

# BIOMEDICAL SCIENCES

<b>Graduate Program Head</b>	Lisa Shantz
<b>Program Code</b>	BMS
<b>Campus(es)</b>	Hershey (Ph.D., M.S.)
<b>Degrees Conferred</b>	Doctor of Philosophy (Ph.D.) Master of Science (M.S.) Dual-Title Ph.D. in Biomedical Sciences and Clinical and Translational Science Joint M.D./Ph.D. with the College of Medicine
<b>The Graduate Faculty</b>	View ( <a href="https://secure.gradsch.psu.edu/gpms/?searchType=fac&amp;prog=BMS">https://secure.gradsch.psu.edu/gpms/?searchType=fac&amp;prog=BMS</a> )

The Biomedical Sciences (BMS) Graduate Program with its Options in Biochemistry, Genetics, and Genomics, Cancer Biology, Cellular and Integrative Physiology, Translational Therapeutics, and Virology and Immunology provides students curricular training with a unique focus on human health and disease and the opportunity to concentrate in one or more disciplinary approaches including: biochemistry, biophysics, cell biology, genetics, immunology, pharmacology, physiology, structural biology, and virology. Students receive rigorous training that provides the skills necessary to be leaders in biomedical research and other endeavors that benefit from advanced scientific training, including industry, education, intellectual property development, technology licensing, journalism, entrepreneurship, and public policy.

The BMS Graduate Program is an interdepartmental program that engages faculty from numerous basic science and clinical departments. This broad-reaching program provides students a wide-ranging understanding of multiple disciplines with specific expertise in a chosen area, and encourages interdisciplinary research that is the hallmark of biomedical sciences in the 21<sup>st</sup> century.

## 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/>).

1. Submission of online Penn State Graduate School application (<http://www.gradschool.psu.edu/prospective-students/how-to-apply/>) and payment of nonrefundable application fee
2. Three letters of recommendation
3. Statement of goals including
  - a. reasons for applying to the BMS Graduate Program,
  - b. previous research experiences,
  - c. particular areas of research interests if known, and
  - d. long-term career goals
4. Official transcripts from all post-secondary institutions attended (<http://www.gradschool.psu.edu/prospective-students/how-to-apply/new-applicants/requirements-for-graduate-admission/>); Note that post-secondary course work should include biochemistry and molecular biology or genetics.

## 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/>)

To receive the M.S. degree in BMS, at least 32 credits from courses at the 400, 500, 600, and 800 level are required, with at least 18 credits at the 500 and 600 level, combined.

Code	Title	Credits
<b>Required Courses</b>		
BMS 502	Cell and Systems Biology	3
BMS 503	Advanced Molecular Genetics	3
BMS 504	Art of Scientific Communication I	1
BMS 505	Art of Scientific Communication II	1
BMS 590	Colloquium	2
BMS 591	Biomedical Research Ethics	1
BMS 596	Individual Studies (Research Rotation)	2
	Colloquium or Journal Club fulfilled by taking 2 credits of any of the following:	2
BICHEM 590	Colloquium	
BMS 553	Cancer Biology Colloquium	
PHARM 590	Colloquium	
PSIO 501	Scientific Analysis and Presentation	
MICRO 572	Literature Reports	
MICRO 590	Colloquium	
NEURO 590	Colloquium	
VIRIM 580	Critical Reading in Immunobiology	
<b>Electives</b>		
	At least 11 credits of elective courses at the 500 or 800 level selected in consultation with the student's thesis adviser and thesis committee.	11
<b>Thesis Research</b>		
BMS 600	Thesis Research <sup>1</sup>	6
<b>Total Credits</b>		<b>32</b>

<sup>1</sup> No more than 6 credits of BMS 600 may be counted toward the 32 credit minimum.

Each candidate for the M.S. 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.

Students must complete original laboratory research that culminates in a thesis. The thesis must be accepted by the master's committee, the chair of the graduate program, and the Graduate School.

### 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/>)

To receive the Ph.D. degree in Biomedical Sciences, at least 29 credits from courses at the 400, 500, 600, and 800 level are required.

