DEPARTMENT OF BIOCHEMISTRY

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Biochemistry is the study of the molecular basis of cellular and organismal function, making it a central discipline in the biological sciences. Biochemists ask the question, “How do life processes work at the molecular level?” The Department of Biochemistry offers undergraduate programs leading to the BA and BS degrees in biochemistry and graduate programs leading to the MS and PhD degrees. There are also dual-degree programs, leading to the MD/PhD, MD/MS in Biomedical Investigation, JD/MS, MS/MBA, and MS/MA in Patent Practice degrees. The department also participates in several interdisciplinary and interdepartmental programs in the School of Medicine and at Case Western Reserve University that provide additional avenues of study.

Research by Biochemistry faculty members covers a range of topics aimed at understanding life processes at the molecular level. Our efforts are broadened by collaborations with faculty in other university departments and with scientists at other academic and biotech research institutions. Research in the department is aimed at understanding the structures of biological macromolecules, the functions of proteins and enzymes, and the growth and differentiation of cells. There is also a focus on antibiotics and drug development.

Major

The two undergraduate major programs in Biochemistry, BA and BS, are based on the Arts and Sciences General Education Requirements, but differ in amount and intensity of the mathematics and physical sciences required. Either degree is excellent for students planning to undertake graduate work in biochemistry or in related areas of the biomedical sciences. Both the BA and the BS programs permit students to follow many options after graduation. Graduates are well prepared to pursue further studies in the biological sciences, for a career in medicine, for Doctor of Pharmacy programs, for employment in the chemical, pharmaceutical, and biotechnology industries, or as research assistants in research laboratories. The BA has a reduced emphasis on the quantitative aspects of science and makes available a considerable amount of elective time that permits a student to either concentrate on biochemistry even more intensively than the curriculum requires, or pursue other subjects in science or liberal arts. The BS degree is for the student who has a particularly strong interest in the quantitative physical sciences.

In both programs, undergraduate research is required. As many as nine hours of Research in Biochemistry (BIOC 391 Research Project) may be credited toward the requirements for graduation. At least six credits are highly recommended. The capstone in Biochemistry (BIOC 393 Senior Capstone Experience) is a thesis and presentation of a student’s undergraduate research studies.

Bachelor of Arts in Biochemistry

Required Courses:

| Course   | Title                                                | Units |
|----------|------------------------------------------------------|-------|
| BIOC 307 | Introduction to Biochemistry: From Molecules To Medical Science | 4     |
| BIOC 308 | Molecular Biology                                    | 4     |
| BIOC 373 | Biochemistry SAGES Seminar (SAGES Departmental Seminar) | 3     |
| Biochemistry elective: |                                      | 3     |
| BIOC 312 | or BIOC 334 Proteins and Enzymes Structural Biology |       |

Two approved technical electives in biochemistry 6

BIOC 393  Senior Capstone Experience 3

Additional Required Courses:

| Course   | Title                                                | Units |
|----------|------------------------------------------------------|-------|
| BIOL 214 & 214L | Genes, Evolution and Ecology and Genes, Evolution and Ecology Lab | 4 |
| BIOL 215 & 215L | Cells and Proteins and Cells and Proteins Laboratory | 4 |
| CHEM 105 or CHEM 111 | Principles of Chemistry I or Principles of Chemistry for Engineers | 3-4 |
| CHEM 106 or ENGR 145 | Principles of Chemistry II or Chemistry of Materials | 3-4 |
| CHEM 113 | Principles of Chemistry Laboratory                   | 3     |
| CHEM 223 or CHEM 323 | Introductory Organic Chemistry I or Organic Chemistry I | 3 |
| CHEM 224 or CHEM 324 | Introductory Organic Chemistry II or Organic Chemistry II | 3 |
| CHEM 233 | Introductory Organic Chemistry Laboratory I          | 2     |
| CHEM 234 | Introductory Organic Chemistry Laboratory II         | 2     |
| CHEM 301 | Introductory Physical Chemistry I                    | 3     |
| MATH 125 or MATH 121 | Math and Calculus Applications for Life, Managerial, and Social Sci I or Calculus for Science and Engineering I | 4 |
| MATH 126 or MATH 122 or MATH 124 | Math and Calculus Applications for Life, Managerial, and Social Sci II or Calculus for Science and Engineering II or Calculus II | 4 |
| PHYS 115 or PHYS 121 or PHYS 123 | Introductory Physics I or General Physics I - Mechanics or Physics and Frontiers I - Mechanics | 4 |
| PHYS 116 or PHYS 122 or PHYS 124 | Introductory Physics II or General Physics II - Electricity and Magnetism or Physics and Frontiers II - Electricity and Magnetism | 4 |

Total Units 66-68

BA Biochemistry, Sample Plan of Study

Freshman

| Course   | Title                                                | Units |
|----------|------------------------------------------------------|-------|
| MATH 125 | Math and Calculus Applications for Life, Managerial, and Social Sci I | 4 |
| or MATH 121 | Calculus for Science and Engineering I | 4 |

BA Biochemistry, Sample Plan of Study

Freshman

| Course   | Title                                                | Units |
|----------|------------------------------------------------------|-------|
| MATH 125 | Math and Calculus Applications for Life, Managerial, and Social Sci I | 4 |
| or MATH 121 | Calculus for Science and Engineering I | 4 |
**Bachelor of Science in Biochemistry**

