Biological Sciences

The biological sciences include the study of living systems at levels ranging from the structure and function of molecules to the behavior and evolution of communities of organisms. The department offers four different routes to mastering skills and knowledge in this broad area. The B.A. and B.S. programs in biology provide a broad introduction to biology with opportunities for students to create a program of study suited to their specific interests. Programs of study focused on particular aspects of biology are the B.A. and B.S. degree in the areas of behavioral neuroscience and molecular biology. For programs in biochemistry and bioengineering, see those separate sections in the catalog.

The Department of Biological Sciences strongly supports the positions of both the American Association for the Advancement of Science and the National Academy of Sciences that intelligent design is not scientific and should not be presented as science in science classes.

The requirements for the B.A. and B.S. in biology, behavioral neuroscience, and molecular biology are listed below. Research interests of the faculty and instrumentation are described in the section on graduate education.

Professors. Michael J. Behe, PhD (University of Pennsylvania); R. Michael Burger, PhD (University of Texas at Austin); Matthias Maria Falk, PhD (University of Heidelberg); Wonpil Im, PhD (Cornell University); Kathy Lovine, PhD (Washington University); Linda J. Lowe-Krentz, PhD (Northwestern University); Jill E. Schneider, PhD (University of North Carolina at Chapel Hill); David Zappulla, PhD (University of Pittsburgh); Vassie C. Ware, PhD (Yale University)

Associate Professors. Julie Haas, PhD (Boston University); Michael R. Kuchka, PhD (Carnegie Mellon University); Gregory Lang, PhD (Harvard University); Michael Layden, PhD (University of Oregon); Julie M. Miwa, PhD (Rockefeller University); Amber Rice, PhD (University of North Carolina at Chapel Hill); David Zappulla, PhD (State University of NY at Stony Brook)

Assistant Professors. Daniel Babcock, PhD (University Texas Houston); Santiago Herrera, PhD (Massachusetts Institute of Technology); Johanna Kowalko, PhD (Harvard University); Wynn Meyer, PhD (University of Chicago)

Professor Of Practice. Lawrence Tartaglia, PhD (University of Florida)

Emeriti. Lynne U. Cassimeris, PhD (University of North Carolina at Chapel Hill); David L. Cundall, PhD (University of Arkansas); Murray Itzkowitz, PhD (University of Maryland); Steven Kowalczyk, PhD (Yale University); John G. Nyby, PhD (University of Texas at Austin); Hayden N. Pritchard, PhD (Lehigh University); Jeffrey A. Sands, PhD (The Pennsylvania State University)

B.A. WITH MAJOR IN BIOLOGY

College and university requirements for all majors

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<td>ENGL 002</td>
<td>Research and Argument</td>
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<tr>
<td>First Year Seminar</td>
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Biology

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<tr>
<td>or BIOS 043</td>
<td>Phage Hunting Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>BIOS 044 &amp; BIOS 045</td>
<td>Introduction to Integrative and Comparative Biology and Introduction to Integrative and Comparative Biology Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>BIOS 115 &amp; BIOS 116</td>
<td>Genetics and Genetics Laboratory</td>
<td>4</td>
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or BIOS 118 Phage Genetics Laboratory

Mathematics

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<td>MATH 021</td>
<td>Calculus I</td>
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<td>MATH 012</td>
<td>Basic Statistics</td>
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<td>BIOS 130</td>
<td>Biostatistics</td>
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Collaborative Sciences

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<tr>
<td>CHM 030 &amp; CHM 031</td>
<td>Introduction to Chemical Principles and Chemical Equilibria in Aqueous Systems</td>
<td>4</td>
</tr>
<tr>
<td>CHM 040 &amp; CHM 041</td>
<td>Honors General Chemistry I and Honors General Chemistry II</td>
<td>4</td>
</tr>
<tr>
<td>CHM 110 &amp; CHM 111</td>
<td>Organic Chemistry I and Organic Chemistry Laboratory I</td>
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<tr>
<td>CHM 112 &amp; CHM 113</td>
<td>Organic Chemistry II and Organic Chemistry Laboratory II</td>
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Total Credits 74-75

1

Biology electives must include one course from List A (see below) and one course from List B (see below). List C (see below) course electives can count as either List A or List B Biology electives. These will be chosen in consultation with the major advisor. No more than 3 credits can be used from the following courses: BIOS 161, BIOS 261, BIOS 262, BIOS 391, BIOS 393, College scholar project. Credits from BIOS 130 cannot be used to fulfill the biology elective requirement.

Biology Electives List A

Choose one of the following:

<table>
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<tr>
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<th>Credits</th>
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<td>Vertebrate Natural History</td>
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<td>BIOS 276</td>
<td>Central Nervous System and Behavior</td>
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<td>BIOS 313</td>
<td>Vertebrate Histology</td>
<td>4</td>
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<tr>
<td>BIOS 314</td>
<td>Vertebrate Development</td>
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<tr>
<td>BIOS 315</td>
<td>Neuropharmacology</td>
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<tr>
<td>BIOS 317</td>
<td>Evolution</td>
<td>3</td>
</tr>
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<td>BIOS 326</td>
<td>Coevolution</td>
<td>3</td>
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<td>BIOS 329</td>
<td>Herpetology</td>
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<td>Behavioral Neuroanatomy</td>
<td>3</td>
</tr>
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<td>BIOS 334</td>
<td>Species and Speciation</td>
<td>3</td>
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<tr>
<td>BIOS 335</td>
<td>Animal Behavior</td>
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<td>BIOS 337</td>
<td>Behavioral Ecology</td>
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<td>BIOS 369</td>
<td>Comparative Physiology of Vertebrate Systems</td>
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<td>Sex Determination and Differentiation</td>
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<td>BIOS 382</td>
<td>Endocrinology of Behavior</td>
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<td>BIOS 385</td>
<td>Synapses, Plasticity and Learning</td>
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<td>EES 152</td>
<td>Ecology</td>
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<tr>
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<tr>
<td>EES 250</td>
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<td>Microbial Ecology</td>
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<td>Wetland Ecology</td>
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Biology Electives List B