Code	Title	Credits
<b>Required Courses</b>		
BMS 502	Cell and Systems Biology	3
BMS 503	Advanced Molecular Genetics	3
BMS 504	Art of Scientific Communication I	1
BMS 505	Art of Scientific Communication II	1
BMS 590	Colloquium	5
BMS 591	Biomedical Research Ethics	1
BMS 596	Individual Studies (Research)	2
BMS 801	Writing Grant Proposals for Biomedical Research	1
Colloquium or Journal Club fulfilled by taking 2 credits of any of the following:		2
BICHEM 590	Colloquium	
BMS 553	Cancer Biology Colloquium	
PHARM 590	Colloquium	
PSIO 501	Scientific Analysis and Presentation	
MICRO 572	Literature Reports	
MICRO 590	Colloquium	
NEURO 590	Colloquium	
VIRIM 580	Critical Reading in Immunobiology	
<b>Electives</b>		
At least 10 credits of elective courses at the 500 or 800 level selected in consultation with the student's dissertation adviser and Ph.D. committee.		10
<b>Total Credits</b>		<b>29</b>

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.

The first-year Fall curriculum provides the student an understanding of basic cellular processes through a core curriculum that includes two integrated three-credit courses: Advanced Molecular Genetics (BMS 503) and Cell and Systems Biology (BMS 502). These courses develop concepts related to genome structure and function, regulation of gene expression, regulation of energy supply and demand, cellular and subcellular structures, cell-to-cell signaling, and the organization and function of cells in multicellular systems. The Fall curriculum also includes the one-credit Art of Scientific Communication I (BMS 504) course that reinforces concepts developed in the integrated courses and aids students in the transition from textbooks to primary literature as a source of information.

The first-year Spring curriculum offers an opportunity to explore one or more curricular paths that lead to entry into one of the Options or to design an individualized curricular path within the BMS Graduate Program. The Spring curriculum also includes the one-credit Art of Scientific Communication II (BMS 505) course that further develops the student's knowledge acquisition from the primary literature and assists improvement of presentation and writing skills necessary for subsequent journal clubs, literature-based courses, and scientific learning and discourse throughout their career.

In addition, students complete at least three research rotations during the first year that expose them to the wide range of research interests of the Penn State Graduate Faculty from both basic and clinical science departments at the College of Medicine in Hershey. These rotations serve

to inform the students with regard to choosing a dissertation adviser and Ph.D. committee.

The BMS Graduate Program Executive Committee, which includes representation from the Program and each Option of the Program, advises students about academic and related matters until the student has a dissertation adviser. If desired, students formally make a decision to join an Option by the end of the Spring semester of their first year and must satisfy all admission requirements of the Option.

Students must have a dissertation adviser by the end of the summer of the first year. The student and dissertation adviser then plan additional course work and develop a research plan in consultation with the Ph.D. committee.

Curriculum in the second year is determined by the choice to participate in one of the Options, or an individualized curricular path designed by the student in consultation with the dissertation adviser and Ph.D. committee.

All doctoral students must pass a qualifying examination, a comprehensive examination, and a final oral examination (the dissertation defense). At the end of the first year, continuation in the Ph.D. program is determined by performance in course work, laboratory rotations, and the BMS Graduate Program Qualifying Examination. Students join their research laboratory by the end of the summer of the first year.

Ph.D. students prepare a written comprehensive examination in the format of a grant application prior to the end of the fifth semester of enrollment. As part of this examination, the candidate also gives an oral presentation of this proposal to their Ph.D. committee.

To earn the Ph.D. degree, doctoral students must write a dissertation that is accepted by the Ph.D. committee, the chair of the graduate program, and the Graduate School. Students are required to have at least one first-author publication accepted or published based on their dissertation research prior to the final oral examination. A student may petition the Chair of the BMS Graduate Program to waive this requirement due to extenuating circumstances (e.g., adviser relocation, abnormal issues with publication process). All waivers must be approved by the Vice Dean for Research and Graduate Studies of the College of Medicine.