**Required Courses:**

| Course   | Units | Fall | Spring |
|----------|-------|------|--------|
| BIOC 307 | 4     |      |        |
| BIOC 308 | 4     |      |        |
| BIOC 312 | 3     |      |        |
| BIOC 334 | 3     |      |        |
| BIOC 373 | 3     |      |        |
| BIOL 214 | 4     |      |        |
| CHEM 105 | 3-4   |      |        |
| CHEM 106 | 3-4   |      |        |
| CHEM 223 | 3     |      |        |

**Year Total:** 16 16

**Senior**

| Course                                                      | Units | Fall | Spring |
|-------------------------------------------------------------|-------|------|--------|
| Biochemistry SAGES Seminar (BIOC 373)                       | 3     |      |        |
| Research Project (BIOC 391)                                 | 3     |      |        |
| Electives                                                   | 6     |      |        |
| Proteins and Enzymes (BIOC 312) (or Approved Technical Electives) | 3     |      |        |
| Senior Capstone Experience (BIOC 393)                       | 3     |      |        |
| Structural Biology (BIOC 334) (or Approved Biochem or Technical Elective) | 3     |      |        |
| Electives                                                   | 6-9   |      |        |
| Year Total:                                                 | 15 12-15 |      |        |

**Total Units in Sequence:** 120-123

Note: At least the 3 credits of undergraduate research, BIOC 391 Research Project, is minimally recommended for the Capstone. An additional 3 credits of BIOC 391 is highly recommended. Students should consult their academic advisers about the elective parts of the curriculum.

a  Selected students may be invited to take CHEM 323 Organic Chemistry I or CHEM 324 Organic Chemistry II

b  Selected students may be invited to take PHYS 123 Physics and Frontiers I - Mechanics and PHYS 124 Physics and Frontiers II - Electricity and Magnetism in place of PHYS 121 General Physics I - Mechanics and PHYS 122 General Physics II - Electricity and Magnetism

c  BA students must take either BIOC 312 Proteins and Enzymes or BIOC 334 Structural Biology. For BA students who take both courses, one course will serve as a technical elective.

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**Sophomore**

| Course                                                      | Units | Fall | Spring |
|-------------------------------------------------------------|-------|------|--------|
| Introductory Organic Chemistry I (CHEM 223)\(^a\) or Organic Chemistry I (CHEM 323) | 3     |      |        |
| Introductory Organic Chemistry Laboratory I (CHEM 223)      | 2     |      |        |
| Introductory Physics I (PHYS 116) or General Physics I - Mechanics (PHYS 121) | 4     |      |        |
| or Physics and Frontiers I - Mechanics (PHYS 123)           |       |      |        |
| GER Course                                                  | 3     |      |        |
| SAGES University Seminar II                                 | 3     |      |        |
| Introductory Organic Chemistry II (CHEM 224)\(^a\) or Organic Chemistry II (CHEM 324) | 3     |      |        |
| Introductory Organic Chemistry Laboratory II (CHEM 224)     | 2     |      |        |
| Introductory Physics II (PHYS 116) or General Physics II - Electricity and Magnetism (PHYS 122) | 4     |      |        |
| or Physics and Frontiers II - Electricity and Magnetism (PHYS 124) |       |      |        |
| GER Course                                                  | 3     |      |        |
| Elective                                                    | 3     |      |        |
| Year Total:                                                 | 15 15 |      |        |

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**Junior**

| Course                                                      | Units | Fall | Spring |
|-------------------------------------------------------------|-------|------|--------|
| Introductory Physical Chemistry I (CHEM 301) or Physical Chemistry I (CHEM 335) | 3     |      |        |
| Introduction to Biochemistry: From Molecules To Medical Science (BIOC 307) | 4     |      |        |
| GER Course                                                  | 3     |      |        |
| Electives                                                   | 6     |      |        |
| Molecular Biology (BIOC 308)                                 | 4     |      |        |
| Approved Technical Elective                                 | 3     |      |        |
| Research Project (BIOC 391)                                 | 3     |      |        |
| Electives or GER Courses                                   | 6     |      |        |
| Units | Fall | Spring |
|-------|------|--------|
| **BS Biochemistry, Sample Plan of Study** | | |

**Freshman**

| Course                                                                 | Units | Fall | Spring |
|-----------------------------------------------------------------------|-------|------|--------|
| Calculus for Science and Engineering I (MATH 121)                     | 4     |      |        |
| Principles of Chemistry I (CHEM 105) or Principles of Chemistry for Engineers (CHEM 111) | 3     |      |        |
| Independent Activity (PHED 100)                                       | 0     |      |        |
| SAGES First Semester                                                  | 4     |      |        |
| Genes, Evolution and Ecology (BIOL 214) & Genes, Evolution and Ecology Lab (BIOL 214L) | 4     |      |        |
| Calculus for Science and Engineering II (MATH 122) or Calculus II (MATH 124) | 4     |      |        |
| Principles of Chemistry II (CHEM 106) or Chemistry of Materials (ENGR 145) | 3     |      |        |
| Principles of Chemistry Laboratory (CHEM 113)                          | 2     |      |        |
| SAGES University Seminar I                                            | 3     |      |        |
| Cells and Proteins (BIOL 215)                                         | 4     |      |        |
& Cells and Proteins Laboratory (BIOL 215L)                            | 4     |      |        |
| Independent Activity (PHED 100)                                       | 0     |      |        |
| **Year Total:**                                                       | 15    | 16   |        |

