Department of Biological Sciences

Aaron P. Mitchell, Department Head
Brigid Campana, Assistant Department Head for Undergraduate Affairs
Undergraduate Office: Doherty Hall 1321
http://www.cmu.edu/bio

A major revolution is occurring in the field of biological sciences. Biology is undergoing unprecedented technological advances in biochemistry, biophysics, cell biology, genetics, molecular biology, developmental biology, neuroscience and computational biology. Carnegie Mellon’s Department of Biological Sciences is nationally recognized as one of the outstanding departments in these areas. Advances in basic research are already being used to solve problems, not only in medicine and public health, but also in areas such as agriculture, forestry, mining, energy, and in industrial and pharmaceutical manufacturing processes. The department provides its students with an education that has both intellectual breadth and depth of exposure to modern research biology. This education can be used to gain employment immediately after graduation in government, industry or academic research laboratories, or to pursue graduate studies in a variety of areas such as science, medicine, public health, law, or business. A degree in biological sciences provides excellent preparation for medical school or other graduate programs in the health professions. These students are aided by the Carnegie Mellon Health Professions Program (HPP), an advisory and resource service for all Carnegie Mellon students who are considering careers in the health care field. (See the HPP (http://courseregistrar.web.cmu.edu/services/undergrads/undergraduateoptions/#healthprofessionsprogram) section in this catalog or www.cmu.edu/hpp for more information.)

The department offers a Bachelor of Science (B.S.) degree in Biological Sciences. This program has a distinctive core curriculum that provides a foundation in biology, chemistry, computer science, mathematics, and physics. In addition to the core courses, the program includes six biology electives, free electives as well as humanities, social science and fine arts electives. With these electives, students can shape a degree program according to their own interests and career goals. For students who have an interest in a particular field of biology and wish to have a specialized focus, the department offers options in biochemistry, biophysics, cell biology, computational biology, developmental biology, genetics, molecular biology and neuroscience that provide the relevant training in each area. The options are especially recommended for students who are considering graduate school in one of these areas. The B.S. degrees in Biological Sciences/Neuroscience Track and Neuroscience are available to those students who wish to pursue an in-depth study of neuroscience.

In this exciting era that includes the influence of biology and the life sciences on many fields from medicine to law, the in-depth exposure to multiple disciplines provides opportunities for students to prepare for involvement at the forefront of emerging new fields, markets, and policy changes. The Department of Biological Sciences at Carnegie Mellon is working at these new interfaces through interdisciplinary research and educational programs. Innovative interdisciplinary degrees which are offered by the department include the inter-college B.S. degrees in Computational Biology and Neuroscience as well as the unified B.S. degree in Biological Sciences and Psychology. Students also explore interdisciplinary studies through the Science and Humanities Scholars program, or pursue interests at the interface between the arts and sciences through the Bachelor of Science and Arts (B.S.A.) degree program combining biological sciences with a discipline in the College of Fine Arts.

A stand-alone Bachelor of Arts (B.A.) degree is available for students who wish to expand their educational training into other fields. Many students choose to broaden their education by pursuing minors and additional majors in disciplines throughout the university, not just within the Mellon College of Science.

One of the most important features of the Department of Biological Sciences is the opportunity for undergraduate students to interact with faculty. Providing a solid foundation to scientific practice is critical; therefore, the department offers first-year students a variety of inquiry-based, hands-on courses that incorporate a wide range of topics and interests within Biological Sciences. These courses kick-start the transformation of science students to scientists. We encourage our students to get to know their faculty through one of these courses, or through mentored, independent research projects in the faculty laboratories. Our faculty members are prominent research scientists who also teach beginning and advanced courses. The upper level teaching laboratories are located in the same building as the faculty research laboratories and share scientific equipment. We encourage students to make themselves aware of the research areas of the faculty and to develop research projects with faculty. While such research is usually most important in the senior year, it may begin earlier in a student’s undergraduate training. The department has an Honors Program in Research Biology to facilitate a more intensive involvement in research for eligible students. During the past four years, more than 80 percent of the undergraduate biology majors have worked with faculty on their research and, in some cases, have been co-authors of research papers and have given presentations at national meetings.

Since the fall of 2011, the Department of Biological Sciences has offered B.S. degrees in Biological Sciences as well as Computational Biology at Carnegie Mellon University in Doha, Qatar. Students enrolled in either of these degree programs will also complete the requirements outlined below. In addition to the limited number of required courses for the CMU-Qatar program are offered through a collaboration with the Weill Cornell Medical College in Qatar. For a listing of how the degree requirements are fulfilled for students enrolled in Doha, please consult the CMU-Qatar website (https://www.qatar.cmu.edu/curriculum-bs).

Program Outcomes

Upon graduation recipients of the BS or BA degree in Biological Sciences will:

• Use the basic concepts and experimental, computational, and theoretical methods of the core fields of science, mathematics and technology.
• Use foundational knowledge from the natural sciences and mathematics for advanced work in the discipline.
• Understand and apply the scientific method.
• Apply disciplinary knowledge toward solving problems.
• Use modern methods for finding and sharing current scientific information and primary literature.
• Convey information including scientific content in written and oral formats within Biological Sciences.
• Work in multidisciplinary and culturally diverse teams.
• Demonstrate proper values and ethics within Biological Sciences, the University, and the larger scientific community.

B.S. Biological Sciences

The Bachelor of Science (B.S.) in Biological Sciences is built around a core program and elective units as detailed in the following section.