## OPTIONS

The Options offered within the BMS Graduate Program provide the student a curricular specialization focused on different approaches to biomedical research.

### Biochemistry, Genetics, and Genomics (BGG) Option

The objective of the BGG Option is to provide course work and laboratory training that focus on the principles and application of biochemical, genetic, and genomic analysis. These approaches play key roles in identifying and characterizing cellular processes and elucidating the structure and function of key macromolecules including DNA, RNA, proteins, lipids, and carbohydrates. The Option also stresses the biological intersections of these classes of macromolecules. The combination of didactic courses, colloquia, seminars, and laboratory research provides students with an integrated approach for applying biochemical, genetic, and genomic analyses to interrogate and manipulate basic cellular processes and macromolecules of biomedical significance. The training afforded by this Option exposes graduates to the fundamentals needed to experimentally address scientific questions in areas such as epigenetic control of gene expression, structure/

function, biomolecular engineering, and systems analysis using these approaches.

### Admission Requirements

To be admitted to the BGG Option, students must successfully complete:

1. the first year of the BMS Graduate Program, and
2. three research rotations, at least two with faculty in the BGG Option.

### Degree Requirements for the M.S.

In addition to the 13 credits of required BMS Core Courses for the M.S. degree and 6 credits of thesis research, students pursuing the M.S. degree in the BGG Option must take:

Code	Title	Credits
<b>Required Courses</b>		
BMS 512	Data Analysis For The Biomedical Laboratory Scientist, A Practical Approach	2
BCHEM 590	Colloquium	2
At least 6 credits from the following courses:		6
BCHEM 522	Molecular Genetics: Genes to Genomes	
BCHEM 581	Enzymology: Structure, Energetics, and Function-A. Structural Biology	
BCHEM 582	Enzymology: Structure, Energetics, and Function-B. Practical Enzymology	
BCHEM 583	Enzymology: Structure, Energetics, and Function-C. Mechanisms of Enzyme Reactions	
GENET 582	Genetics of Model Organisms: Molecular Genetic Analysis of Signaling Pathways: B	
GENET 587	Genetic Approaches to Biomedical Problems	
MCIBS 551	Genomics	
At least 3 credits of 500-level elective courses selected in consultation with the student's thesis adviser and thesis committee.		3
<b>Total Credits</b>		<b>13</b>

### Degree Requirements for the Ph.D.

In addition to the 17 credits of required BMS Core Courses for the Ph.D. degree, students pursuing the Ph.D. degree in the BGG Option must take:

Code	Title	Credits
<b>Required Courses</b>		
BMS 512	Data Analysis For The Biomedical Laboratory Scientist, A Practical Approach	2
BCHEM 590	Colloquium	2
At least 6 credits from the following courses:		6
BCHEM 522	Molecular Genetics: Genes to Genomes	
BCHEM 581	Enzymology: Structure, Energetics, and Function-A. Structural Biology	
BCHEM 582	Enzymology: Structure, Energetics, and Function-B. Practical Enzymology	
BCHEM 583	Enzymology: Structure, Energetics, and Function-C. Mechanisms of Enzyme Reactions	
GENET 582	Genetics of Model Organisms: Molecular Genetic Analysis of Signaling Pathways: B	
GENET 587	Genetic Approaches to Biomedical Problems	
MCIBS 551	Genomics	

At least 2 credits of 500-level elective courses selected in consultation with the student's dissertation adviser and Ph.D. committee.	2
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**Total Credits** **12**

### Cancer biology (CB) Option

The CB Option provides comprehensive, interdisciplinary training in cancer research, thus preparing students to pursue competitive careers in the field of cancer biology. The Option provides fundamental knowledge in cancer biology, while emphasizing state-of-the-art research approaches. The curriculum provides an appreciation for the dynamic nature of cancer research by exposing students to current paradigms in this quickly changing field of research. The CB Option includes courses that highlight essential knowledge of the basic cellular and molecular mechanisms underlying cancer etiology, cancer progression, and metastasis, together with an understanding of translational research and cancer treatment. The Option also allows flexibility for students to individually tailor their studies by choosing additional CB courses in basic, population, or clinical science aspects of cancer research. This intensive training program will prepare trainees for advanced careers in a variety of areas of cancer research.