**Sophomore**

| Course                                                                 | Units | Fall | Spring |
|-----------------------------------------------------------------------|-------|------|--------|
| Introductory Organic Chemistry I (CHEM 223) or Organic Chemistry I (CHEM 323) | 3     |      |        |
| Introductory Organic Chemistry Laboratory I (CHEM 223)                | 2     |      |        |
| Calculus for Science and Engineering III (MATH 223) or Calculus III (MATH 227) | 3     |      |        |
| General Physics I - Mechanics (PHYS 121) or Physics and Frontiers I - Mechanics (PHYS 123) | 4     |      |        |
| SAGES University Seminar II                                           | 3     |      |        |
| Introductory Organic Chemistry II (CHEM 224) or Organic Chemistry II (CHEM 324) | 3     |      |        |
| Introductory Organic Chemistry Laboratory II (CHEM 234)               | 2     |      |        |
| Elementary Differential Equations (MATH 224) or Differential Equations (MATH 228) | 3     |      |        |
| General Physics II - Electricity and Magnetism (PHYS 122) or Physics and Frontiers II - Electricity and Magnetism (PHYS 124) | 4     |      |        |
| GER Course                                                            | 3     |      |        |
| **Year Total:**                                                       | 15    | 15   |        |

**Junior**

| Course                                                                 | Units | Fall | Spring |
|-----------------------------------------------------------------------|-------|------|--------|
| Introductory Physical Chemistry I (CHEM 301) or Physical Chemistry I (CHEM 335) | 3     |      |        |
| Introduction to Biochemistry: From Molecules To Medical Science (BIOC 307) | 4     |      |        |
| GER Course                                                            | 3     |      |        |
| GER Course or elective                                               | 3     |      |        |
| Basic Statistics for Engineering and Science Using R Programming (STAT 312R) or Statistics for Experimenters (STAT 313) | 3     |      |        |
| Introductory Physical Chemistry II (CHEM 302) or Physical Chemistry II (CHEM 336) | 3     |      |        |
| Molecular Biology (BIOC 308)                                          | 4     |      |        |
| Introduction to Modern Physics (PHYS 221)                             | 3     |      |        |
| Research Project (BIOC 391)                                           | 3     |      |        |
| GER Course or Elective                                               | 3     |      |        |
| **Year Total:**                                                       | 16    | 16   |        |

**Senior**

| Course                                                                 | Units | Fall | Spring |
|-----------------------------------------------------------------------|-------|------|--------|
| Proteins and Enzymes (BIOC 312)                                       | 3     |      |        |
| Biochemistry SAGES Seminar (BIOC 373)                                 | 3     |      |        |
| Research Project (BIOC 391)                                           | 3     |      |        |
| Electives                                                             | 6     |      |        |
| Structural Biology (BIOC 334)                                         | 3     |      |        |
| Senior Capstone Experience (BIOC 393)                                 | 3     |      |        |
| Electives                                                             | 9     |      |        |
| **Year Total:**                                                       | 15    | 15   |        |
Note: At least the 3 credits of undergraduate research, BIOC 391 Research Project, is a prerequisite to the Capstone. An additional 3 credits of BIOC 391 is highly recommended. Students should consult their academic advisers about the elective parts of the curriculum.

a. Selected students may be invited to take CHEM 323 Organic Chemistry I or CHEM 324 Organic Chemistry II
b. Selected students may be invited to take PHYS 123 Physics and Frontiers I - Mechanics and PHYS 124 Physics and Frontiers II - Electricity and Magnetism in place of PHYS 121 General Physics I - Mechanics and PHYS 122 General Physics II - Electricity and Magnetism.

Honors Program
Biochemistry majors who have excellent academic records may be admitted to the department’s Undergraduate Honors Program. To graduate with departmental honors in biochemistry, a student must satisfy the following requirements:

1. A combined grade point average of at least 3.600
2. A minimum of 6 credit hours of undergraduate research (BIOC 391) in one laboratory
3. A BIOC 393 capstone report approved by the Undergraduate Education Committee of the department on the basis of the quality of the research, the written report, and an oral presentation. An acceptable report:
   a. Should follow a standard journal format
   b. Should demonstrate the student’s understanding of the research area, experimental techniques, goals and implications of the project
   c. Should show that the student has advanced his/her knowledge of the applicable techniques and the underlying scientific concepts.
4. Using all or part of the capstone report, the student must be a co-author on a manuscript either submitted, in press or published in a peer reviewed journal.

Masters Degrees
The Biochemistry Department offers a two-year Masters of Science in Biochemistry provides students with advanced study in biochemistry and related fields. This degree may be combined with other degrees in four dual-degree programs: MD/MS, JD/MS, MS/MBA, and MS/MA in Patent Practice.

Prerequisites for admission into any of the Biochemistry MS Programs are one year each of chemistry, organic chemistry, calculus, and physics. Applicants must also have a BA, BS or equivalent undergraduate degree. As part of the application process, students are required to take the Graduate Record Examination. Students with excellent qualifications who lack some of the prerequisites may be conditionally admitted and allowed to make up the deficiencies. Students with advanced training (coursework, laboratory research, MS degree, etc.) may be given advanced standing. Please visit the department’s web page (http://www.cwru.edu/med/biochemistry) for details about the application process.

MS in Biochemistry
The program leading to the MS degree in biochemistry prepares students for employment in academia and biotechnology and for advancement to other degree programs. Classroom work provides the latest advancements in biochemistry and related fields. In addition, laboratory courses allow students to acquire technical laboratory skills in biotechnology and a solid understanding of the practice of research in this area. Students typically enroll in three courses for each of four semesters.

The duration of the program is 21 months; it follows the Plan B for the Master’s degree. The advisor for this program is usually the Graduate Advisor, but another advisor may be selected. The student’s progress is monitored by the Graduate Advisor and by the Graduate Education Committee. The program requires 36 hours of academic credit of which 18 hours must be graded coursework. Although the program focuses on coursework, students often take 6-12 hours of BIOC 601 Biochemical Research working in the laboratory of a faculty mentor. All courses must be at the 400 level or higher; they must be on the list of approved electives or be approved by the advisor.

