

BIOMEDICAL SCIENCES

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 |
|--|--|-----------|
| Required Courses | | |
| 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 | |
| Electives | | |
| 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 |
| Thesis Research | | |
| BMS 600 | Thesis Research ¹ | 6 |
| Total Credits | | 32 |

¹ 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 |
|---|---|-----------|
| Required Courses | | |
| 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 | |
| Electives | | |
| 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 |
| Total Credits | | 29 |

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 |
|---|---|-----------|
| Required Courses | | |
| 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 |
| Total Credits | | 13 |

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 |
|--|---|---------|
| Required Courses | | |
| 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

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 |
|--|---|-----------|
| Required Courses | | |
| 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 | |
| 3 credits of 500-level elective courses selected in consultation with the student's thesis adviser and thesis committee. | | 3 |
| Total Credits | | 13 |

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 |
|-------------------------|--------------------------------|---------|
| Required Courses | | |
| 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

Total Credits 12

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 |
|---|---|-----------|
| Required Courses | | |
| 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 |
| Total Credits | | 13 |

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 |
|-------------------------|---|---------|
| Required Courses | | |
| 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 |
| Total Credits | | 12 |

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 |
|---|--|-----------|
| Required Courses | | |
| 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 |
| Total Credits | | 13 |

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 |
|-------------------------|-----------------------------|---------|
| Required Courses | | |
| 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 |
| Total Credits | | 12 |

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 |
|---|--|-----------|
| Required Courses | | |
| 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 advisor and thesis committee. | | 2 |
| Total Credits | | 13 |

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 |
|--|--|----------------|
| Required Courses | | |
| 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 |
| Total Credits | | 12 |