### Admission Requirements

To be admitted to the CB Option, students must successfully complete:

1. the first year of the BMS Graduate Program, and
2. three research rotations, at least two with faculty in the CB Option.

### Degree Requirements for the M.S.

In addition to the 13 credits of required BMS Core Courses for the M.S. degree and 6 credits of thesis research, students pursuing the M.S. degree in the CB Option must take:

Code	Title	Credits
<b>Required Courses</b>		
BMS 550	Fundamentals of Cancer Biology	1
BMS 551	Cancer Genetics	1
BMS 552	Tumor Metabolism	1
BMS 553	Cancer Biology Colloquium	2
BMS 554	Cancer Therapy and Immunology	2
At least 3 credits from the following courses:		3
BCHEM 510	Carcinogenesis and Chemoprevention	
BMS 568	Current Topics in Translational Cancer Research	
BMS 571	Graduate Clinical Rotation	
PHS 552	Molecular Epidemiology of Chronic Disease	
3 credits of 500-level elective courses selected in consultation with the student's thesis adviser and thesis committee.		3
<b>Total Credits</b>		<b>13</b>

### Degree Requirements for the Ph.D.

In addition to the 17 credits of required BMS Core Courses for the Ph.D. degree, students pursuing the Ph.D. degree in the CB Option must take:

Code	Title	Credits
<b>Required Courses</b>		
BMS 550	Fundamentals of Cancer Biology	1
BMS 551	Cancer Genetics	1
BMS 552	Tumor Metabolism	1
BMS 553	Cancer Biology Colloquium	2

BMS 554	Cancer Therapy and Immunology	2
At least 3 credits from the following courses:		3
BICHEM 510	Carcinogenesis and Chemoprevention	
BMS 568	Current Topics in Translational Cancer Research	
BMS 571	Graduate Clinical Rotation	
PHS 552	Molecular Epidemiology of Chronic Disease	
2 credits of 500-level elective courses selected in consultation with the student's thesis adviser and thesis committee.		2
<b>Total Credits</b>		<b>12</b>

### Cellular and Integrative Physiology (CIP) Option

The objective of the CIP Option is to provide students training that focuses on cellular and integrative physiology, which includes the functions and interactions between different tissues and cell types and different organ systems. The training afforded by this Option exposes graduates to the fundamentals needed to experimentally address scientific questions in areas such as intracellular organization, and the regulation of key biological processes including cell signaling, ion channel and transport function, gene expression, protein translation and turnover, molecular motors, and intercellular communication. In addition, the Option stresses the importance of systems biology and inter-organ signaling to understand the biological basis of health and disease. The combination of didactic courses, colloquia, seminars, and laboratory research provides students with an integrated approach for applying advanced imaging, biochemical, and molecular analyses to interrogate and manipulate basic cellular processes and macromolecules of biomedical significance.

#### Admission Requirements

To be admitted to the CIP Option, students must successfully complete:

1. the first year of the BMS Graduate Program, and
2. three research rotations, at least two with faculty in the CIP Option.

#### Degree Requirements for the M.S.

In addition to the 13 credits of required BMS Core Courses for the M.S. degree and 6 credits of thesis research, students pursuing the M.S. degree in the CIP Option must take:

Code	Title	Credits
<b>Required Courses</b>		
PSIO 504	Cellular and Integrative Physiology	3
PSIO 505	Cellular and Integrative Physiology II	3
BMS 581	Molecular and Translational Approaches to Human Disease	3
PSIO 501	Scientific Analysis and Presentation	2
At least 2 credits of 500-level elective courses selected in consultation with the student's thesis adviser and thesis committee.		2
<b>Total Credits</b>		<b>13</b>

#### Degree Requirements for the Ph.D.

In addition to the 17 credits of required BMS Core Courses for the Ph.D. degree, students pursuing the Ph.D. degree in the CIP Option must take:

Code	Title	Credits
<b>Required Courses</b>		
PSIO 504	Cellular and Integrative Physiology	3
PSIO 505	Cellular and Integrative Physiology II	3
BMS 581	Molecular and Translational Approaches to Human Disease	3

PSIO 501	Scientific Analysis and Presentation	2
At least 1 credit of a 500-level elective course selected in consultation with the student's dissertation adviser and Ph.D. committee.		1
<b>Total Credits</b>		<b>12</b>

### Translational Therapeutics (TT) Option

The TT Option is designed to give students a combination of didactic instruction, informal interaction, and laboratory experience that enables them to obtain a firm foundation in the principles, methods, and contributions of pharmacology, defined broadly as the science of the interaction of chemical agents with biological systems. Of primary importance, this Option focuses on identification of disease targets, development of therapeutic strategies, and refinement of drug delivery approaches. With this preparation, graduates of the TT Option will be capable of designing and executing high-quality independent research, and of assuming positions of responsibility within the therapeutic community.

This Option offers studies in the general areas of drug discovery and development, molecular pathophysiology, drug metabolism, molecular pharmacology, endocrine pharmacology, neuropharmacology, cardiovascular-renal pharmacology, pharmacogenetics, and clinical pharmacology. Primary emphasis is placed on the molecular mechanism by which drugs act in the body and by which the body transforms drugs.

#### Admission Requirements

To be admitted to the TT Option, students must successfully complete:

1. the first year of the BMS Graduate Program, and
2. three research rotations, at least two with faculty in the TT Option.

#### Degree Requirements for the M.S.

In addition to the 13 credits of required BMS Core Courses for the M.S. degree and 6 credits of thesis research, students pursuing the M.S. degree in the TT Option must take:

Code	Title	Credits
<b>Required Courses</b>		
PHARM 520	Principles of Drug Action	2
PHARM 551	Anti-infective Therapeutics	1
PHARM 552	Integrated System Pharmacology	1
PHARM 553	Gastrointestinal and Immunomodulatory Therapeutics	1
PHARM 554	Anticancer Therapeutics	1
PHARM 561	Neuropharmacology	2
PHARM 562	Endocrine Pharmacology	2
PHARM 590	Colloquium	1
At least 2 credits of 500-level elective courses selected in consultation with the student's thesis advisor and thesis committee.		2
<b>Total Credits</b>		<b>13</b>

#### Degree Requirements for the Ph.D.

In addition to the 17 credits of required BMS Core Courses for the Ph.D. degree, students pursuing the Ph.D. degree in the TT Option must take:

Code	Title	Credits
<b>Required Courses</b>		
PHARM 520	Principles of Drug Action	2
PHARM 551	Anti-infective Therapeutics	1

PHARM 552	Integrated System Pharmacology	1
PHARM 553	Gastrointestinal and Immunomodulatory Therapeutics	1
PHARM 554	Anticancer Therapeutics	1
PHARM 561	Neuropharmacology	2
PHARM 562	Endocrine Pharmacology	2
PHARM 590	Colloquium	1
At least 1 credit of a 500-level elective course selected in consultation with the candidate's dissertation adviser and Ph.D. committee.		1
<b>Total Credits</b>		<b>12</b>

### Virology and Immunology (VIRIM) Option

The objective of the VIRIM Option is to provide graduate students the opportunity to focus their graduate-level coursework and laboratory research in areas related to virology and immunology. The areas of research within virology include viral oncology, virus-cell interactions, the structure and assembly of viruses, functional role of viral gene products, the molecular biology of virus replication, and viral induced latency. The areas of research within immunology include adaptive and innate immunity, cellular and humoral immunity, antigen presentation, tumor immunology, vaccine development, and neuroimmunology. The VIRIM Option allows students to develop an integrative research approach using aspects of biochemistry, molecular and cellular biology, and genetics to approach scientific questions associated with areas of virology and immunology.

#### Admission Requirements

To be admitted to the VIRIM Option, students must successfully complete:

1. the first year of the BMS Graduate Program, and
2. three research rotations, at least two with faculty members in the VIRIM Option.