MS in Biochemistry Plan of Study

| First Year | Units |
|------------|-------|
| **Fall** | **Spring** |
| Introduction to Biochemistry: From Molecules To Medical Science (BIOC 407) | 4 |
| BIOC electives | 5 |
| Molecular Biology (BIOC 408) | 4 |
| BIOC electives | 5 |
| Year Total: | 9 |
|  | 9 |

| Second Year | Units |
|-------------|-------|
| **Fall** | **Spring** |
| Proteins and Enzymes (BIOC 412) | 3 |
| BIOC electives | 6 |
| Structural Biology (BIOC 434) | 3 |
| BIOC electives | 5 |
| Master’s Comprehensive Exam (EXAM 600) | 1 |
| Year Total: | 9 |
|  | 9 |
**MD/MS Biomedical Investigation-Biochemistry Track**

The joint MD/MS program combine type B MS programs (http://bulletin.case.edu/schoolofgraduatestudies/academicrequirements) at the School of Medicine with the MD, using a common template. The core activities for this degree include limited credit from the medical core curriculum, 3-6 graduate courses in specific tracks, participation in a common seminar series, scientific integrity training, and a requirement for a special problems project that reflects a full year of research (18 hours of BIOC 601 Biochemical Research) culminating in a written report and examination. Both degrees can be completed within 5 years. Students who wish to join the MD/MS program may apply to the program after arriving at the University any time prior to fall of their second year of medical school. For more information, please see MD Dual Degrees.

The Biochemistry track is designed to provide students with knowledge of the latest advances in biochemistry and related fields. Courses offered by other departments may be included with the approval of the Graduate Advisor. Depending on the research project, students may substitute one of the courses below in lieu of one of the biochemistry electives with permission from the Graduate Advisor.

**Students in the Biochemistry track must complete:**

| Course Code | Course Name                                      | Units |
|-------------|-------------------------------------------------|-------|
| IBIS 401    | Integrated Biological Sciences I                | 3     |
| IBIS 402    | Integrated Biological Sciences II               | 3     |
| BIOC 412    | Proteins and Enzymes                           | 3     |
| or BIOC 434 | Structural Biology                             |       |
| Electives in Biochemistry (graded) |                                                  | 6     |
| BIOC 601    | Biochemical Research                           | 18    |
| IBMS 500    | On Being a Professional Scientist:             | 1     |
|             | The Responsible Conduct of Research            |       |
| IBIS 600    | Exam in Biomedical Investigation               | 0     |

Note: Students may finish in 18 months if they devote a summer to research (6 credits of BIOC 601 Biochemical Research).

**JD/MS in Biochemistry**

This program allows students in the School of Law to earn an MS degree in Biochemistry with an additional year of study. This program is useful for students planning careers in patent law or in areas related to biotechnology or pharmaceutical research.

Students in the School of Law can apply to the Biochemistry program for admission to the JD/MS program. In the dual degree program, students complete 12 fewer hours of law school coursework than they would if they were in the JD program alone. The Department of Biochemistry accepts 9 hours of law school classwork in courses dealing with science issues, in place of 9 credits of other elective work. Thus, the student will take a total of 27 hours of Biochemistry coursework of which at least 12 hours must be letter graded.

Dual degree students are advised about matters related to the JD degree by the Associate Dean for Academic Affairs at the School of Law. In addition, dual degree students are granted priority registration for upper-level courses, ensuring that they will be able to adjust their schedules to take all the required classes. Dual degree students are advised concerning matters related to the MS in Biochemistry by the program’s Graduate Advisor.

**JD/MS in Biochemistry Plan of Study (plan B)** (http://bulletin.case.edu/schoolofgraduatestudies/academicrequirements)

Because most students will apply for the JD/MS in Biochemistry Program after beginning Law School, the sample schedule below begins with Biochemistry coursework in the third year. However, Biochemistry coursework in the second year may be taken if the student has completed all the required law coursework.

| Year | Fall | Spring |
|------|------|--------|
| 1    |      |        |
| 2    |      |        |
| 3    | 4    | 3      |
| 4    | 3    | 1      |
| 5    | 1    | 0      |

**Total Units in Sequence:** 36
PhD Biochemistry

The PhD in Biochemistry program prepares students for careers in biochemistry. The emphasis of the doctoral program is on research, culminating in the completion of an original independent research project under the guidance of a faculty member in the biochemistry program. In addition to the research activities, graduate students participate in formal courses both within and outside the department, formal and informal seminars, discussions of current literature, and career development activities. Although students choose from the various tracks within the department, all are broadly trained in modern aspects of biochemistry and become familiar with techniques and literature in a variety of areas. Many collaborative projects with other departments also are available to broaden the spectrum of training offered. Most students begin with an integrated curriculum in cellular and molecular biology in addition to specialized courses in biochemistry. Students are admitted to the Biochemistry PhD program through the Biomedical Sciences Training Program (BSTP) (http://casemed.case.edu/bstp) or via the Medical Scientist Training Program (MSTP) (https://case.edu/medicine/admissions-programs/md-phd-program). The BSTP offers a common entry point to most of our biomedical PhD programs. The MSTP is available for students desiring the dual MD/PhD degrees and research careers in medicine and related biosciences.

