required. During the first year of study, Ph.D. students are required to take 22 credits of core required courses. Subsequently, 13 credits of elective courses are also required:

Code	Title	Credits
Core Required Courses		
BGEN 551	Genomics	3
MCIBS 554	Foundations in Data Driven Life Sciences	3
BGEN 541	Critical Analysis of Bioinformatics and Genomics Research Topics	3
BGEN 590	Colloquium	1
MCIBS 591	Ethics, Rigor, Reproducibility and Conduct of Research in the Life Sciences	2
BMMB 852	Applied Bioinformatics	2
STAT 555	Statistical Analysis of Genomics Data	3
Choose one of the following:		3
BIOL 405	Molecular Evolution	
BIOL 428	Population Genetics	
BIOL 460	Human Genetics	
BGEN 596	Individual Studies (representing three Research Rotations)	2
Electives		
Elective credits chosen from a list of approved courses maintained by the graduate program office		13
Total Credits		**35**

Depending on the student's prior background, STAT 500, STAT 501, or STAT 502 may also be required.

Each candidate for the Ph.D. degree must fulfill written and spoken English communication requirements that are satisfied by preparing written and oral reports describing the laboratory rotations during the first year.

At the end of the first year, continuation in the Ph.D. program is determined by performance in course work, laboratory rotations, and the BG Graduate Program Qualifying Examination. Students join their research laboratory by the end of the second semester of the first year.

The Ph.D. committee is formed following entry into the dissertation laboratory, and must comply with all Graduate Council requirements (http://gradschool.psu.edu/graduate-education-policies/gcac/gcac-600/phd-dissertation-committee-formation/). Students may consider joint co-advisers, each representing a different area of expertise within the field of bioinformatics and genomics.

During the second year, students may take additional courses in consultation with the Ph.D. committee. Students may select an option area in which they conduct research and take additional courses specified by the Option (see below). Students are not required to choose an Option. Additionally, students will complete a Teaching Experience, which may be fulfilled by serving as a Teaching Assistant for an undergraduate course or a Student Instructional Assistant for a graduate course, the development of content for and delivery of a comprehensive bioinformatics and genomics training workshop, or other pedagogy-related training and practical experience as approved by the program chair.

Ph.D. students must pass a comprehensive examination; to maintain satisfactory progress in the program this should take place by the end of the fifth semester of enrollment. The written portion of the comprehensive examination is in the format of a grant application. As part of this examination, the candidate also gives an oral presentation of this proposal to their Ph.D. committee.

A dissertation must be prepared and defended by each Ph.D. student. Students must present their dissertation in accordance with Graduate Council and Graduate School guidelines as described in the THESIS GUIDE: Requirements for the Preparation of Master's Theses and Doctoral Dissertations (http://www.gradschool.psu.edu/current-students/etd/thesisdissertationguidepdf/). To earn the Ph.D. degree, the dissertation must be accepted by the Ph.D. committee, the head of the graduate program, and the Graduate School and the student must pass a final oral examination (the dissertation defense).

The final examination of the doctoral candidate is an oral examination administered and evaluated by the entire Ph.D. committee. It consists of an oral presentation of the dissertation by the candidate and a period of questions and responses. These will relate in large part to the dissertation, but may cover the candidate's entire program of study, because a major purpose of the examination is also to assess the general scholarly attainments of the candidate. The portion of the examination in which the dissertation is presented is open to the University community and the public; therefore, it is expected that the examination will take place at University Park or the Hershey campus. It is expected that the Ph.D. candidate will have at least one paper submitted for publication in a major peer-reviewed scientific journal prior to the final oral examination.

Ph.D. students in Bioinformatics and Genomics may enroll in one of two options, but are not required to do so.

Option in Algorithms and Computation

Students are admitted to the Option in Algorithms and Computation after successfully completing:

1. the first year of the IGDP in BG;
2. three research rotations, of which at least two must be with faculty affiliated with the Algorithms and Computation Option; and
3. the qualifying examination.

During the second year, Ph.D. students choosing this option will be required to take:

Code	Title	Credits
CSE/BMMB 566	Algorithms and Data Structures in Bioinformatics	3
CMPSC 465	Data Structures and Algorithms	3
or CSE 565	Algorithm Design and Analysis	
Two courses from a list of prescribed electives which includes but is not limited to the following:		6
CMPSC 431W	Database Management Systems	
CMPSC 450	Concurrent Scientific Programming	
CSE 557	Concurrent Matrix Computation	
CMPSC 464	Introduction to the Theory of Computation	
CSE 583	Pattern Recognition and Machine Learning	

CSE 562	Probabilistic Algorithms	
CMPEN 455	An Introduction to Digital Image Processing	
CMPEN 454	Fundamentals of Computer Vision	
CHE 512	Optimization and Biological Networks	
Total Credits		**12**

Option in Statistical Genomics

Students are admitted to the Option in Statistical Genomics, after successfully completing:

- the first year of the IGDP in BG;
- three research rotations, of which at least two must be with faculty affiliated with the Statistical Genomics Option; and
- the qualifying examination.