Degree Requirements:

- Biological Sciences
  - 03-121 Modern Biology
  - 03-151 or 21-124 Honors Modern Biology
  - 03-201 Undergraduate Colloquium for Sophomores
  - 03-220 Genetics
  - 03-231/232 Biochemistry I
  - 03-250 Introduction to Computational Biology
  - 03-251 AND 03-252
  - 03-320 Cell Biology
  - 03-343 Experimental Techniques in Molecular Biology
  - 03-344 Experimental Biochemistry
  - 03-345 or 03-346 Experimental Cell and Developmental Biology
  - 03-239
  - 03-411 Topics in Research
  - 03-412 Topics in Research
  - 03-xxx Biological Sciences Electives

Total Biology units: 130

1. Details on electives can be found in the "Biological Sciences Electives" section (see below).

- Mathematics, Physics and Computer Science
  - 02-201 Programming for Scientists
  - 21-120 Differential and Integral Calculus
  - 21-122 Integration and Approximation
  - 33-121 Physics I for Science Students
  - 33-122 Physics II for Biological Sciences & Chemistry Students

Units

10
10
10
10
12
9
The following specifications apply to Biological Sciences electives:

1. Life Sciences: any courses in this category except for the 03-XXX courses (these can be counted as general bio electives towards your degree).
2. Physical Sciences: 09-105, 09-106, 33-121 and 33-122
3. Math/CS/Stats: 21-120 and (21-122 or 21-124)
4. STEM Elective: will be filled by courses above or any STEM course from the approved list.

Biological Sciences Electives

The following specifications apply to Biological Sciences electives:

- At least 18 units must be at the 03-3xx level or above, exclusive of 03-445 and 03-370.
- Up to three interdisciplinary electives may count as biology electives.
- Up to 18 units of 03-445 Undergraduate Research may count as general biology electives; a maximum of 36 units can count for the minimum units required for graduation.
- Courses in biology taken through cross-registration or study abroad at another university may count as electives if prior permission is obtained from the Carnegie Mellon Department of Biological Sciences advisor.

Departmental Electives Group

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>03-115/116</td>
<td>Phage Genomics Research</td>
<td>6</td>
</tr>
<tr>
<td>03-116</td>
<td>Phage Genomics Research</td>
<td>6</td>
</tr>
<tr>
<td>03-124</td>
<td>Modern Biology Laboratory</td>
<td>9</td>
</tr>
<tr>
<td>03-125</td>
<td>Evolution</td>
<td>9</td>
</tr>
<tr>
<td>03-126</td>
<td>Cellular Response to the Environment</td>
<td>4</td>
</tr>
<tr>
<td>03-127</td>
<td>How Biological Experiments Work - A Project Course</td>
<td>9</td>
</tr>
<tr>
<td>03-133</td>
<td>Neurobiology of Disease</td>
<td>9</td>
</tr>
<tr>
<td>03-161</td>
<td>Molecules to Mind</td>
<td>9</td>
</tr>
<tr>
<td>03-326</td>
<td>Evolution of Regulatory Genomics</td>
<td>4.5</td>
</tr>
<tr>
<td>03-327</td>
<td>Phylogenetics</td>
<td>9</td>
</tr>
<tr>
<td>03-350</td>
<td>Developmental Biology</td>
<td>9</td>
</tr>
<tr>
<td>03-362</td>
<td>Cellular Neuroscience</td>
<td>9</td>
</tr>
<tr>
<td>03-363</td>
<td>Systems Neuroscience</td>
<td>9</td>
</tr>
<tr>
<td>03-364</td>
<td>Developmental Neuroscience</td>
<td>9</td>
</tr>
<tr>
<td>03-365</td>
<td>Neural Correlates of Learning and Memory</td>
<td>9</td>
</tr>
<tr>
<td>03-366</td>
<td>Biochemistry of the Brain</td>
<td>9</td>
</tr>
<tr>
<td>03-370</td>
<td>Principles of Biotechnology</td>
<td>9</td>
</tr>
<tr>
<td>03-390</td>
<td>Molecular and Cellular Immunology</td>
<td>9</td>
</tr>
<tr>
<td>03-391</td>
<td>Microbiology</td>
<td>9</td>
</tr>
<tr>
<td>03-392</td>
<td>Microbiology Laboratory</td>
<td>6</td>
</tr>
<tr>
<td>03-428</td>
<td>Genome Editing Biotechnology</td>
<td>4.5</td>
</tr>
<tr>
<td>03-435</td>
<td>Cancer Biology</td>
<td>9</td>
</tr>
<tr>
<td>03-439</td>
<td>Introduction to Biophysics</td>
<td>9</td>
</tr>
<tr>
<td>03-442</td>
<td>Molecular Biology</td>
<td>9</td>
</tr>
<tr>
<td>03-445</td>
<td>Undergraduate Research</td>
<td>Var.</td>
</tr>
<tr>
<td>03-451</td>
<td>Advanced Developmental Biology and Human Health</td>
<td>9</td>
</tr>
<tr>
<td>03-511</td>
<td>Computational Molecular Biology and Genomics</td>
<td>9</td>
</tr>
<tr>
<td>03-512</td>
<td>Computational Methods for Biological Modeling and Simulation</td>
<td>9</td>
</tr>
<tr>
<td>03-534</td>
<td>Biological Imaging and Fluorescence Spectroscopy</td>
<td>9</td>
</tr>
<tr>
<td>03-545</td>
<td>Honors Research</td>
<td>9</td>
</tr>
<tr>
<td>03-620</td>
<td>Techniques in Electron Microscopy</td>
<td>9</td>
</tr>
<tr>
<td>03-709</td>
<td>Applied Cell and Molecular Biology</td>
<td>12</td>
</tr>
<tr>
<td>03-711</td>
<td>Computational Molecular Biology and Genomics</td>
<td>12</td>
</tr>
<tr>
<td>03-712</td>
<td>Computational Methods for Biological Modeling and Simulation</td>
<td>12</td>
</tr>
<tr>
<td>03-713</td>
<td>Bioinformatics Data Integration Practicum</td>
<td>6</td>
</tr>
<tr>
<td>03-726</td>
<td>Evolution of Regulatory Genomics</td>
<td>6</td>
</tr>
<tr>
<td>03-727</td>
<td>Phylogenetics</td>
<td>12</td>
</tr>
<tr>
<td>03-728</td>
<td>Genome Editing Biotechnology</td>
<td>6</td>
</tr>
<tr>
<td>03-730</td>
<td>Advanced Genetics</td>
<td>12</td>
</tr>
<tr>
<td>03-740</td>
<td>Advanced Biochemistry</td>
<td>12</td>
</tr>
<tr>
<td>03-741</td>
<td>Advanced Cell Biology</td>
<td>12</td>
</tr>
<tr>
<td>03-742</td>
<td>Molecular Biology</td>
<td>12</td>
</tr>
<tr>
<td>03-744</td>
<td>Membrane Trafficking</td>
<td>9</td>
</tr>
<tr>
<td>03-751</td>
<td>Advanced Developmental Biology and Human Health</td>
<td>12</td>
</tr>
<tr>
<td>03-762</td>
<td>Advanced Cellular Neuroscience</td>
<td>12</td>
</tr>
<tr>
<td>03-763</td>
<td>Advanced Systems Neuroscience</td>
<td>12</td>
</tr>
<tr>
<td>03-765</td>
<td>Advanced Neural Correlates of Learning and Memory</td>
<td>12</td>
</tr>
<tr>
<td>03-770</td>
<td>Principles of Biotechnology</td>
<td>12</td>
</tr>
<tr>
<td>03-791</td>
<td>Advanced Microbiology</td>
<td>12</td>
</tr>
<tr>
<td>03-871</td>
<td>Structural Biophysics</td>
<td>12</td>
</tr>
</tbody>
</table>