Prerequisites for admission into the Biochemistry PhD Program include one year each of chemistry, organic chemistry, calculus, biology and physics. Applicants must also have a BA, BS or equivalent undergraduate degree. Students must submit scores from the Graduate Record Examination and may submit scores from an advanced area test, usually in biology, biochemistry or chemistry. Some students with otherwise excellent qualifications, but lacking some of the prerequisites may be conditionally admitted allowed to make up the deficiencies. Please visit the Department’s web page (http://www.cwru.edu/med/biochemistry) for details about the application process.

To earn a PhD in Biochemistry, a student must complete rotations in at least three laboratories, followed by selection of a research advisor, and complete core and elective coursework, including Responsible Conduct of Research, as described in the Course of Study below. Students who have completed relevant coursework elsewhere, (for example, with an MS) may petition to complete alternative courses.

In addition, each PhD student must complete a qualifying examination on their research topic in the form of a short grant proposal with oral defense for advancement to candidacy. The qualifying examination is usually completed during the second year. During the dissertation period, students are expected to meet yearly with their thesis committees, present seminars in the department, and fulfill journal publication requirements. Throughout the doctoral training, students are expected to be enthusiastic participants in seminars, journal clubs, and research meetings in the lab and program. Completion of the PhD degree requires 36 hours of coursework (24 hours of which are graded) and 18 hours of BIOC 701 Dissertation Ph.D.

PhD Biochemistry Plan of Study

| First Year | Units |
|------------|-------|
|           |       |
| Fall       |       |
| Cell Biology I (BIOC 453) | 3 |
| Molecular Biology I (BIOC 455) | 3 |
| Biochemical Research (BIOC 601) | 2 |
| or Research Rotation in Biomedical Sciences Training Program (BSTP 400) | |
| or Research Rotation in Medical Scientist Training Program (MSTP 400) | |
| Since You Were Born: Nobel Prize Biomedical Research in the Last 21 Years- Section A (BIOC 456A) | 1 |
| or Since You Were Born: Nobel Prize Biomedical Research in the Last 21 Years- Section B (BIOC 456B) | |
| or Since You Were Born: Nobel Prize Biomedical Research in the Last 21 Years- Section C (BIOC 456C) | |
| or Since You Were Born: Nobel Prize Biomedical Research in the Last 21 Years- Section D (BICO 456D) | |
| Structural Biology (BIOC 434) | 3 |
| BIOC Elective | 3 |
| Biochemical Research (BIOC 601) | 2 |
| On Being a Professional Scientist: The Responsible Conduct of Research (IBMS 500) | 1 |
| Year Total: | 9 |
|   | 9 |

| Second Year | Units |
|-------------|-------|
|           |       |
| Fall       |       |
| Biochemistry Seminar I (BIOC 611) | 1 |
| BIOC Elective | 3 |
| Biochemical Research (BIOC 601) (601 for pre-candidacy, 701 for post-candidacy) | 5 |
| or Dissertation Ph.D. (BIOC 701) | |
| Biochemistry Seminar II (BIOC 612) | 1 |
| BIOC Elective | 3 |
| Dissertation Ph.D. (BIOC 701) | 3 |
| Proposition I (BIOC 641) | 2 |
| Year Total: | 9 |
|   | 9 |

| Third Year | Units |
|------------|-------|
|           |       |
| Fall       |       |
| Dissertation Ph.D. (BIOC 701) | 4 |
| BIOC Elective | 3 |
| Dissertation Ph.D. (BIOC 701) | 3 |
| Year Total: | 4 |
|   | 6 |

| Fourth Year | Units |
|-------------|-------|
|           |       |
| Fall       |       |
| Dissertation Ph.D. (BIOC 701) | 2 |
| Dissertation Ph.D. (BIOC 701) | 2 |
| Year Total: | 2 |
|   | 2 |

| Fifth Year | Units |
|------------|-------|
|           |       |
| Fall       |       |
| Dissertation Ph.D. (BIOC 701) | 2 |
| Dissertation Ph.D. (BIOC 701) | 2 |
| Year Total: | 4 |
|   | 4 |

§ Please also see Graduate Studies Academic Requirements for Doctoral Degrees (http://bulletin.case.edu/schoolofgraduatestudies/academicrequirements)
Year Total: 2 2

Total Units in Sequence: 54

Courses

BIOC 307. Introduction to Biochemistry: From Molecules To Medical Science. 4 Units.
Overview of the macromolecules and small molecules key to all living systems. Topics include: protein structure and function; enzyme mechanisms, kinetics and regulation; membrane structure and function; bioenergetics; hormone action; intermediary metabolism, including pathways and regulation of carbohydrate, lipid, amino acid, and nucleotide biosynthesis and breakdown. The material is presented to build links to human biology and human disease. One semester of biology is recommended. Offered as BIOC 307, BIOC 407, and BIOL 407. Prereq: CHEM 223 and CHEM 224.

BIOC 308. Molecular Biology. 4 Units.
An examination of the flow of genetic information from DNA to RNA to protein. Topics include: nucleic acid structure; mechanisms and control of DNA, RNA, and protein biosynthesis; recombinant DNA; and mRNA processing and modification. Where possible, eukaryotic and prokaryotic systems are compared. Special topics include yeast as a model organism, molecular biology of cancer, and molecular biology of the cell cycle. Current literature is discussed briefly as an introduction to techniques of genetic engineering. Recommended preparation: BIOC 307. Offered as BIOC 308, BIOL 308, BIOC 408, and BIOL 408. Prereq: CHEM 223, BIOL 214, and BIOL 215.