### Degree Requirements for the M.S.

In addition to the 13 credits of required BMS Core Courses for the M.S. degree and 6 credits of thesis research, students pursuing the M.S. degree in the VIRIM Option must take:

Code	Title	Credits
<b>Required Courses</b>		
MICRO 550	Current Topics in Virology	1
MICRO 581	Immunology A: Basic Concepts in Innate and Adaptive Immunity	1
MICRO 582	Immunology B: Adaptive Immunity	1
BMS 566	Viral Oncogenesis	1
BMS 564	Concepts in Virology	2
BMS 567	Viral Pathogenesis	1
MICRO 560	Concepts in Immunology	2
MICRO 572	Literature Reports	1
MICRO 590	Colloquium	1
At least 2 credits of 500-level elective courses selected in consultation with the student's thesis adviser and thesis committee.		2
<b>Total Credits</b>		<b>13</b>

### Degree Requirements for the Ph.D.

In addition to the 17 credits of required BMS Core Courses for the Ph.D. degree, students pursuing the Ph.D. degree in the VIRIM Option must take:

Code	Title	Credits
<b>Required Courses</b>		
MICRO 550	Current Topics in Virology	1
MICRO 581	Immunology A: Basic Concepts in Innate and Adaptive Immunity	1
MICRO 582	Immunology B: Adaptive Immunity	1
BMS 566	Viral Oncogenesis	1
BMS 564	Concepts in Virology	2
MICRO 560	Concepts in Immunology	2
BMS 567	Viral Pathogenesis	1
MICRO 572	Literature Reports	1
MICRO 590	Colloquium	1
At least 1 credit of a 500-level elective course selected in consultation with the candidate's dissertation adviser and Ph.D. committee.		1
<b>Total Credits</b>		<b>12</b>

## Dual-Titles

### Dual-Title Ph.D. in Biomedical Sciences and Clinical and Translational Sciences

Requirements listed here are in addition to requirements listed in GCAC-208 Dual-Title Graduate Degree Programs (<https://gradschool.psu.edu/graduate-education-policies/gcac/gcac-200/gcac-208-dual-titles/>).

#### Admission Requirements

Potential dual-title students can express an interest in the dual-title program as early as during the recruitment process for the BMS Graduate Program. Students must apply and be admitted to the graduate program in BMS and the Graduate School before they can apply for admission to the dual-title Ph.D. in Clinical and Translational Sciences (CTS). Refer to the Admission Requirements section of the Clinical and Translational Sciences Bulletin page (<http://bulletins.psu.edu/graduate/programs/majors/clinical-translational-sciences/>). Students must apply and be admitted to the dual-title program in CTS prior to taking the qualifying exam.

#### Degree Requirements

To qualify for the dual-title degree in Biomedical Sciences and Clinical and Translational Sciences, students must satisfy the BMS Ph.D. degree requirements listed on the Degree Requirements tab. In addition, students pursuing the dual-title Ph.D. in BMS and CTS must complete the degree requirements for the dual-title CTS Ph.D., listed on the CTS Bulletin page (<http://bulletins.psu.edu/graduate/programs/majors/clinical-translational-sciences/>). Up to 7 credits for the Ph.D. degree in BMS that overlap with the CTS elective requirements can be counted toward the CTS dual-title.

The choice of CTS electives is subject to approval by the student's academic adviser(s) from the BMS and CTS programs. The electives should complement the student's work in BMS. A list of approved electives is maintained by the CTS program office.

The qualifying examination contains elements of both BMS and CTS. In accordance with Graduate Council policy, the qualifying examination

committee must include at least one member of the CTS Graduate Faculty. Faculty with graduate appointments in both programs may serve in a combined role. Dual-title graduate degree students may require an additional semester to fulfill requirements for both areas of study and, therefore, the qualifying examination may be delayed one semester beyond the normal period allowable.