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<tr>
<td>or BIOS 043</td>
<td>Phage Hunting Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>BIOS 044</td>
<td>Introduction to Integrative and Comparative Biology and Introduction to Integrative and Comparative Biology Laboratory</td>
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<tr>
<td>BIOS 115 &amp; BIOS 116</td>
<td>Genetics and Genetics Laboratory</td>
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or BIOS 118 Phage Genetics Laboratory

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<th>Course</th>
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<td>Honors General Chemistry I and Honors General Chemistry II</td>
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<td>CHM 112 &amp; CHM 113</td>
<td>Organic Chemistry II and Organic Chemistry Laboratory II</td>
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Total Credits 74-75

1

Biology electives must include one course from List A (see below) and one course from List B (see below). List C (see below) course electives can count as either List A or List B Biology electives. These will be chosen in consultation with the major advisor. No more than 3 credits can be used from the following courses: BIOS 161, BIOS 261, BIOS 262, BIOS 391, BIOS 393, College scholar project. Credits from BIOS 130 cannot be used to fulfill the biology elective requirement.
**Requirements for the B.S. in Biology**

Progression through the program is best served through early commitment.

**Biology Electives List C**

These courses can count as either List A or List B Biology Electives:

- BIOS 235  Human Physiology  3
- BIOS 233  Evolution of Development  3
- BIOS 338  Neurodegenerative Diseases in Model Organisms  3
- BIOS 365  Neurobiology of Sensory Systems  3
- BIOS 366  Diseases of the Nervous System  3
- BIOS 376  Developmental Biology  3
- BIOS 386  Genes and the Brain  3

**THE B.S. IN BIOLOGY**

The Bachelor of Science in biology offers broad scientific preparation in biology to facilitate advanced work in the life sciences. Progression through the program is best served through early commitment.

**Requirements for the B.S. in Biology**

**College and university requirements for all majors**

<table>
<thead>
<tr>
<th>Course</th>
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<td>ENGL 001</td>
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<td>ENGL 002</td>
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<td>First Year Seminar</td>
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<td>Social Sciences</td>
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<td>Humanities</td>
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**Biology**

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**Biology electives**

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**Mathematics**

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**Collateral Sciences**

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**Biology Electives List A**

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No more than one of the following:

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**Biology Electives List B**

Choose two of the following:

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<th>Credits</th>
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**Total Credits** 98-99

Biology electives must include two courses from List A (see below) and two courses from List B (see below) and at least four credits of laboratory experience (e.g., two 2 credit laboratory courses). List C (see below) course electives can count as either List A or List B Biology electives. These will be chosen in consultation with the major advisor.
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<tr>
<td>BIOS 367</td>
<td>Cell Biology</td>
<td>3</td>
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<tr>
<td>BIOS 371</td>
<td>Elements of Biochemistry I</td>
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<td>BIOS 372</td>
<td>Elements of Biochemistry II</td>
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<td>BIOS 380</td>
<td>Molecular and Cellular Biophysics</td>
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<tr>
<td>BIOS 384</td>
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**Biology Electives List C**

These courses can count as either List A or List B Biology Electives:

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<td>BIOS 323</td>
<td>Evolution of Development</td>
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<td>BIOS 338</td>
<td>Neurodegenerative Diseases in Model Organisms</td>
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<td>BIOS 365</td>
<td>Neurobiology of Sensory Systems</td>
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<td>BIOS 366</td>
<td>Diseases of the Nervous System</td>
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<tr>
<td>BIOS 376</td>
<td>Developmental Biology</td>
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<tr>
<td>BIOS 386</td>
<td>Genes and the Brain</td>
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**RECOMMENDED B.S. BIOLOGY SEQUENCE**

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<tr>
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</tr>
<tr>
<td>AND/OR BIOS 121 &amp; BIOS 122</td>
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<td>CHM 110 &amp; CHM 111</td>
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<td>CHM 112 &amp; CHM 113</td>
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<tr>
<td>BIOS 130</td>
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<th>Third Year</th>
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<td>BIOS 115 &amp; BIOS 116 AND/OR BIOS 121 &amp; BIOS 122</td>
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<tr>
<td>PHY 010 &amp; PHY 012</td>
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<td>PHY 013 &amp; PHY 022</td>
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Approved biology electives including two from list A and two from list B

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<th>Fourth Year</th>
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<td>BIOS 317</td>
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Biology electives including at least 4 credits of laboratory

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TOTAL CREDITS 17-18

**B.A. WITH MAJOR IN BEHAVIORAL NEUROSCIENCE**

The B.A. in Behavioral Neuroscience is a natural science major for B.A. distribution purposes.

**Required Major Courses**

| BIOS 041 & BIOS 042 | Introduction to Cellular and Molecular Biology and Introduction to Cellular and Molecular Biology Laboratory |
| BIOS 044 & BIOS 045 | Introduction to Integrative and Comparative Biology and Introduction to Integrative and Comparative Biology Laboratory |
| BIOS 115 & BIOS 116 | Genetics and Genetics Laboratory |
| BIOS 130 | Biostatistics |
| BIOS 276 | Central Nervous System and Behavior |

Select one of the following:

- BIOS 277 Experimental Neuroscience Laboratory
- BIOS 278 Neurophysiology Laboratory
- BIOS 279 Experimental Molecular Neuroscience Laboratory
- BIOS 382 Endocrinology of Behavior

Select one of the following:

- BIOS 315 Neuropharmacology
- BIOS 323 Evolution of Development
- BIOS 365 Neurobiology of Sensory Systems
- BIOS 366 Diseases of the Nervous System
- BIOS 384 Eukaryotic Signal Transduction
- BIOS 385 Synapses, Plasticity and Learning
- BIOS 386 Genes and the Brain
- BIOS 395 Miscellaneous

**Major Electives**

Select two of the following:

- Any 300-level BIOS course not fulfilling another BNS requirement above
- PSYC 117 Cognitive Psychology
- PSYC 153 Personality
- PSYC 176 Cognitive Neuroscience

**Math and Science Requirements for the B.A.**

Select one of the following:

- MATH 021 Calculus I
- MATH 022 and Calculus II
- MATH 051 Survey of Calculus I
- MATH 052 and Survey of Calculus II

Select one of the following:

- CHM 030 Introduction to Chemical Principles and Chemical Equilibria in Aqueous Systems

**MINOR IN BIOLOGY**

A minor in biology may be achieved by completing the following requirements (17-18 credits):
CHM 040 & CHM 041 Honors General Chemistry I and Honors General Chemistry II 4
CHM 110 & CHM 111 Organic Chemistry I and Organic Chemistry Laboratory I 4
CHM 112 & CHM 113 Organic Chemistry II and Organic Chemistry Laboratory II 4
PSYC 001 Introduction to Psychology 4

Total Credits 56-57

1

Except BIOS 320, BIOS 347, BIOS 383, BIOS 387, BIOS 388, BIOS 391, or BIOS 393.