BIOC 312. Proteins and Enzymes. 3 Units.
Aspects of protein and nucleic acid function and interactions are discussed, including binding properties, protein-nucleic acid interactions, kinetics and mechanism of proteins and enzymes, and macromolecular machines. Recommended Preparation: CHEM 301. Offered as BIOC 312 and BIOC 412. Prereq: BIOC 307.

BIOC 315. Nuclear Receptors in Health and Disease. 3 Units.
This course focuses on hormone-gene interactions mediated by the ligand-inducible transcription factors termed nuclear hormone receptors. The class will address the mechanisms of action, regulatory features, and biological activities of several nuclear receptors. The usage of nuclear receptors as therapeutic targets in disease states such as cancer, inflammation, and diabetes will also be discussed. The course aims to teach students to critically evaluate primary literature relevant to nuclear hormone receptors biology, and to reinforce presentation/discussion skills. Grades for undergraduates will be based on midterm, final exam; grades for graduates will be based on midterm, final exam, and presentation of a recently published research article related to the role of nuclear receptors in health and disease. Offered as PHRM 315, BIOC 315, PHRM 415 and BIOC 415.

BIOC 334. Structural Biology. 3 Units.
Introduces basic chemical properties of proteins and discusses the physical forces that determine protein structure. Topics include: the elucidation of protein structure by NMR and by X-ray crystallographic methods; the acquisition of protein structures from data bases; and simple modeling experiments based on protein structures. Offered as BIOC 334, BIOL 334, BIOC 434, and BIOL 434. Prereq: BIOC 307.

BIOC 354. Biochemistry and Biology of RNA. 3 Units.
Systematic overview of RNA biochemistry and biology. Course provides solid foundation for understanding processes of post-transcriptional regulation of gene expression. Topics include: RNA structure, RNA types, RNA-protein interactions, eukaryotic RNA metabolism including mRNA processing, ribosome biogenesis, tRNA metabolism, miRNA processing and function, bacterial RNA metabolism, transcriptomics. BIOC 454 requires an additional research proposal. Recommended preparation for BIOC 354: Undergraduate Biology (1 semester minimum), equivalents of CHEM 301, BIOC 307 or BIOC 308, CHEM 223, CHEM 224. Offered as BIOC 354 and BIOC 454. Prereq: CHEM 223, CHEM 224.

BIOC 373. Biochemistry SAGES Seminar. 3 Units.
Discussion of current topics in biochemical research using readings from the scientific literature. The goals are for the student: 1) to discuss and critically analyze selections from the biochemical literature; 2) to gain a broader understanding of important topics not formally covered in the didactic courses; and 3) to learn to write in the style of journals in the field of biochemistry. Counts as SAGES Departmental Seminar. Prereq: BIOC 307 and BIOC 308. Restricted to majors in Biochemistry.

BIOC 391. Research Project. 1 - 9 Units.
(Credit as arranged.) Offered on a pass/fail basis only. Maximum 9 hours total credit.

BIOC 393. Senior Capstone Experience. 3 Units.
Students will complete their Capstone Projects, begun in BIOC 391. Pertinent research activities will depend on the nature of the student's project. The student will meet regularly with their Capstone adviser, at least twice monthly, to provide progress reports, discuss the project, and for critique and guidance. By the end of this course, the student will have completed their SAGES Senior Capstone research project, written a project report in the form of a manuscript, and presented their project reports orally in the department and at the Senior Capstone Fair, or its equivalent. Counts as SAGES Senior Capstone. Prereq: BIOC 307 and BIOC 308.

BIOC 405. Principles of Biochemistry: An Introduction to the Molecules of Life. 3 Units.
This summer course provides an introduction to the macromolecules and small molecules that are the foundation of living systems. The focus is on mammalian biochemistry, with links to human biology and human disease. Topics include: protein structure and function; enzyme mechanisms, kinetics and regulation; membranes; hormone action; bioenergetics; intermediary metabolism, including pathways and regulation of carbohydrate, lipid, amino acid, and nucleotide biosynthesis and breakdown. One semester of biology is recommended. Suitable for students interested in careers in the health professions. This course is not open to undergraduate Biochemistry majors or Biochemistry graduate students. Prereq: CHEM 223 and CHEM 224.

BIOC 407. Introduction to Biochemistry: From Molecules To Medical Science. 4 Units.
Overview of the macromolecules and small molecules key to all living systems. Topics include: protein structure and function; enzyme mechanisms, kinetics and regulation; membrane structure and function; bioenergetics; hormone action; intermediary metabolism, including pathways and regulation of carbohydrate, lipid, amino acid, and nucleotide biosynthesis and breakdown. The material is presented to build links to human biology and human disease. One semester of biology is recommended. Offered as BIOC 307, BIOC 407, and BIOL 407. Prereq: CHEM 223 and CHEM 224.
BIOC 408. Molecular Biology. 4 Units.
An examination of the flow of genetic information from DNA to RNA to protein. Topics include: nucleic acid structure; mechanisms and control of DNA, RNA, and protein biosynthesis; recombinant DNA; and mRNA processing and modification. Where possible, eukaryotic and prokaryotic systems are compared. Special topics include yeast as a model organism, molecular biology of cancer, and molecular biology of the cell cycle. Current literature is discussed briefly as an introduction to techniques of genetic engineering. Recommended preparation: BIOC 307. Offered as BIOC 308, BIOL 308, BIOC 408, and BIOL 412.

BIOC 412. Proteins and Enzymes. 3 Units.
Aspects of protein and nucleic acid function and interactions are discussed, including binding properties, protein-nucleic acid interactions, kinetics and mechanism of proteins and enzymes, and macromolecular machines. Recommended Preparation: CHEM 301. Offered as BIOC 312 and BIOC 412.