In addition to the general Graduate Council requirements for Ph.D. committees (<http://gradschool.psu.edu/graduate-education-policies/gcac/gcac-600/phd-dissertation-committee-formation/>), the Ph.D. committee must include at least one member of the CTS Graduate Faculty. Faculty members who hold appointments in the Graduate Faculty of both programs may serve in a combined role. If the chair of the Ph.D. committee is not a member of the Graduate Faculty in CTS, the member of the committee representing CTS must be appointed as co-chair. The fields of BMS and CTS will be integrated in the student's comprehensive exam, and the Ph.D. committee member representing CTS is responsible for insuring coverage of information relevant to the CTS field of study.

The candidate must complete a dissertation on a topic that reflects their original research and education in both BMS and CTS. To earn the dual-title Ph.D. degree, the dissertation must be accepted by the Ph.D. committee, the chair of the graduate program, and the Graduate School, and the student must pass a final oral examination (the dissertation defense).

## 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

Prospective students interested in simultaneously pursuing a 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. Applicants must also meet the admission requirements of the Graduate School and the Ph.D. admission requirements listed on the Admission Requirements tab, however, GRE scores are not required. The M.D./Ph.D. Admissions Committee reviews applications and evaluates candidates for acceptance into both the M.D. and Ph.D. programs. 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. Students must be admitted to the joint degree program prior to taking the first course they intend to count towards the graduate degree. Applicants not accepted into the joint-degree program may be referred to either the M.D. or Ph.D. program, depending on their qualifications.

Applicants to this program generally have very strong grades and MCAT scores, as well as a strong and sustained background in research.

Applicants must be able to clearly articulate reasons for pursuing the joint degree. Letters of recommendation from faculty who have advised the applicant in research and who can comment on the applicant's passion and potential for research are strongly encouraged.

#### Degree Requirements

Students must fulfill all requirements for each degree in order to be awarded that degree. Degree requirements for the M.D. program are listed

on the Penn State College of Medicine website (<http://www.med.psu.edu/web/md/home/>). 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 the Ph.D. degree requirements have been satisfied.

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 student enters the BMS Graduate Program and may be admitted to one of its options.

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 as the qualifying examination for the BMS Graduate Program.

In addition to the requirements for the Ph.D. committee (<http://gradschool.psu.edu/graduate-education-policies/gcac/gcac-600/phd-dissertation-committee-formation/>) for a Ph.D. student in the BMS Graduate Program, at least one member of the Ph.D. committee must be on the M.D./Ph.D. Steering Committee. This member may serve other roles on the Ph.D. committee.

M.D./Ph.D. students must complete 28 credits:

Code	Title	Credits
<b>Required Courses</b>		
8 credits from the first two years of medical school will be double-counted towards the Ph.D., replacing the following required core courses:		8
BMS 502	Cell and Systems Biology	
BMS 503	Advanced Molecular Genetics	
BMS 596	Individual Studies	
In addition to the curriculum of the first two years of medical school at the Penn State College of Medicine, all M.D./Ph.D. students in the BMS Graduate Program take the following core courses:		
BMS 506A	Biological Basis of Human Health and Disease A	2
BMS 506B	Biological Basis of Human Health and Disease B	2
BMS 512	Data Analysis For The Biomedical Laboratory Scientist, A Practical Approach	2
BMS 590	Colloquium	4
BMS 591	Biomedical Research Ethics	1
BMS 801	Writing Grant Proposals for Biomedical Research	1
In addition, students must take 2 credits of Colloquium or Journal Club, which is fulfilled by taking any of the following:		2
BCHEM 590	Colloquium	
PSIO 501	Scientific Analysis and Presentation	
PHARM 590	Colloquium	
MICRO 590	Colloquium	
MICRO 572	Literature Reports	
NEURO 590	Colloquium	
VIRIM 580	Critical Reading in Immunobiology	
At least 6 elective credits of 500-level elective courses selected in consultation with the student's dissertation adviser and Ph.D. committee.		6
<b>Total Credits</b>		<b>28</b>

The M.D./Ph.D. candidate 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.