During the second year, Ph.D. students choosing this option will be required to take:

Code	Title	Credits
STAT 501	Regression Methods	3
or STAT 511	Regression Analysis and Modeling	
STAT 557	Data Mining I	3
Two courses from a list of prescribed electives which includes but is not limited to the following:		6
STAT 414	Introduction to Probability Theory	
STAT 415	Introduction to Mathematical Statistics	
STAT 416	Stochastic Modeling	
STAT 502	Analysis of Variance and Design of Experiments	
STAT 504	Analysis of Discrete Data	
STAT 505	Applied Multivariate Statistical Analysis	
STAT 540	Statistical Computing	
Total Credits		**12**

Joint Degrees

Joint M.D. / Ph.D. with the College of Medicine

Requirements listed here are in addition to requirements listed in GCAC-211 Joint Degree Programs (https://gradschool.psu.edu/graduate-education-policies/gcac/gcac-200/gcac-211-joint-degree-programs/).

Admission Requirements

Students interested in simultaneously pursuing an M.D. and Ph.D. degree must apply to the College of Medicine M.D. program using the national American Medical College Application Service (AMCAS) application system and indicate their intent to pursue the joint degree program. The College of Medicine M.D./Ph.D. Admissions Committee reviews applications and evaluates candidates for acceptance into both the M.D. and Ph.D. program. Students not accepted into the joint degree program can be referred to either the M.D. or Ph.D. program, depending on their qualifications.

The general admission requirements for the Ph.D. degree are listed on the Admission Requirements tab. Additional requirements for the joint degree are listed below. Admissions requirements and applications for admission for Penn State College of Medicine are available at the M.D. Program (http://med.psu.edu/md/) section of the Penn State College of Medicine website. After the review committee has accepted an applicant to the joint degree program, s/he must apply to the Graduate School

(http://www.gradschool.psu.edu/prospective-students/how-to-apply/) for admission to the graduate program.

In addition to the basic college level premedical school requirements for the Penn State College of Medicine (one year each of biology, chemistry, physics, math, and organic chemistry), the M.D./Ph.D. program has the following requirements:

- **Academic Achievement**. Applicants to our program generally have very strong grades and MCAT scores. In recent years, successful applicants have an average GPA of 3.75 and MCAT scores of 33-34. Applicants are not required to take the GREs.
- **Research Experience**. We are especially interested in students with a strong and sustained background in research. Students who have spent 1-2 years after graduation conducting research are strongly encouraged to apply. Alternatively in-depth research experience as an undergraduate can suffice.
- **Recommendations**. We are especially interested in receiving letters of recommendation from faculty with whom you conducted research and who can comment on your passion and potential for research.
- **Goals**. Applicants must be able to clearly articulate the reasons for pursuing the joint degree.
- **International Students**. All qualified students are eligible to apply regardless of citizenship.

Degree Requirements

Students must fulfill all requirements for each degree in order to be awarded that degree, subject to the double-counting of credits as outlined below. Degree requirements for the M.D. program are listed on the Penn State College of Medicine (http://med.psu.edu/md/) website. Degree requirements for the Ph.D. degree are listed in the Ph.D. Degree Requirements section.

During the first two years of medical school, the student conducts at least three research rotations. After successful completion of the first two years of medical school the candidate enters the BGEN Graduate Program.

During the summer after the second year of medical school, M.D./Ph.D. students take Step 1 of the United States Medical Licensing Examination (USMLE), which serves in lieu of the knowledge-based part of the qualifying examination for the BG program. Successful completion of BMS 506A and BMS 506B, which are taken in the second year of medical school, with a grade of B or higher meets the critical thinking and paper analysis requirement of the qualifying exam.

The Ph.D. committee of an M.D./Ph.D. student in the BG program 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/phd-dissertation-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.