Other Options
The B.A. in Behavioral Neuroscience can be structured for a wide variety of possibilities (see listing of recommended elective courses).

By using free electives to take additional science, the B.A. also can serve as a pre-professional degree for many graduate and professional schools. Students interested in a particular career should consult their advisor or the program director, Professor Michael Kuchka.

B.S. IN BEHAVIORAL NEUROSCIENCE
An early commitment to the B.S. is desirable to meet all the requirements of this program.

Required Major Courses
BIOS 041 Introduction to Cellular and Molecular Biology 4
& BIOS 042 or BIOS 043
& BIOS 044 Introduction to Integrative and Comparative Biology 4
or BIOS 045
BIOS 115 & BIOS 116 Genetics and Genetics Laboratory 4
& BIOS 118 Phage Genetics Laboratory 4
BIOS 130 Biostatistics 4
BIOS 276 Central Nervous System and Behavior 3

Select one of the following: 2
BIOS 277 Experimental Neuroscience Laboratory 2
BIOS 278 Neurophysiology Laboratory 2
BIOS 279 Experimental Molecular Neuroscience Laboratory 2
BIOS 382 Endocrinology of Behavior 2

Additional Biological Sciences Requirements for the B.S.
BIOS 371 Elements of Biochemistry I 3
BIOS 372 Elements of Biochemistry II 3

Select one of the following: 2-4
BIOS 234 Comparative Vertebrate Anatomy 4
BIOS 368 Cell Biology Laboratory 4
BIOS 377 Biochemistry Laboratory 4
BIOS 277 or BIOS 278 or BIOS 279 (must be different than course chosen for Required Major Courses) 4

Advanced BIOS Course Requirement
Select two of the following: 6
BIOS 315 Neuropharmacology 4
BIOS 323 Evolution of Development 4
BIOS 338 Neurodegenerative Diseases in Model Organisms 4
BIOS 365 Neurobiology of Sensory Systems 4
BIOS 366 Diseases of the Nervous System 4
BIOS 384 Eukaryotic Signal Transduction 4
BIOS 385 Synapses, Plasticity and Learning 4
BIOS 386 Genes and the Brain 4

Math and Science Requirements for the B.S.
Select one of the following: 7-8
MATH 021 Calculus I 4
& MATH 022 and Calculus II 4
MATH 051 Survey of Calculus I 4
& MATH 052 and Survey of Calculus II 4

Select one of the following: 8
CHM 030 Introduction to Chemical Principles and Chemical Equilibria in Aqueous Systems 4
& CHM 031 Honors General Chemistry I and Honors General Chemistry II 4
CHM 110 Organic Chemistry I 4
& CHM 111 and Organic Chemistry Laboratory I 4
CHM 112 Organic Chemistry II 4
& CHM 113 and Organic Chemistry Laboratory II 4

Select one of the following: 5
PHY 010 General Physics I 4
& PHY 012 and Introductory Physics Laboratory I 4
PHY 011 Introductory Physics I 4
& PHY 012 and Introductory Physics Laboratory I 4

Select one of the following: 4-5
PHY 013 General Physics II 4
& PHY 022 and Introductory Physics Laboratory II 4
PHY 021 Introductory Physics II 4
& PHY 022 and Introductory Physics Laboratory II 4
PSYC 001 Introduction to Psychology 4

Major Electives
Select two of the following: 6
Any 300-level BIOS course not fulfilling another BNS requirement above. 2
PSYC 117 Cognitive Psychology 4
PSYC 153 Personality 4
PSYC 176 Cognitive Neuroscience 4

Total Credits 77-81

1

If this course is elected, Cell Biology BIOS 367 must be taken as an elective.

2

Except BIOS 320, BIOS 347, BIOS 383, BIOS 387, BIOS 388, BIOS 391, or BIOS 383.

B.A. WITH MAJOR IN MOLECULAR BIOLOGY
Requirements for the B.A. in Molecular Biology
College and university requirements for all majors
ENGL 001 Critical Reading and Composition 3
ENGL 002 Research and Argument 3
First Year Seminar 3
Social Sciences 8
Humanities 8

Biology
BIOS 041 & BIOS 042 Introduction to Cellular and Molecular Biology 4
or BIOS 043 and Introduction to Cellular and Molecular Biology Laboratory 4
BIOS 044 & BIOS 045 Introduction to Integrative and Comparative Biology 4
or BIOS 043 and Introduction to Integrative and Comparative Biology Laboratory 4
BIOS 115 & BIOS 116 Genetics and Genetics Laboratory 4
or BIOS 118  Phage Genetics Laboratory
Select one of the following:  3
  BIOS 324  Microbiology
  BIOS 328  Immunology
Select one of the following:  2-3
  BIOS 325  Microbiology Laboratory
  BIOS 368  Cell Biology Laboratory
  BIOS 377  Biochemistry Laboratory
BIOS 371  Elements of Biochemistry I  3
BIOS 345  Molecular Genetics  5
& BIOS 346  and Molecular Genetics Laboratory
BIOS 367  Cell Biology  3
BIOS approved electives  6

Mathematics
Select one of the following:  7-8
  MATH 021  Calculus I
  & MATH 022  and Calculus II
  MATH 051  Survey of Calculus I
  & MATH 052  and Survey of Calculus II

Chemistry
Select one of the following:  4
  CHM 030  Introduction to Chemical Principles
  CHM 040  Honors General Chemistry I
Select one of the following:  4
  CHM 031  Chemical Equilibria in Aqueous Systems
  CHM 041  Honors General Chemistry II
CHM 110  Organic Chemistry I  4
& CHM 111  and Organic Chemistry Laboratory I
CHM 112  Organic Chemistry II  4
& CHM 113  and Organic Chemistry Laboratory II