A dissertation must be prepared and defended by each M.D./Ph.D. candidate. The dissertation must be accepted by the Ph.D. committee, the chair of the graduate program, and the Graduate School, and the student must pass a final oral examination (the dissertation defense). Students are required to have at least one first-author publication accepted or published based on their dissertation research prior to the final oral examination.

## 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.

Biological Chemistry (BCHEM) Course List (<https://bulletins.psu.edu/university-course-descriptions/graduate/bchem/>)

Biomedical Sciences (BMS) Course List (<https://bulletins.psu.edu/university-course-descriptions/graduate/bms/>)

Genetics (GENET) Course List (<https://bulletins.psu.edu/university-course-descriptions/graduate/genet/>)

Microbiology (MICRO) Course List (<https://bulletins.psu.edu/university-course-descriptions/graduate/micro/>)

Pharmacology (PHARM) Course List (<https://bulletins.psu.edu/university-course-descriptions/graduate/pharm/>)

Physiology (PSIO) Course List (<https://bulletins.psu.edu/university-course-descriptions/graduate/psio/>)

Virology (VIRIM) Course List (<https://bulletins.psu.edu/university-course-descriptions/graduate/virim/>)

## Learning Outcomes

### Master of Science (M.S.)

1. **Know:** Graduates will demonstrate a) a broad base of the biological knowledge and concepts required to understand the molecular, cellular, and organismal processes related to biomedical sciences; b) a broad understanding of experimental approaches used to investigate biomedical problems; c) specific knowledge within their area of research interest, and d) the highest standards of research ethics.
2. **Apply/Create:** Graduates will participate in the development of experimental approaches to test hypotheses and ideas of current relevance to their research interests.
3. **Apply/Create:** Graduates will perform experiments that address current problems in biomedical sciences leading to rigorous and reproducible outcomes.
4. **Think:** Graduates will begin developing skills to evaluate experimental approaches and results of their research.
5. **Communicate:** Graduates will convey ideas, experimental approaches, and results in clear and concise oral and written formats.
6. **Professional Practice:** Graduates will collaborate in a collegial and ethical manner with other professionals within their field.
7. **Professional Practice:** Graduates will evaluate potential careers to pursue following graduation and choose their specific career interest(s).

### Doctor of Philosophy (Ph.D.)

1. **Know:** Graduates will demonstrate a) a broad base of the biological knowledge and concepts required to understand the molecular, cellular, and organismal processes related to biomedical sciences; b) a broad understanding of experimental approaches used to investigate biomedical problems; c) in-depth knowledge within their specific areas of research interests, and d) the highest standards of research ethics.
2. **Apply/Create:** Graduates will creatively synthesize theory and literature to generate questions, ideas, or hypotheses addressing current problems in human health and disease, and will devise critical experimental approaches to test these ideas and hypotheses.
3. **Apply/Create:** Graduates will perform independent and original research studies that address current problems in biomedical sciences leading to rigorous and reproducible experimental outcomes.
4. **Think:** Graduates will critically evaluate experimental approaches and results of their own research and the research of others.
5. **Communicate:** Graduates will convey ideas, experimental approaches, and results in clear, concise, well-organized papers, posters, proposals, oral presentations, and discussions.

6. **Professional Practice:** Graduates will collaborate in a collegial and ethical manner with other professionals within their field or with diverse scientific backgrounds.
7. **Professional Practice:** Graduates will evaluate potential careers to pursue following graduation and choose their specific career interest(s).

## Contact

<b>Campus</b>	Hershey Med Ctr
<b>Graduate Program Head</b>	Lisa M Shantz
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<b>Program Website</b>	View ( <a href="http://med.psu.edu/biomedical-sciences-phd/">http://med.psu.edu/biomedical-sciences-phd/</a> )

**BMS Program Director:** Lisa Shantz

**Biochemistry, Genetics, and Genomics Option Director:** Thomas Spratt

**Cancer Biology Option Director:** Douglas Stairs

**Cellular and Integrative Physiology Option Director:** Lisa Shantz

**Translational Therapeutics Option Director:** Yuval Silberman

**Virology and Immunology Option Director:** Joseph Wang