Code	Title	Credits
Required Courses		
BGEN 590	Colloquium	1
MCIBS 591	Ethics, Rigor, Reproducibility and Conduct of Research in the Life Sciences	2
BGEN 551	Genomics	3
MCIBS 554	Foundations in Data Driven Life Sciences	3

BGEN 541	Critical Analysis of Bioinformatics and Genomics Research Topics	3
STAT 555	Statistical Analysis of Genomics Data	3
BMMB 852	Applied Bioinformatics	2
Electives		
Elective credits chosen from a list of approved courses maintained by the graduate program office; must include an evolutionary genomics course (BIOL 405, BIOL 428, BIOL 460, or another evolutionary genomics course approved by the program chair); depending on student's prior background, STAT 500, STAT 501, or STAT 502 may also be required.		6
Total Credits		**23**

The BG program will accept SPM 711 in lieu of 6 credits of elective courses and 2 credits of BGEN 596. If students accepted into the joint degree program are unable to complete the M.D. degree, they are still eligible to receive the Ph.D. degree if all Ph.D. degree requirements have been satisfied.

The College of Medicine will accept 8 credits of BGEN 600/BGEN 601 Thesis Research/Ph.D. Dissertation conducted over the four years of the graduate portion of the training program in lieu of two months of elective rotations (MED 797). In addition, the College of Medicine requires all M.D. students to complete a Medical Student Research project; this requirement is waived for all M.D./Ph.D. students.

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 Ph.D. 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. A dissertation must be prepared and defended by each M.D./Ph.D. candidate.

Minor

A graduate minor is available in any approved graduate major or dual-title program. The default requirements for a graduate minor are stated in Graduate Council policies listed under GCAC-600 Research Degree Policies (https://gradschool.psu.edu/graduate-education-policies/) and GCAC-700 Professional Degree Policies (https://gradschool.psu.edu/graduate-education-policies/), depending on the type of degree the student is pursuing:

- GCAC-611 Minor - Research Doctorate (https://gradschool.psu.edu/graduate-education-policies/gcac/gcac-600/gcac-611-minor-research-doctorate/)
- GCAC-641 Minor - Research Master's (https://gradschool.psu.edu/graduate-education-policies/gcac/gcac-600/gcac-641-minor-research-masters/)
- GCAC-709 Minor - Professional Doctorate (https://gradschool.psu.edu/graduate-education-policies/gcac/gcac-700/gcac-709-professional-doctoral-minor/)
- GCAC-741 Minor - Professional Master's (https://gradschool.psu.edu/graduate-education-policies/gcac/gcac-700/gcac-741-masters-minor-professional/)

Student Aid

Graduate assistantships available to students in this program and other forms of student aid are described in the Tuition & Funding (https://gradschool.psu.edu/graduate-funding/) section of The Graduate School's website. Students on graduate assistantships must adhere to the course load limits (https://gradschool.psu.edu/graduate-education-policies/gsad/gsad-900/gsad-901-graduate-assistants/) set by The Graduate School.

Courses

Graduate courses carry numbers from 500 to 699 and 800 to 899. Advanced undergraduate courses numbered between 400 and 499 may be used to meet some graduate degree requirements when taken by graduate students. Courses below the 400 level may not. A graduate student may register for or audit these courses in order to make up deficiencies or to fill in gaps in previous education but not to meet requirements for an advanced degree.

Molecular, Cellular, and Integrative Biosciences (MCIBS) Course List (https://bulletins.psu.edu/university-course-descriptions/graduate/mcibs/)

Learning Outcomes

1. **Know**: demonstrate knowledge of core principles and primary literature in their specialty area including comprehension of methods, results, and data analysis in the specialty area.
2. **Apply/Create**: demonstrate ability to design and carryout a major research project in the field, including a description of previous work in the field and assemble new findings into a written work that advances understanding in the field.
3. **Communicate**: demonstrate ability to convey scientific ideas and results in clear, concise and original writing as well as formal oral presentations.
4. **Think**: demonstrate ability to critically analyze work by others in the fields of bioinformatics, computational, statistical, functional and evolutionary genomics.
5. **Professional Practice**: demonstrate comprehension of and commitment to ethical standards in the discipline. Demonstrate the ability to teach key concepts.
6. **Teach**: demonstrate the ability to teach key concepts of the discipline of bioinformatics, computational, statistical, functional and evolutionary genomics.

Contact

Campus	Hershey Med Ctr
Graduate Program Head	David Koslicki
Director of Graduate Studies (DGS) or Professor-in-Charge (PIC)	Dajiang Liu
Program Contact	Freya Heryla 101 Huck Life Sciences Building University Park PA 16802 fqh5144@psu.edu (814) 863-3273
Program Website	View (https://www.huck.psu.edu/graduate-programs/bioinformatics-and-genomics/)

Campus	University Park
Graduate Program Head	David Koslicki
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Program Website	View (https://www.huck.psu.edu/graduate-programs/bioinformatics-and-genomics/)