Interdisciplinary Electives Group

Up to three of the following courses may count as biology electives:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>09-518</td>
<td>Bioorganic Chemistry: Nucleic Acids and Carbohydrates</td>
<td>9</td>
</tr>
<tr>
<td>09-519</td>
<td>Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry</td>
<td>9</td>
</tr>
<tr>
<td>09-521</td>
<td>Metals in Biology: Function and Reactivity</td>
<td>6</td>
</tr>
<tr>
<td>09-535</td>
<td>Applied topics in Macromolecular and Biophysical Techniques</td>
<td>9</td>
</tr>
<tr>
<td>21-127</td>
<td>Concepts of Mathematics</td>
<td>10</td>
</tr>
<tr>
<td>21-259</td>
<td>Calculus in Three Dimensions</td>
<td>9</td>
</tr>
<tr>
<td>21-260</td>
<td>Differential Equations</td>
<td>9</td>
</tr>
<tr>
<td>36-201</td>
<td>Statistical Reasoning and Practice</td>
<td>9</td>
</tr>
<tr>
<td>36-247</td>
<td>Statistics for Lab Sciences</td>
<td>9</td>
</tr>
<tr>
<td>42-202</td>
<td>Physiology</td>
<td>9</td>
</tr>
<tr>
<td>85-219</td>
<td>Biological Foundations of Behavior</td>
<td>9</td>
</tr>
</tbody>
</table>
Options for the B.S. in Biological Sciences

Students who wish to specialize in a particular area of biology can do so through a set of departmentally defined options. A student who completes the required biology electives for any option can have up to two noted on his or her transcript. Options need not be declared. The elective courses required for each of the options are listed below.

**Biochemistry Option**

Required Biology Electives:

- 03-740 Advanced Biochemistry 12
- 21-259 Calculus in Three Dimensions 9
- or 21-260 Differential Equations

Any ONE of the following courses:

- 09-518 Bioorganic Chemistry: Nucleic Acids and Carbohydrates 9
- 09-519 Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry
- 09-521 Metals in Biology: Function and Reactivity 6

Recommended Biology Electives:

- 03-442 Molecular Biology 9
- 03-534 Biological Imaging and Fluorescence Spectroscopy 9
- 03-439 Introduction to Biophysics 9
- 03-871 Structural Biophysics 12

**Biophysics Option**

Required Biology Electives:

- 03-740 Advanced Biochemistry 12
- 03-439 Introduction to Biophysics 9
- 21-259 Calculus in Three Dimensions 9
- or 21-260 Differential Equations

Recommended Biology Electives:

- 03-534 Biological Imaging and Fluorescence Spectroscopy 9
- 03-871 Structural Biophysics 12

**Cell Biology Option**

Required Biology Electives:

- 03-350 Developmental Biology 9
- 03-741 Advanced Cell Biology 12

Any ONE of the following courses:

- 03-362 Cellular Neuroscience 9
- 03-390 Molecular and Cellular Immunology 9

**Computational Biology Option**

Required Biology Electives:

- 03-711 Computational Molecular Biology and Genomics 12
- 15-210 Parallel and Sequential Data Structures and Algorithms 12

Any ONE of the following courses:

- 36-247 Statistics for Lab Sciences 9
- 21-260 Differential Equations 9
- 21-241 Matrices and Linear Transformations 10

Recommended Biology Electives:

- 03-512 Computational Methods for Biological Modeling and Simulation 9
- 15-451 Algorithm Design and Analysis 12
- 09-560 Computational Chemistry 12

**Developmental Biology Option**

Required Biology Electives:

- 03-350 Developmental Biology 9
- 03-442 Molecular Biology 9
- 03-751 Advanced Developmental Biology and Human Health 12

Recommended Biology Electives:

- 03-326 Evolution of Regulatory Genomics 4.5
- 03-741 Advanced Cell Biology 12

**Genetics Option**

Required Biology Electives:

- 03-326 Evolution of Regulatory Genomics 4.5
- 03-327 Phylogenetics 9
- 03-442 Molecular Biology 9
- 03-730 Advanced Genetics 6

6 Minimum grade of B in 03-330 or 03-220 required.

Recommended Biology Electives:

- 03-391 Microbiology 9

**Molecular Biology Option**

Required Biology Electives:

- 03-442 Molecular Biology 9
- 09-518 Bioorganic Chemistry: Nucleic Acids and Carbohydrates 9
- 03-726 Evolution of Regulatory Genomics 6
- 03-727 Phylogenetics 12

Recommended Biology Electives:

- 03-390 Molecular and Cellular Immunology 9
- 03-391 Microbiology 9
- 03-730 Advanced Genetics 12

**Neuroscience Option**

Required Biology Electives:

- 03-362 Cellular Neuroscience 7 9
- 03-363 Systems Neuroscience 7 9

Any ONE of the following courses:

- 03-133 Neurobiology of Disease 9
- 03-350 Developmental Biology 9
- 03-364 Developmental Neuroscience 9
- 03-365 Neural Correlates of Learning and Memory 9
- 03-366 Biochemistry of the Brain 9
- 03-534 Biological Imaging and Fluorescence Spectroscopy 9
- 42-202 Physiology 9
- 85-219 Biological Foundations of Behavior 9

7 One of these courses must be completed at the Graduate Level (Complete either 03-762 or 03-763).

B.S. Biological Sciences/Neuroscience Track

The Bachelor of Science in Biological Sciences/Neuroscience Track provides an option for those Biological Sciences majors who are interested in an intensive curricular focus in neuroscience. The requirements of the Track are the same as those listed for the B.S. in Biological Sciences with the following changes to the biological sciences elective requirements:

**Degree Requirements:**

- 03-362 Cellular Neuroscience 9
- 03-363 Systems Neuroscience 9
- 03-765 Advanced Neural Correlates of Learning and Memory 12

Plus three of the following electives:

- 03-133 Neurobiology of Disease 9
- 03-350 Developmental Biology 9
B.S. Neuroscience

The Bachelor of Science in Neuroscience is listed in the Intercollege (http://coursecatalog.web.cmu.edu/servicesandoptions/intercollegeprograms/#bachelorofscienceinneurosciencetext) section of this catalog. It is a joint degree program offered between the Mellon College of Science and the Dietrich College of Humanities and Social Sciences. Current MCS students interested in pursuing this degree should contact Dr. Becki Campanaro (DH 1320). More information can also be found on the CMU Neuroscience website (http://www.cmu.edu/neuro).

B.S. Biological Sciences and Psychology

This major is intended to reflect the interdisciplinary nature of current research in the fields of biology and psychology, as well as the national trend in some professions to seek individuals broadly trained in both the social and natural sciences.

Note: Students entering from the Dietrich College of Humanities and Social Sciences will earn a Bachelor of Science in Psychology and Biological Sciences. Students in the Mellon College of Science will earn a Bachelor of Science in Biological Sciences and Psychology. Students in the joint Science and Humanities Scholars (SHS) program can complete the SHS educational core and choose either departmental order for their diploma.

Depending on a student's home college (DC or MCS), General Education (GenEd) requirements will be different. GenEd requirements for DC (http://coursecatalog.web.cmu.edu/dietrichcollegeofhumanitiesandsocialsciences/#hampssgeneraleducationprogram160) and MCS (http://coursecatalog.web.cmu.edu/servicesandoptions/intercollegeprograms/#bachelorofscienceinneurosciencetext) section of this catalog. It is a joint degree program offered between the Mellon College of Science and the Dietrich College of Humanities and Social Sciences. Current MCS students must also complete 33-122 Physics II for Biological Sciences & Chemistry Students.

Degree Requirements:

<table>
<thead>
<tr>
<th>Biological Sciences</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>03-121 Modern Biology</td>
<td>9</td>
</tr>
<tr>
<td>or 03-151 Honors Modern Biology</td>
<td>9</td>
</tr>
<tr>
<td>03-220 Genetics</td>
<td>9</td>
</tr>
<tr>
<td>03-231/232 Biochemistry I</td>
<td>9</td>
</tr>
<tr>
<td>03-320 Cell Biology</td>
<td>9</td>
</tr>
<tr>
<td>03-343 Experimental Techniques in Molecular Biology</td>
<td>12</td>
</tr>
<tr>
<td>03-411 Topics in Research</td>
<td>1</td>
</tr>
<tr>
<td>03-412 Topics in Research</td>
<td>1</td>
</tr>
<tr>
<td>03-xxx General Biology Elective 1</td>
<td>9</td>
</tr>
<tr>
<td>03-xxx Advanced Biology Elective 2</td>
<td>18</td>
</tr>
</tbody>
</table>