BIOC 415. Nuclear Receptors in Health and Disease. 3 Units.
This course focuses on hormone-gene interactions mediated by the ligand-inducible transcription factors termed nuclear hormone receptors. The class will address the mechanisms of action, regulatory features, and biological activities of several nuclear receptors. The usage of nuclear receptors as therapeutic targets in disease states such as cancer, inflammation, and diabetes will also be discussed. The course aims to teach students to critically evaluate primary literature relevant to nuclear hormone receptors biology, and to reinforce presentation/discussion skills. Grades for undergraduates will be based on midterm, final exam; grades for graduates will be based on midterm, final exam, and presentation of a recently published research article related to the role of nuclear receptors in health and disease. Offered as PHRM 315, BIOC 315, PHRM 415 and BIOC 415.

BIOC 420. Current Topics in Cancer. 3 Units.
The concept of cancer hallmarks has provided a useful guiding principle in our understanding of the complexity of cancer. The hallmarks include sustaining proliferative signaling, evading growth suppressors, enabling replicative immortality, activating invasion and metastasis, inducing angiogenesis, resisting cell death, deregulating cellular energetics, avoiding immune destruction, tumor-promoting inflammation, and genome instability and mutation. The objectives of this course are to (1) examine the principles of some of these hallmarks, and (2) explore potential therapies developed based on these hallmarks of cancer. This is a student-driven and discussion-based graduate course. Students should have had some background on the related subjects and have read scientific papers in their prior coursework. Students will be called on to present and discuss experimental design, data and conclusions from assigned publications. There will be no exams or comprehensive papers but students will submit a one-page critique (strengths and weaknesses) of one of the assigned papers prior to each class meeting. The course will end with a full-day student-run symposium on topics to be decided jointly by students and the course director. Grades will be based on class participation, written critiques, and symposium presentations. Offered as BIOC 420, MBIO 420, PATH 422, and PHRM 420. Prereq: CBIO 453 and CBIO 455.

BIOC 432. Current Topics in Vision Research. 3 Units.
Vision research is an exciting and multidisciplinary area that draws on the disciplines of biochemistry, genetics, molecular biology, structural biology, neuroscience, and pathology. This graduate level course will provide the student with broad exposure to the most recent and relevant research currently being conducted in the field. Topics will cover a variety of diseases and fundamental biological processes occurring in the eye. Regions of the eye that will be discussed include the cornea, lens, and retina. Vision disorders discussed include age-related macular degeneration, retinal ciliopathies, and diabetic retinopathy. Instructors in the course are experts in their field and are members of the multidisciplinary visual sciences research community here at Case Western Reserve University. Students will be exposed to the experimental approaches and instrumentation currently being used in the laboratory and in clinical settings. Topics will be covered by traditional lectures, demonstrations in the laboratory and the clinic, and journal club presentations. Students will be graded on their performance in journal club presentations (40%), research proposal (40%), and class participation (20%). Offered as NEUR 432, PATH 432, PHRM 432 and BIOC 432.

BIOC 434. Structural Biology. 3 Units.
Introduces basic chemical properties of proteins and discusses the physical forces that determine protein structure. Topics include: the elucidation of protein structure by NMR and by X-ray crystallographic methods; the acquisition of protein structures from data bases; and simple modeling experiments based on protein structures. Offered as BIOC 334, BIOL 334, BIOC 434, and BIOL 434.

BIOC 452. Nutritional Biochemistry and Metabolism. 3 Units.
Mechanisms of regulation of pathways of intermediary metabolism; amplification of biochemical signals; substrate cycling and use of radioactive and stable isotopes to measure metabolic rates. Recommended preparation: BIOC 307 or equivalent. Offered as BIOC 452 and NTRN 452.

BIOC 454. Biochemistry and Biology of RNA. 3 Units.
Systematic overview of RNA biochemistry and biology. Course provides solid foundation for understanding processes of post-transcriptional regulation of gene expression. Topics include: RNA structure, RNA types, RNA-protein interactions, eukaryotic RNA metabolism including mRNA processing, ribosome biogenesis, tRNA metabolism, miRNA processing and function, bacterial RNA metabolism, transcriptomics. BIOC 454 requires an additional research proposal. Recommended preparation for BIOC 354: Undergraduate Biology (1 semester minimum), equivalents of CHEM 301, BIOC 307 or BIOC 308, CHEM 223, CHEM 224. Offered as BIOC 354 and BIOC 454.
BIOC 460. Introduction to Microarrays. 3 Units.
Microarray technology is an exciting new technique that is used to analyze gene expression in a wide variety of organisms. The goal of this course is to give participants a hands-on introduction to this technology. The course is intended for individuals who are preparing to use this technique, including students, fellows, and other investigators. This is a hands-on computer-based course, which will enable participants to conduct meaningful analyses of microarray data. Participants will gain an understanding of the principles underlying microarray technologies, including: theory of sample preparation, sample processing on microarrays, familiarity with the use of Affymetrix Microarray Suite software and generation of data sets. Transferring data among software packages to manipulate data will also be discussed. Importation of data into other software (GeneSpring and DecisionSite) will enable participants to mine the data for higher-order patterns. Participants will learn about the rationale behind the choice of normalization and data filtering strategies, distance metrics, use of appropriate clustering choices such as K-means, Hierarchical, and Self Organizing Maps. Offered as BIOC 460, PATH 460 and CNCR 460. Prereq: CBIO 455.