Physics
Select one of the following:  5
  PHY 010  General Physics I
  & PHY 012  and Introductory Physics Laboratory I
  PHY 011  Introductory Physics I
  & PHY 012  and Introductory Physics Laboratory I
Select one of the following:  4-5
  PHY 013  General Physics II
  & PHY 022  and Introductory Physics Laboratory II
  PHY 021  Introductory Physics II
  & PHY 022  and Introductory Physics Laboratory II

Molecular Biology
BIOS 041  Introduction to Cellular and Molecular Biology
& BIOS 042  and Introduction to Cellular and Molecular Biology Laboratory
or BIOS 043  and Phage Hunting Laboratory
BIOS 044  Introduction to Integrative and Comparative Biology
& BIOS 045  and Introduction to Integrative and Comparative Biology Laboratory
BIOS 115  Genetics
& BIOS 116  and Genetics Laboratory
or BIOS 118  Phage Genetics Laboratory
Select one of the following:  3
  BIOS 324  Microbiology
  BIOS 328  Immunology
Select one of the following:  2-3
  BIOS 325  Microbiology Laboratory
  BIOS 368  Cell Biology Laboratory
  BIOS 377  Biochemistry Laboratory
BIOS 345  Molecular Genetics  5
& BIOS 346  and Molecular Genetics Laboratory
BIOS 367  Cell Biology  3
BIOS 371  Elements of Biochemistry I  3
BIOS 372  Elements of Biochemistry II  3
BIOS 381  Physical Biochemistry  3
BIOS Approved Molecular Biology Electives  12

Total Credits  82-85

RECOMMENDED SEQUENCE FOR THE B.S. IN MOLECULAR BIOLOGY

THE B.S. IN MOLECULAR BIOLOGY
Requirements for the B.S. in Molecular Biology

Mathematics
Select one of the following:  7-8
  MATH 021  Calculus I
  & MATH 022  and Calculus II
  MATH 051  Survey of Calculus I
  & MATH 052  and Survey of Calculus II
BIOS 130  Biostatistics  4

Chemistry
Select one of the following:  4
  CHM 030  Introduction to Chemical Principles
  CHM 040  Honors General Chemistry I
Select one of the following:  4
  CHM 031  Chemical Equilibria in Aqueous Systems
  CHM 041  Honors General Chemistry II
CHM 110  Organic Chemistry I  4
& CHM 111  and Organic Chemistry Laboratory I
CHM 112  Organic Chemistry II  4
& CHM 113  and Organic Chemistry Laboratory II
CHM 112  Organic Chemistry II
& CHM 113  and Organic Chemistry Laboratory II  4

Physics
Select one of the following:  5
  PHY 010  General Physics I
  & PHY 012  and Introductory Physics Laboratory I
  PHY 011  Introductory Physics I
  & PHY 012  and Introductory Physics Laboratory I
Select one of the following:  4-5
  PHY 013  General Physics II
  & PHY 022  and Introductory Physics Laboratory II
  PHY 021  Introductory Physics II
  & PHY 022  and Introductory Physics Laboratory II

Total Credits  91-94

The B.S. in Molecular Biology

First Year  CR
BIOS 041  4
& BIOS 042  4
MATH 021  4
MATH 022  4
CHM 030  4
CHM 031  4

Second Year  CR
BIOS 115  4
& BIOS 116  4
CHM 110  4
& CHM 111  4
CHM 112  4
& CHM 113  4
PHY 010  5
& PHY 012  5

Total Credits  20
**GRADUATE STUDY IN THE BIOLOGICAL SCIENCES**

A research oriented program leading to a Doctor of Philosophy in Biology is offered, with concentrations in: biochemistry (https://www.lehigh.edu/~inbios/Grad/Grad_DDP.html#biochem), evolution and behavior (https://www.lehigh.edu/~inbios/Grad/Grad_DDP.html#evolution), neuroscience (https://www.lehigh.edu/~inbios/Grad/Grad_DDP.html#neuro) and cell and molecular biology (https://www.lehigh.edu/~inbios/Grad/Grad_DDP.html#cell). To complete the program students must successfully complete core courses, pass a qualifying exam, prepare, submit, and successfully defend a written research proposal, complete the research described in the proposal, and submit a written dissertation and defend the completed research to the department.

Once students enter the department, their progress is monitored by the graduate committee until they are admitted to candidacy. Members of the committee meet with the student each semester to assess the student’s progress towards the degree and to assist students in choosing the appropriate courses to provide a solid scientific foundation and an up-to-date understanding of the discipline. This will be assessed by the qualifying exam.

The qualifying exam generally should be taken after the third semester and no later than the fourth semester of course work. It will be prepared, administered and graded by the faculty associated with the specific graduate program in which the student is enrolled. It consists of a two-day written exam and an oral examination. The exam can be repeated once. Admission to candidacy is granted after successful completion of the qualifying exam and the thesis proposal. The proposal is a written description of an original research project developed under the guidance of a faculty member chosen by the student to be his/her advisor. The proposal will be presented orally to the thesis committee, typically after the fifth semester. Following the presentation of the proposal, an oral examination will take place in which the thesis committee will question the student about general science related to the project. This will constitute the general examination.

Core requirements for each division are listed below. The graduate school requires students to register for at least 72-post baccalaureate credits to earn the Ph.D. In addition, all students must take BIOS 408 (0 credits) Responsible Conduct of Science within their first year of graduate study. All students must also attend departmental seminars and enroll in BIOS 406 (1 credit) Biological Sciences Seminar at least twice in the first four semesters. A minimum of 24 course credits may be chosen from upper level courses in biochemistry, molecular biology, cell biology, behavioral biology and evolutionary biology, and neuroscience. At least 12 of these credits must be at the 400 level.