Total Biology units: 77

1 Please see description and requirements for electives under the B.S. in Biological Sciences section of this Catalog.

<table>
<thead>
<tr>
<th>Mathematics, Statistics, Physics and Computer Science</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>21-120 Differential and Integral Calculus</td>
<td>10</td>
</tr>
<tr>
<td>21-122 Integration and Approximation</td>
<td>10</td>
</tr>
<tr>
<td>or 21-124 Calculus II for Biologists and Chemists</td>
<td></td>
</tr>
<tr>
<td>36-247 Statistics for Lab Sciences</td>
<td>9</td>
</tr>
<tr>
<td>or 36-201 Statistical Reasoning and Practice</td>
<td></td>
</tr>
<tr>
<td>36-309 Experimental Design for Behavioral and Social Sciences</td>
<td>9</td>
</tr>
<tr>
<td>33-121 Physics I for Science Students 2</td>
<td>12</td>
</tr>
<tr>
<td>15-110 Principles of Computing</td>
<td>10-12</td>
</tr>
<tr>
<td>or 15-112 Fundamentals of Programming and Computer Science</td>
<td></td>
</tr>
<tr>
<td>or 02-201 Programming for Scientists</td>
<td></td>
</tr>
</tbody>
</table>

99-10x Computing at Carnegie Mellon: 3

Total Science units: 63-65

2 MCS students must also complete 33-122 Physics II for Biological Sciences & Chemistry Students.

<table>
<thead>
<tr>
<th>Chemistry</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>09-105 Introduction to Modern Chemistry I</td>
<td>10</td>
</tr>
<tr>
<td>09-106 Modern Chemistry II</td>
<td>10</td>
</tr>
<tr>
<td>09-217 Organic Chemistry I</td>
<td>9</td>
</tr>
<tr>
<td>or 09-219 Modern Organic Chemistry</td>
<td></td>
</tr>
<tr>
<td>09-218 Organic Chemistry II</td>
<td>9</td>
</tr>
<tr>
<td>or 09-220 Modern Organic Chemistry II</td>
<td></td>
</tr>
<tr>
<td>09-207 Techniques in Quantitative Analysis</td>
<td>9-12</td>
</tr>
<tr>
<td>or 09-221 Laboratory I: Introduction to Chemical Analysis</td>
<td></td>
</tr>
<tr>
<td>09-208 Techniques for Organic Synthesis and Analysis</td>
<td>9-12</td>
</tr>
<tr>
<td>or 09-222 Laboratory II: Organic Synthesis and Analysis</td>
<td></td>
</tr>
</tbody>
</table>

Total Chemistry units: 56-62

<table>
<thead>
<tr>
<th>Psychology Courses</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>85-102 Introduction to Psychology</td>
<td>9</td>
</tr>
<tr>
<td>85-219 Biological Foundations of Behavior</td>
<td>9</td>
</tr>
<tr>
<td>85-2xx Survey Psychology Courses 1</td>
<td>18</td>
</tr>
<tr>
<td>85-310 Research Methods in Cognitive Psychology</td>
<td>9</td>
</tr>
<tr>
<td>or 85-340 Research Methods in Social Psychology</td>
<td></td>
</tr>
<tr>
<td>or 85-320 Research Methods in Developmental Psychology</td>
<td></td>
</tr>
<tr>
<td>or 85-314 Cognitive Neuroscience Research Methods</td>
<td></td>
</tr>
<tr>
<td>or 85-330 Analytic Research Methods</td>
<td></td>
</tr>
<tr>
<td>85-3xx Advanced Psychology Electives</td>
<td>18</td>
</tr>
</tbody>
</table>

Total Psychology units: 63

* Excluding 85-261 Abnormal Psychology

Additional Advanced Elective: 9 units

(Choose one of the following courses)

| 85-3xx Advanced Psychology Elective | 9 |
| or 03-3xx Advanced Biology Elective | 9 |

Additional Laboratory or Research Methods: 9-12 units

(Choose one of the following courses)

| 03-344 Experimental Biochemistry | 12 |
| 03-345 Experimental Cell and Developmental Biology | 12 |
| 85-310 Research Methods in Cognitive Psychology | 9 |
| 85-314 Cognitive Neuroscience Research Methods | 9 |
| 85-320 Research Methods in Developmental Psychology | 9 |
| 85-340 Research Methods in Social Psychology | 9 |

Elective Units: 33-36

Free Electives: 36-48

MCS Nonterminal Breadth or DC General Education requirements:

Total Elective units: 69-84

Minimum number of units required for degree: 360

B.A. Biological Sciences

The Department of Biological Sciences offers a Bachelor of Arts (B.A.) degree that is intended for students who wish to combine their interest in science with their interest(s) in other discipline(s) across campus. The requirements for the B.A. degree are distributed as follows:

Degree Requirements:

<table>
<thead>
<tr>
<th>Biological Sciences</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>03-121 Modern Biology</td>
<td>9</td>
</tr>
<tr>
<td>or 03-151 Honors Modern Biology</td>
<td></td>
</tr>
<tr>
<td>03-201 Undergraduate Colloquium for Sophomores</td>
<td>2</td>
</tr>
</tbody>
</table>
Courses for the Minor in Biological Sciences

Prerequisites:

- 09-105 Introduction to Modern Chemistry I 10
- 09-217 Organic Chemistry I 9

Required courses:

- 09-107 Honors Chemistry: Fundamentals, Concepts and Applications 10
- 09-216 Modern Organic Chemistry 9
- 09-218 Modern Organic Chemistry II 9
- 09-219 Techniques in Quantitative Analysis 9-12

Total Chemistry units 47-50

Students who complete 09-107 with an A grade will be exempted from the requirement to take 09-106 Modern Chemistry II.