BIOC 475. Protein Biophysics. 3 Units.
This course focuses on in-depth understanding of the molecular biophysics of proteins. Structural, thermodynamic and kinetic aspects of protein function and structure-function relationships will be considered at the advanced conceptual level. The application of these theoretical frameworks will be illustrated with examples from the literature and integration of biophysical knowledge with description at the cellular and systems level. The format consists of lectures, problem sets, and student presentations. A special emphasis will be placed on discussion of original publications. Offered as BIOC 475, CHEM 475, PHOL 475, PHRM 475, and NEUR 475.

BIOC 500. Biotechnology Laboratory: Molecular Biology Basics. 1 Unit.
This course provides basic hands-on laboratory experience in molecular biology with a focus on handling and manipulating DNA in bacterial systems. Specific topics include: General laboratory safety, buffers, media, and other reagent preparation, sterile technique, transformation and culture of bacterial cells, DNA molecular biology techniques including DNA isolation and purification, polymerase chain reaction (PCR), restriction digests, ligation, agarose gel electrophoresis, and sequence analysis. Prereq: Biochemistry Graduate student or Requisites Not Met permission.

BIOC 501. Biochemical and Cellular Techniques for Biotechnology. 3 Units.
This lecture course covers the basics of common, essential laboratory and analytical techniques used in biomedical research and the biotechnology industry. The course will cover recombinant protein production and characterization, mammalian cell culture, molecular and cell biology, and mass spectrometry. Specific topics include: general laboratory safety, record keeping, preparation of research reports, manipulation of bacteria, protein overexpression and purification, enzyme assays, high-throughput techniques, high performance liquid chromatography (HPLC) and mass spectrometry, mammalian cell culture, Western blotting, protein-protein interactions, reverse transcription-quantitative polymerase chain reaction (RT-qPCR), immunofluorescence microscopy and assays for gene expression. This course is suitable for Biochemistry MS students interested in pursuing careers in academia or biotechnology. It is also recommended for undergraduate students to enhance their technical skills and position them for productive research experiences. Graduate students in other programs within or outside the School of Medicine are permitted to enroll. Prereq: BIOC 460 and CHEM 113 or Graduate standing. Coreq: CHEM 233 or Graduate standing.

BIOC 502. Biotechnology Laboratory: Biochemical and Cellular Techniques for Biotechnology. 5 Units.
This course provides hands-on, project-based laboratory experience in techniques used in biomedical research and the biotechnology industry. Students will perform laboratory projects in expression and characterization of recombinant proteins, mammalian cell culture, molecular and cell biology, and mass spectrometry. Specific topics include: general laboratory safety, good laboratory practices (GLP), standard operating procedures (SOPs), buffers, media, and other reagent preparation, sterile technique, manipulation of bacterial and mammalian cells, mammalian cell culture, work with DNA and RNA, polymerase chain reaction (PCR) techniques including reverse transcription-quantitative PCR (RT-qPCR) and molecular cloning, protein overexpression and purification, assays (enzyme, stability, and reporter), high-throughput techniques, transient transfection reporter assays, immunoprecipitation, immunofluorescence, DNA and protein gel electrophoresis, high performance liquid chromatography (HPLC), and mass spectrometry. Suitable for Biochemistry MS students interested in academia, biotechnology, or industry. All other graduate students and/ or undergraduate students must contact the instructor for permission to enroll. Prereq: BIOC 401 and BIOC 501 or Requisites Not Met permission.

BIOC 511. Practice and Professionalism in Biotechnology. 1 Unit.
This course provides an overview of a variety of topics that are relevant to biotechnology research and development in academic and industrial settings. It also provides an opportunity for students to develop professional written and oral communication skills. Specific topics include: Professional communications by email, letters, reports, and oral presentations; data documentation, security, and confidentiality; laboratory safety, certification, and regulation; intellectual property protection and patents; the drug discovery pipeline and approval process; financial aspects of research and development. Prereq: Graduate Student in Biochemistry.

BIOC 519. Molecular Biology of RNA. 3 Units.
Selected topics regarding editing, enzymatic function, splicing, and structure of RNA. Offered as BIOC 519, CLBY 519, and MBIO 519.
BIOC 528. Contemporary Approaches to Drug Discovery. 3 Units.
This course is designed to teach the students how lead compounds are discovered, optimized, and processed through clinical trials for FDA approval. Topics will include: medicinal chemistry, parallel synthesis, drug delivery and devices, drug administration and pharmacokinetics, and clinical trials. A special emphasis will be placed on describing how structural biology is used for in silico screening and lead optimization. This component will include hands-on experience in using sophisticated drug discovery software to conduct in silico screening and the development of drug libraries. Each student will conduct a course project involving in silico screening and lead optimization against known drug targets, followed by the drafting of an inventory disclosure. Another important aspect of this course will be inclusion of guest lectures by industrial leaders who describe examples of success stories of drug development. Offered as BIOC 528, PHOL 528, PHRM 528, and SYBB 528.

BIOC 601. Biochemical Research. 1 - 18 Units.
Credit as arranged.

BIOC 611. Biochemistry Seminar I. 1 Unit.
Student presentations of topics from the current scientific literature unrelated to the student’s research project. Participants are required to present a seminar.

BIOC 612. Biochemistry Seminar II. 1 Unit.
Discussion of current research.

BIOC 641. Proposition I. 2 Units.
Design of research proposal.

BIOC 651. Thesis M.S.. 1 - 6 Units.
(Credit as arranged.)

BIOC 701. Dissertation Ph.D.. 1 - 9 Units.
(Credit as arranged.) Prereq: Predoctoral research consent or advanced to Ph.D. candidacy milestone.