### Concentration: Biochemistry

In the Biochemistry concentration, research areas include DNA/RNA structure and function, regulation of protein synthesis, and signal transduction. Students admitted to graduate study in the biochemistry concentration will typically have an undergraduate degree in Chemistry or Biology. Students with an undergraduate degree in a related discipline are expected to have the following undergraduate preparation for graduate study: beyond introductory chemistry and a year of organic chemistry, at least one semester of analytical chemistry and one semester of physical chemistry—thermodynamics and kinetics, with appropriate math. Students without that background are expected to take courses to fulfill those requirements as part of their graduate study.

### GRADUATE STUDY IN BIOLOGY

A rigorous, research-oriented graduate program leading to a Doctor of Philosophy in Biology with concentrations in biochemistry; molecular and cell biology; neuroscience; and evolution and behavior is offered in the Department of Biological Sciences. To complete the program students must successfully complete core courses, pass a qualifying exam, prepare, submit, and successfully defend a written research proposal, complete the research described in the proposal, and submit a written dissertation and defend the completed research to the department.

Once students enter the department, their progress is monitored by the graduate committee until they are admitted to candidacy. Members of the committee meet with the student each semester to assess the student's progress towards the degree and to assist students in choosing the appropriate courses to provide a solid foundation and an up-to-date understanding of the discipline.
scientific foundation and an up-to-date understanding of the discipline. This will be assessed by the qualifying exam. The qualifying exam generally should be taken after the third semester and no later than the fourth semester of course work. It will be prepared, administered and graded by the faculty associated with the specific concentration in which the student is enrolled. It consists of a two-day written exam and an oral examination. The exam can be repeated once. Admission to candidacy is granted after successful completion of the qualifying exam and the thesis proposal. The proposal is a written description of an original research project developed under the guidance of a faculty member chosen by the student to be his/her advisor. The proposal will be presented orally to the thesis committee, typically after the fifth semester. Following the presentation of the proposal, an oral examination will take place in which the thesis committee will question the student about general science related to the project. This will constitute the general examination.

Core requirements for each concentration are listed below. The graduate school requires students to register for at least 72-post baccalaureate credits to earn the Ph.D. In addition, all students must take BIOS 408 (http://catalog.lehigh.edu/search/?P=BIOS%20408) (0 credits) Responsible Conduct of Science within their first year of graduate study. All students must also attend departmental seminars and enroll in BIOS 406 (http://catalog.lehigh.edu/search/?P=BIOS%20406) (1 credit) Biological Sciences Seminar at least twice in the first four semesters. A minimum of 24 course credits may be chosen from upper level courses in biochemistry, molecular biology, cell biology, behavioral biology and evolutionary biology, and neuroscience. At least 12 of these credits must be at the 400 level.

Biochemistry concentration
In the biochemistry program, research areas include DNA structure and function, regulation of protein synthesis, and signal transduction. Students admitted to graduate study in biochemistry will typically have an undergraduate degree in chemistry or biochemistry. Students with an undergraduate degree in a related discipline will be expected to have the following undergraduate preparation for graduate study beyond introductory chemistry and a year of organic chemistry: at least one semester of analytical chemistry and one semester of physical chemistry thermodynamics and kinetics, with appropriate math. Students without that background will be expected to take courses to fulfill those requirements as part of their graduate study.

Required courses
- BIOS 371 Elements of Biochemistry I 3
- BIOS 372 Elements of Biochemistry II 3
- CHM 423 Chemical Biology 3
- BIOS 345 Molecular Genetics 3
- Seminar course
  - BIOS 406 Biological Sciences Seminar 1
  - or CHM 400 First Year Graduate Student Seminar

Molecular Cell Biology concentrations
The graduate program in molecular cell biology is designed to train students in advanced topics in molecular biology with emphases on molecular and cellular biology, neurobiology, and physiology. The mission of the program is to create students who are broadly trained and uniquely capable of asking questions and solving problems at the interface of these traditionally defined fields. Students admitted to the program should have a basic knowledge of evolution, anatomy, physiology and/or behavioral ecology. Students will begin by taking core courses providing a broad, integrative foundation in evolution and behavior at the graduate level and work toward a Ph.D. with a concentration in evolution and behavior. Regardless of concentration, all students develop an appreciation for the fact that all aspects of biology, whether cellular, physiological, anatomical, behavioral, evolutionary, or social, are inextricably linked and cannot be fully understood as separate, parallel systems of knowledge.

ANIMAL BEHAVIOR AND EVOLUTION CONCENTRATION
The graduate program in evolution and behavior is designed to train students in advanced organismal biology with emphases on behavioral ecology, evolution, and/or functional morphology. The mission of the program is to create students who are broadly trained and uniquely capable of asking questions and solving problems at the interface of these traditionally defined fields. Students admitted to the program should have a basic knowledge of evolution, anatomy, physiology and/or behavioral ecology. Students will begin by taking core courses providing a broad, integrative foundation in evolution and behavior at the graduate level and work toward a Ph.D. with a concentration in evolution and behavior. Regardless of concentration, all students develop an appreciation for the fact that all aspects of biology, whether cellular, physiological, anatomical, behavioral, evolutionary, or social, are inextricably linked and cannot be fully understood as separate, parallel systems of knowledge.

ANIMAL BEHAVIOR AND EVOLUTION CONCENTRATION
Required Courses
Take three (3) of the following:
- BIOS 423 Evolution of Development
- BIOS 426 Coevolution
- BIOS 428 Molecular Evolution
- BIOS 434 Speciation
- BIOS 439 Advanced Behavioral Ecology

Take one (1) course from EITHER the 400-level Cell and Molecular offerings (see Catalog entry) OR the 400-level Animal Behavior and Evolution offerings (see above)

Additional Requirements
- BIOS 401 Professional Skills for Biological Sciences Graduate Students (strongly recommended to be taken in first two years)
- BIOS 406 Biological Sciences Seminar (2 semesters)
- BIOS 408 Responsible Conduct of Science

CELL AND MOLECULAR BIOLOGY CONCENTRATION
In the cell and molecular biology program, research areas include microbial evolution and genetics, plant and animal molecular genetics, eukaryotic cell biology, and regulation of gene expression.