Mathematics, Physics, and Computer Science

- 02-201 Programming for Scientists 10
- 21-120 Differential and Integral Calculus 10
- 21-122 Integration and Approximation 10
- 21-124 Calculus II for Biologists and Chemists 10
- 33-121 Physics I for Science Students 12
- 33-122 Physics II for Biological Sciences & Chemistry Students 9
- 99-10x Computing at Carnegie Mellon 3

Total Science units 54

- 15-112 Fundamentals of Programming and Computer Science or 15-110 Principles of Computing can substitute for 02-201 towards completion of the Programming course requirement.
- 33-111 Physics I for Science Students can substitute for 33-121 Physics I for Science Students towards completion of the Physics I requirement.
- 33-112 Physics II for Science Students can substitute for 33-122 Physics II for Biological Sciences & Chemistry Students towards completion of the Physics II requirement.

Elective courses 9-12

MCS Nontechnical Breadth Requirements 72

Total Elective units 168-171

360 Minimum number of units required for degree:

Minor in Biological Sciences

All university students are eligible to pursue a minor in biological sciences in conjunction with a major in any other department in the university. A minimum of six biological sciences courses (and two chemistry prerequisites) must be completed to fulfill the minor in biological sciences. The curriculum includes four required courses and two elective courses as specified below. Units awarded for undergraduate research are not applicable to elective courses. Courses taken in other departments or colleges will be considered on an individual basis.

Courses for the Minor in Biological Sciences

Prerequisites:

- 09-105 Introduction to Modern Chemistry I 10
- 09-217 Organic Chemistry I 9

Required courses:

- 03-220 Genetics 9
- 03-231/232 Biochemistry I 9
- 03-310 Cell Biology 9
- 03-343 Experimental Techniques in Molecular Biology 9-12
- 03-124 Modern Biology Laboratory
- 03-411 Topics in Research 1
- 03-412 Topics in Research 1
- 03-xxx General Biology Electives 8 18
- 03-3xx Advanced Biology Electives 8 18

Total Biology units 85-88

*NOTE: Please see description and requirements for electives under the B.S. in Biological Sciences section of this Catalog.

Minor in Neuroscience

The curriculum within the Neuroscience minor will allow students from various disciplines to gain fundamental knowledge of neuroscience concepts. The interdisciplinary nature of the coursework echoes the nature of the field itself; students will select courses from the natural, social, and computer sciences. Neuroscientists not only require foundational knowledge of molecular, cellular, and systems neuroscience, but they should also understand the behavioral significance and appreciate how computational work and imaging techniques can aid in clarifying normal and abnormal functioning of these fundamental processes.

Students pursuing the minor in Neuroscience will:

- Acquire foundational knowledge of the basic biological foundations of the nervous system, from the cellular through systems levels.
- Understand the effects of basic neurological function on behavior, including cognition.
- Gain an appreciation of the interdisciplinary nature of the field of neuroscience.

NOTE: Because the curriculum within this minor may overlap with some degree requirements, no more than 2 courses fulfilling Neuroscience Minor requirements may count towards the requirements of a student’s major or other minor.

Course Requirements

Minimum units required for Neuroscience minor 63

Required courses (4):

- 03-121 Modern Biology 9
- 03-151 Honors Modern Biology 9
- 03-362 Cellular Neuroscience 9
- 03-363 Systems Neuroscience 9
- 85-219 Biological Foundations of Behavior 9
- 03-161 Molecules to Mind 9

Distribution Requirements:

Three courses, including at least 1 from each of the following categories:

Approaches to Neuroscience Category

- 15-386 Neural Computation 9
- 15-883 Computational Models of Neural Systems 12
- 85-412 Cognitive Modeling 9
- 85-414 Cognitive Neuropsychology 9
- 85-419 Introduction to Parallel Distributed Processing 9
- 85-429 Cognitive Brain Imaging 9

Cognitive Neuroscience Category

- 03-133 Neurobiology of Disease 9
- 03-364 Developmental Neuroscience 9
- 85-211 Cognitive Psychology 9
- 85-370 Perception 9
- 85-390 Human Memory 9
- 85-406 Autism: Psychological and Neuroscience Perspectives 9

*NOTE: 85-213 may be used instead of 85-211 when offered
**B.S. in Computational Biology**

Students who entered CMU in Fall 2016 and earlier may pursue the Intercollege Bachelor of Science in Computational Biology joint program between the Mellon College of Sciences and the School of Computer Science. Degree requirements for this program can be found in the 2016-2017 catalog (http://coursecatalog.web.cmu.edu/previous). Interested students should contact Dr. Becki Campanaro (bcampana@andrew.cmu.edu) for more information.

**Masters Degree in Computational Biology**

Students who are interested in more advanced training in this emerging field may want to consider the Master of Science Program in Computational Biology. For more information about this program, contact the Biological Sciences Graduate Programs Office (bio-gradoffice@andrew.cmu.edu).

**Honors Program in Research Biology**

The departmental Honors Program offers an opportunity to become extensively involved in research. The program requires students to conduct an independent project and to prepare a formal thesis that is written and defended in the senior year. This program does not preclude a student from completing any of the options within the department nor is it the only way in which students can participate in undergraduate research, although it is excellent preparation for graduate studies.

**Transfer credit for Modern Biology**

Students wishing to transfer credit for 03-121 Modern Biology from another institution must meet the following requirements:

1. The course in question should have at least an 80% match in topics with 03-121. Topics in 03-121 cover the genetic, molecular, cellular, developmental, and evolutionary mechanisms that underlie biological processes and include: Cell theory; Cell chemistry; Cell structure; Function and structure of proteins, DNA, RNA, lipids and carbohydrates; Cell respiration and fermentation; The cell cycle; Cell-cell interactions and communication; Transcription; Translation; RNA processing in Eukaryotes; DNA replication; DNA mutation and repair; Meiosis; Mitosis; and Regulation of Gene Expression. This information is sometimes available in the course description, but more detail is often found in a course syllabus.


3. Introductory level courses that focus on other biology areas (i.e. anatomy, physiology, ecology, evolution, and/or development) will not be accepted for 03-121 credit. These courses may receive credit for a general biology elective.

4. Students should contact their departmental academic advisor for the transfer credit approval process in their college.

**Faculty**

ALISON L. BARTH, Professor – Ph.D., University of California, Berkeley; Carnegie Mellon, 2002–.

MOHAMMED BOUAOUINA, Assistant Teaching Professor, Carnegie Mellon-Qatar – Ph.D., Carnegie Mellon, 2013–.

DANIEL BRASIER, Assistant Teaching Professor – Ph.D., University of California, San Diego; Carnegie Mellon, 2012–.

MAGGIE BRAUN, Associate Teaching Professor and Associate Dean of Undergraduate Affairs for MCS – Ph.D., University of Pittsburgh; Carnegie Mellon, 2011–.

MARCEL BRUCHEZ, Associate Professor in Biological Sciences and Chemistry, Associate Director of MBIC – Ph.D., University of California, Berkeley; Carnegie Mellon, 2006–.

AMY L. BURKERT, Teaching Professor and Vice Provost for Education – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1997–.

BECKI M. CAMPANARO, Assistant Teaching Professor and Assistant Department Head for Undergraduate Affairs – Ph.D., Arizona State University; Carnegie Mellon, 2015–.

CLAIREE CHEETHAM, Assistant Research Professor – Ph.D., King’s College London, Carnegie Mellon, 2015–.

JASON M. D’ANTONIO, Assistant Teaching Professor and Director of the Health Professions Program – Ph.D., University of Pittsburgh School of Medicine; Carnegie Mellon, 2013–.

CARRIE B. DOONAN, Teaching Professor and Director of Undergraduate Laboratories – Ph.D., University of Connecticut; Carnegie Mellon, 1993–.

EMILY DRILL, Assistant Teaching Professor – Ph.D., University of Pittsburgh; Carnegie Mellon, 2012–.

M. DANNIE DURAND, Associate Professor – Ph.D., Columbia University; Carnegie Mellon, 2000–.

CHARLES A. ETTENSOHN, Professor – Ph.D., Yale University; Carnegie Mellon, 1987–.

ARYN GITTIS, Associate Professor – Ph.D., University of California, San Diego; Carnegie Mellon, 2012–.

DAVID D. HACKNEY, Professor – Ph.D., University of California, Berkeley; Carnegie Mellon, 1978–.

N. LUISA HILLER, Assistant Professor – Ph.D., Northwestern University Medical School; Carnegie Mellon, 2012–.

VERONICA F. HINMAN, Associate Professor – Ph.D., University of Queensland; Carnegie Mellon, 2006–.

CHIEN HO, Professor and Director of NMR Center of Pittsburgh – Ph.D., Yale University; Carnegie Mellon, 1979–.

JEFFREY O. HOLLINGER, Professor of Biological Sciences and Biomedical Engineering – Ph.D., D.D.S., University of Maryland; Carnegie Mellon, 2000–.

KENNETH HOVIS, Associate Teaching Professor and Assistant Dean for Educational Initiatives for MCS – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2011–.

VALENTIN ILYIN, Associate Teaching Professor of Computational Biology at CMU-Qatar – Ph.D., Carnegie Mellon, 2012–.

JONATHAN W. JARVICK, Associate Professor – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1978–.

SANDRA KUHLMAN, Assistant Professor – Ph.D., University of Kentucky; Carnegie Mellon, 2012–.

FREDERICK LANNI, Associate Professor – Ph.D., Harvard University; Carnegie Mellon, 1982–.

CHRISTINA H. LEE, Associate Professor – Ph.D., University of California, San Francisco; Carnegie Mellon, 2000–.

ADAM D. LINSTEDT, Professor – Ph.D., University of California, San Francisco; Carnegie Mellon, 1995–.

A. JAVIER LOPEZ, Associate Professor – Ph.D., Duke University; Carnegie Mellon, 1989–.

BROOKE M. MCCARTNEY, Associate Professor – Ph.D., Duke University; Carnegie Mellon, 2003–.

C. JOEL MCMANUS, Assistant Professor – Ph.D., University of Wisconsin-Madison; Carnegie Mellon, 2011–.

JONATHAN S. MINDEN, Professor – Ph.D., Albert Einstein College of Medicine; Carnegie Mellon, 1990–.

AARON P. MITCHELL, Department Head and Professor – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2008–.

ROBERT F. MURPHY, Professor of Biological Sciences and Department Head of Computational Biology – Ph.D., California Institute of Technology; Carnegie Mellon, 1983–.