Required Courses
Take one (1) of the following:
- BIOS 453 General Neuroanatomy
- BIOS 457 Advanced Behavioral Neuroendocrinology

Take one (1) of the following:
- BIOS 415 Synapses, Plasticity and Learning
- BIOS 424 Advanced Neurobiology of Sensory Systems

Take one (1) of the following:
- BIOS 471 Eukaryotic Signal Transduction
- BIOS 486 Genes and the Brain

Take one (1) course from EITHER the 400-level Cell and Molecular offerings (see Catalog entry) OR the 400-level Animal Behavior and Evolution offerings (see above)

ANIMAL BEHAVIOR AND EVOLUTION CONCENTRATION
Required Courses
Take three (3) of the following:
- BIOS 423 Evolution of Development
- BIOS 426 Coevolution
- BIOS 428 Molecular Evolution
- BIOS 434 Speciation
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CELL AND MOLECULAR BIOLOGY CONCENTRATION
In the cell and molecular biology program, research areas include microbial evolution and genetics, plant and animal molecular genetics, eukaryotic cell biology, and regulation of gene expression.

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Take one (1) of the following:
- BIOS 415 Synapses, Plasticity and Learning
- BIOS 424 Advanced Neurobiology of Sensory Systems

Take one (1) of the following:
- BIOS 471 Eukaryotic Signal Transduction
- BIOS 486 Genes and the Brain

Take one (1) course from EITHER the 400-level Cell and Molecular offerings (see Catalog entry) OR the 400-level Animal Behavior and Evolution offerings (see above)
Courses

BIOS 010 Biocience in the 21st Century 3 Credits
A multidisciplinary survey of advances in bioscience. Exploration of theme-based topics (e.g., infectious diseases, cancer, genomebase medicine, engineered biomedical systems) coupled with social/ethical considerations. Three lectures per week. Participation in online multidisciplinary discussion, writing assignments, field trips, and/or other activities.
Attribute/Distribution: NS

BIOS 032 (EES 032) Oceanography 3 Credits
An introduction to the structure, composition, and processes of the earth from a marine perspective. Topics include earth structure, plate tectonics, continental margins, coastal processes, seawater chemistry, ocean circulation, wave dynamics, primary productivity, plankton and plants, marine organisms and communities. May be combined with EES 022 or EES 004 for 4 credits.
Attribute/Distribution: NS

BIOS 041 Introduction to Cellular and Molecular Biology 0,3 Credits
Basic building blocks and higher order structures required for cellular processes. Topics include the character of membranes, the molecular/cellular basis of energy production, cell cycle progression, DNA replication, gene expression, basic Mendelian genetics, signal transduction, and cell division.
Prerequisites: CHM 075 or CHM 025 or CHM 030 or CHM 040
Can be taken Concurrently: CHM 075, CHM 025, CHM 030, CHM 040

BIOS 042 Introduction to Cellular and Molecular Biology Laboratory 1 Credit
Techniques and experiments related to the principal topics covered in BIOS 041; emphasis on experimental design and scientific communication.
Prerequisites: BIOS 041
Can be taken Concurrently: BIOS 041

BIOS 043 Phage Hunting Laboratory 2 Credits
The first laboratory research course in a two-semester series (as part of the Howard Hughes Medical Institute’s SEA-PHAGES Program) that focuses on the isolation (from local soil), as well as the physical and genomic characterization of novel bacteriophages that infect mycobacteria. Course will substitute for BIOS 42. Application and acceptance into Lehigh’s SEA program required (see www.lehigh.edu/~insea); freshman status in the spring semester or permission of the instructor. Co-requisite: BIOS 41 or instructor permission.
Prerequisites: BIOS 041
Can be taken Concurrently: BIOS 041

BIOS 044 Introduction to Integrative and Comparative Biology 0,3 Credits
Experimental and historical approaches to the analysis of structural and functional properties in organisms. Use of scientific method to study species diversity. Introduction to the analysis of organismal attributes that explain behavioral repertoire and ecological relationships.
Prerequisites: BIOS 041 and (BIOS 042 or BIOS 043).

BIOS 045 Introduction to Integrative and Comparative Biology Laboratory 1 Credit
Experiments and discussions related to the topics covered in BIOS 044; emphasis on experimental design and scientific communication.
Prerequisites: BIOS 044
Can be taken Concurrently: BIOS 044
Corequisites: BIOS 044
Attribute/Distribution: NS

BIOS 115 Genetics 0,3 Credits
Prerequisites: BIOS 041
Attribute/Distribution: NS

BIOS 116 Genetics Laboratory 1 Credit
Introduction to model organisms; techniques used in molecular genetics; experimental design and scientific communication.
Prerequisites: BIOS 115
Can be taken Concurrently: BIOS 115
Attribute/Distribution: NS

BIOS 118 Phage Genetics Laboratory 2 Credits
Part of a 2-semester series focusing on genetic analysis of novel bacteriophage genomes to determine gene function using recombining strategies. Phage genome annotation using bioinformatics for previously sequenced phage genomes. Additional genetics, molecular biology, and/or biochemical research on previously isolated bacteriophages may also be included.
Prerequisites: BIOS 115
Can be taken Concurrently: BIOS 115
Corequisites: BIOS 115

BIOS 130 (MATH 130) Biostatistics 4 Credits
Elements of statistics and probability theory with emphasis on biological applications. Statistical analysis of experimental and observational data.
Prerequisites: BIOS 041 and MATH 052 or MATH 022
Attribute/Distribution: ND

BIOS 161 Supervised Research 1-3 Credits
Apprenticeship in ongoing faculty research program. Literature review, experimental design, data collection and analysis, and professional writing under faculty sponsor supervision. Only 3 credits can be counted toward any life science major. Consent of instructor required.
Repeat Status: Course may be repeated.
Prerequisites: BIOS 041

BIOS 202 Biomedical Externship 0-3 Credits
Analysis of individualized experiences at external biomedical clinical or research sites. Limited enrollment. May not be taken for pass/fail grading. May not be used to satisfy any life science major or minor requirement. Consent of department chair required.
Attribute/Distribution: NS

BIOS 234 Comparative Vertebrate Anatomy 4 Credits
A course in vertebrate zoology with emphasis on the study of homologous body structures in the various vertebrate classes and their relationship to the functional demands of habit and environment in each class. Detailed dissections of representative vertebrates are made in the laboratory. Two lectures and two laboratory periods.
Prerequisites: BIOS 044 and BIOS 045
Attribute/Distribution: NS

BIOS 235 Human Physiology 3 Credits
The goal of this course is to provide students with a thorough understanding of the major systems of the human body. Students will examine many of the major body systems including Nervous, Muscular, Cardiac, Respiratory, and Digestive systems. These systems will be analyzed by their components at both the cellular and molecular level. Students will also examine how each system functions as a whole and how it interacts with other systems at the organismal level.
Prerequisites: BIOS 044
Attribute/Distribution: NS
BIOS 237 (BIOC 237) Introductory Molecular Modeling and Simulation 3 Credits
Key concepts, methods, and tools used in molecular modeling and simulation. A hybrid lecture/hands-on practice course using the lectures and tools in CHARMM-GUI (http://www.charmm-gui.org/lecture). Topics include (but not limited to) UNIX operating system, text editors, Python programming, scientific programming using Python, PDB (Protein Data Bank), molecular mechanics, minimization, molecular dynamics, Monte Carlo simulation. The understanding of these concepts and algorithms as well as their applications to well-defined practical examples involving currently important biological problems will be emphasized.
Prerequisites: CHM 030 or CHM 040
Attribute/Distribution: NS

BIOS 238 Epigenetics, Health, and Environment 3 Credits
Foundational concepts in environmental epigenetics. Course will be centered around presentations and discussions of studies that address current issues, such as the mechanisms behind heritable health effects of acute malnourishment in human populations across multiple generations, or the potential for extremely fast evolutionary adaptation in species threatened by environmental change. This course may be listed as a Writing Intensive course.
Prerequisites: BIOS 044
Attribute/Distribution: NS

BIOS 241 Vertebrate Natural History 4 Credits
An introduction to the ecology, behavior, distribution and evolution of vertebrates, with emphasis on the North American fauna. Two lectures, one tutorial and one laboratory and field trip. This course may be used to fulfill junior writing requirements with the permission of the instructor.
Prerequisites: BIOS 044 and BIOS 045
Attribute/Distribution: NS

BIOS 251 Writing and Biological Sciences 3 Credits
A course designed to acquaint students with some of the intellectual foundations of science, with attention to the distinctiveness of the biological sciences. Format includes readings, intensive writing, extemporaneous speaking, and discussion. May not be used to fulfill Biology B.A. elective requirements.
Attribute/Distribution: NS

BIOS 261 Special Topics in Biological Sciences 1-3 Credits
Research, conferences and reports on selected topics not covered in the general undergraduate offerings. Consent of instructor required.
Repeat Status: Course may be repeated.
Attribute/Distribution: NS

BIOS 262 Research Proposal 3 Credits
Literature and methods of research in area of department faculty expertise. Requires development of detailed proposal for research to be performed in senior year. Must have major in any biological sciences degree program, junior standing, GPA of 3.0 in major, and consent of department.
Attribute/Distribution: NS

BIOS 274 (HMS 274) Neuroethics 3 Credits
The intersection of neuroscience and ethics. History of biomedical science and current topics in neuroethics explored through weekly case studies and relevant readings in neurobiology. Examples include: definitions of mental illness, definitions of consciousness and brain death, addiction neuroscience, brain-machine interfaces, wearable technology, social determinants of health and equity within science and medicine. Reading and critical analysis of scientific articles, integration of biological concepts with moral reasoning, effective written communication and participation in peer review, oral presentations and group discussions.
Prerequisites: BIOS 044
Attribute/Distribution: NS

BIOS 276 Central Nervous System and Behavior 3 Credits
Neuronal anatomy and neurophysiology of animal and human behavior. Feeding, thirst, sleep, emotions, learning, and psychopathology.
Prerequisites: BIOS 044
Attribute/Distribution: NS

BIOS 277 Experimental Neuroscience Laboratory 2 Credits
Structure and function of the mammalian brain with special attention to cellular morphology and organization. Widely used histological and behavioral techniques to determine how the shape and function of the nervous system regulates behavior. Experimental design, hypothesis testing, statistical analysis, reading and writing of scientific papers, basic histology and imaging.
Prerequisites: BIOS 276
Can be taken Concurrently: BIOS 276
Attribute/Distribution: NS

BIOS 278 Neurophysiology Laboratory 2 Credits
The functional electrical underpinnings of the nervous system explored through direct recordings and thorough data analyses. Experimental design, hypothesis testing, numerical analysis, reading and writing of primary science.
Prerequisites: BIOS 276
Can be taken Concurrently: BIOS 276
Attribute/Distribution: NS

BIOS 279 Experimental Molecular Neuroscience Laboratory 2 Credits
Inquiry-based lab course emphasizing molecular and cellular neuroscience approaches to understanding the nervous system. Opportunity for making real research discoveries on the genetic and cellular underpinnings of brain function. Molecular genetic, bioinformatic, and neurochemical techniques. Can be taken more than once with instructor approval.
Repeat Status: Course may be repeated.
Prerequisites: BIOS 276
Can be taken Concurrently: BIOS 276
Attribute/Distribution: NS

BIOS 300 Apprentice Teaching 1-4 Credits
Repeat Status: Course may be repeated.

BIOS 313 Vertebrate Histology 4 Credits
Microstructural and ultrastructural properties of vertebrate cells and tissues. Techniques of tissue preparation. Two lectures and two labs.
Prerequisites: BIOS 044 and BIOS 045
Attribute/Distribution: ND, NS

BIOS 314 Vertebrate Development 4 Credits
Germ cell formation, fertilization, early development, and the origin of the principal organ systems. Location, structure, and regulation of information from molecular to organismal levels of organization.
Prerequisites: BIOS 044 and BIOS 045
Attribute/Distribution: NS

BIOS 315 Neuropharmacology 3 Credits
Prerequisites: BIOS 276
Attribute/Distribution: NS