GORDON S. RULE, Professor and Associate Dean for Research, Carnegie Mellon-Qatar – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1996–.

RUSSELL S. SCHWARTZ, Professor – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2002–.

SHOBA SUBRAMANIAN, Assistant Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2011–.

JOSEPH P. SUHAN, Lecturer – M.A., Hofstra University; Carnegie Mellon, 1987–.

ANNETTE VINCENT, Assistant Teaching Professor, Carnegie Mellon-Qatar – Ph.D., National University of Singapore; Carnegie Mellon, 2012–.

LINDA VISOMIRSKI-ROBIC, Lecturer – Ph.D., Case Western Reserve University; Carnegie Mellon, 2003–.
ALAN S. WAGGONER, Professor and Director of MBIC – Ph.D., University of Oregon; Carnegie Mellon, 1999–.
JOHN L. WOOLFORD JR., Professor and Co-Director of CNAST – Ph.D., Duke University; Carnegie Mellon, 1979–.
ERIC YTTRI, Assistant Professor – Ph.D., Washington University in St. Louis; Carnegie Mellon, 2017–.
YONGXIN ZHAO, Assistant Professor – Ph.D., University of Alberta; Carnegie Mellon, 2017–.

Affiliated Faculty
BRUCE A. ARMITAGE, Professor of Chemistry and Co-Director of CNAST – Ph.D., University of Arizona; Carnegie Mellon, 1997–.
ZIV BAR-JOSEPH, Associate Professor of Computer Science and Machine Learning – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2003–.
PHIL G. CAMPBELL, Research Professor at the Institute for Complex Engineering Systems – Ph.D., Pennsylvania State University; Carnegie Mellon, 1999–.
PHILLIP COMPEAU, Assistant Teaching Professor – Ph.D., University of California-San Diego; Carnegie Mellon, 2006–.
KIRS DAHL, Assistant Professor of Biomedical Engineering – Ph.D., University of Pennsylvania; Carnegie Mellon, 2006–.
WILLIAM F. EDDY, Professor of Statistics – Ph.D., Yale University; Carnegie Mellon, 1976–.
ALEX EVILEVITCH, Associate Professor of Physics – Ph.D., Lund University; Carnegie Mellon, 2009–.
T. D. JACOBSEN, Assistant Director and Principal Research Scientist at the Hunt Institute for Botanical Documentation – Ph.D., Washington State University; Carnegie Mellon, 1979–.
ROBERT W. KIGER, Distinguished Service Professor and Botany Professor and the History of Science Director and Principal Research Scientist for the Hunt Institute for Botanical Documentation – Ph.D., University of Maryland; Carnegie Mellon, 1974–.
CHRISTOPHER J. LANGMEAD, Associate Professor of Computer Science – Ph.D., Dartmouth College; Carnegie Mellon, 2004–.
PHILIP R. LEDUC, Professor of Mechanical Engineering – Ph.D., The Johns Hopkins University; Carnegie Mellon, 2002–.
CARL R. OLSON, Professor of the CNBC – Ph.D., University of California, Berkeley; Carnegie Mellon, 1996–.
ANDREAS R PFENNING, Assistant Professor of Computational Biology – Ph.D., Duke University; Carnegie Mellon, 2016–.
FREDERICK H. UTECH, Principal Research Scientist at the Hunt Institute for Botanical Documentation – Ph.D., Washington University; Carnegie Mellon, 1977–.
ERICK P. XING, Associate Professor of Computer Science, Language Technologies Institute, and Machine Learning – Ph.D., University of California, Berkeley; Carnegie Mellon, 2004–.
GE YANG, Assistant Professor of Biomedical Engineering and the Lane Center for Computational Biology – Ph.D., University of Minnesota, Twin Cities; Carnegie Mellon, 2010–.

Emeriti Faculty
PETER B. BERGET, Professor Emeritus – Ph.D., University of Minnesota; Carnegie Mellon, 1986–.
ERIC W. GROTZINGER, Teaching Professor Emeritus – Ph.D., University of Pittsburgh; Carnegie Mellon, 1979–.
LINDA R. KAUFFMAN, Teaching Professor, Emeritus – Ph.D., University of Pittsburgh; Carnegie Mellon, 1981–.
WILLIAM R. MCCLURE, Professor Emeritus – Ph.D., University of Wisconsin; Carnegie Mellon, 1976–.
JAMES F. WILLIAMS, Professor Emeritus – Ph.D., University of Toronto; Carnegie Mellon, 1976–.
C. ROY WORTHINGTON, Professor Emeritus – Ph.D., Adelaide University; Carnegie Mellon, 1969–.

Adjunct Faculty
JON W. JOHNSON, Professor of Neuroscience at the University of Pittsburgh – Ph.D., Stanford University; Carnegie Mellon, 2006–.
KARL KANDLER, Professor of Otolaryngology and Neurobiology at the University of Pittsburgh – Ph.D., University of Tubingen, Germany; Carnegie Mellon, 2006–.
CYNTHIA LANCE-JONES, Associate Professor of Neurobiology at the University of Pittsburgh – Ph.D., University of Massachusetts; Carnegie Mellon, 2006–.
CYNTHIA M. MORTON, Associate Curator and Head of Botany at the Carnegie Museum of Natural History – Ph.D., New York Botanical Garden/CUNY; Carnegie Mellon, 2002–.
PAUL L. STRICK, Co-Director of CNBC and Distinguished Professor of Neurobiology at the University of Pittsburgh – Ph.D., University of Pennsylvania; Carnegie Mellon, 2000–.