BIOS 317 Evolution 3 Credits
Prerequisites: BIOS 044
Attribute/Distribution: NS

BIOS 318 Advanced Phage Research Laboratory 1-3 Credits
Apprentice-based laboratory research in phage biology in collaboration with faculty who direct Lehigh's SEA Phages Program (sponsored by the Howard Hughes Medical Institute). Research will focus on discoveries uncovered in SEA Phage courses and may include genetic, molecular, and biochemical analyses of novel bacteriophage genes, genomes, and novel gene functions. Additional research may include phage genome annotation using computational biology tools.
Repeat Status: Course may be repeated.
Prerequisites: BIOS 115 and BIOS 118
Attribute/Distribution: NS
BIOS 320 (ENTP 320) The Business of Life Science 3 Credits
An examination of business process in startup, early stage and developing bioscience companies. Technology assessment, business plan and proposal preparation, financial strategies, resource management, intellectual property, and legal as well as regulatory issues. Cannot be used to fulfill major or minor requirements in Biological Sciences.
Prerequisites: BIOS 121
Attribute/Distribution: NS

BIOS 323 Evolution of Development 3 Credits
This course examines how changes in the blueprint that describes the development of a multicellular animal from a single fertilized egg lead to the evolution of new species or new forms within a species.
Prerequisites: BIOS 317 or BIOS 376 or BIOS 327
Can be taken Concurrently: BIOS 317, BIOS 376, BIOS 327

BIOS 324 Microbiology 3 Credits
An examination of microbial life, including archaea, bacteria, fungi, protists and viruses. Emphasis on microbial molecular genetics and its relationship to the origin of life, human health/medicine, and the environment.
Prerequisites: CHM 110 and BIOS 115
Attribute/Distribution: NS

BIOS 325 Microbiology Laboratory 2 Credits
Laboratory studies of microorganisms, focusing on bacteria and fungi. Techniques for isolating, culturing, and identifying microorganisms. Experiments in microbial molecular genetics, phylogenetics, and evolution using traditional and modern techniques, as well as other topics covered in BIOS 324.
Prerequisites: BIOS 324
Can be taken Concurrently: BIOS 324

BIOS 326 Coevolution 3 Credits
Discussion-based seminar course covering readings from the primary literature. Course will examine evolutionary consequences of species interactions, interactions between the sexes, and genetic interactions. Topics will include predator-prey interactions, host-parasite interactions, sexual conflict, genomic conflict, mutualism, and more. Consequences of coevolution for biodiversity and human health will also be examined.
Prerequisites: BIOS 317
Attribute/Distribution: NS

BIOS 327 Development and Disease 3 Credits
Development of organs from precursor cells; diseases that impact organ function. Focus on understanding how mutations or other causes influence organ development and function. Combination lecture and primary literature.
Prerequisites: BIOS 376
Attribute/Distribution: NS

BIOS 328 Immunology 3 Credits
Distinction of "self" and "nonself" through humoral and cellular mechanisms. Antigens; biochemical structures, cellular mechanisms, genetic control and processing, phylogenetic distribution, diseased states.
Prerequisites: BIOS 115
Attribute/Distribution: NS

BIOS 329 Herpetology 3 Credits
Biology of amphibians and reptiles. Two lectures, one laboratory or field trip per week.
Prerequisites: BIOS 044 and BIOS 045
Attribute/Distribution: ND

BIOS 330 Molecular Evolution 3 Credits
This course will focus on evolution at the level of individual genes, proteins, and genomes, alternating between lecture and discussion of papers from the recent primary literature. Topics include pathways for adaptive evolution, directionality in evolution, epistasis, evolvability, genome rearrangements and speciation, gene duplication, and evolutionary dynamics. We will draw on examples from the molecular evolution in nature, laboratory model systems, and human pathogens.
Prerequisites: BIOS 317 or BIOS 345
Can be taken Concurrently: BIOS 317, BIOS 345
Attribute/Distribution: NS

BIOS 332 Behavioral Neuroanatomy 3 Credits
The study of neuroanatomy that underlies social and motivated behaviors and the techniques that support this study. Students learn by researching and reporting on original research, and ultimately designing and describing an original study on the topic.
Prerequisites: BIOS 276
Attribute/Distribution: NS

BIOS 334 Species and Speciation 3 Credits
Consideration of the origin of species. Discussion of a variety of "species" definitions and exploration of the evolutionary mechanisms by which new species arise. Alternation between lecture and discussion, drawing on the textbook and on current and classical literature.
Prerequisites: BIOS 317

BIOS 335 (PSYC 335) Animal Behavior 3 Credits
Discussion of the behavior of invertebrates and vertebrates and analysis of the physiological mechanisms responsible for behavioral stimuli, and adaptive value of specific behavior patterns.
Prerequisites: BIOS 044
Attribute/Distribution: NS

BIOS 336 Animal Behavior Laboratory 2 Credits
Experiments and field observations illustrating principles discussed in BIOS 335. Emphasis on observing animals, performing experiments, collecting and analyzing data, and individual research. Six hours of laboratory per week.
Prerequisites: BIOS 335 or BIOS 337
Can be taken Concurrently: BIOS 335, BIOS 337
Attribute/Distribution: NS

BIOS 337 Behavioral Ecology 3 Credits
Social systems of vertebrate and invertebrate groups. Emphasis on ecological and evolutionary factors that influence social behavior.
Prerequisites: BIOS 044
Attribute/Distribution: NS

BIOS 338 Neurodegenerative Diseases in Model Organisms 3 Credits
Discussion-based seminar course on the use of model systems to investigate neurodegenerative diseases. The primary focus will be on invertebrate model systems, including Drosophila. Critical reading of primary scientific literature and student discussion is required.
Prerequisites: BIOS 115

BIOS 339 Computational, Molecular Modeling and Simulation 3 Credits
This course is designed to introduce the most basic and key concepts, methods, and tools used in molecular modeling and simulation. This class is a hybrid of lecture and hands-on practice styles, using the lectures and tools in CHARM-GUI (http://www.charmm-gui.org/lecture). Some topics include the UNIX operating system, text editors, Python programming and Monte Carlo simulation. The understanding of these concepts and algorithms, as well as their applications to well-defined practical examples involving currently important biological problems will be emphasized.
Attribute/Distribution: NS

BIOS 340 Molecular Basis of Disease 3 Credits
Lectures and student projects on molecular mechanisms of human disease. Physiology of disease, molecular mechanisms, therapeutic approaches, ongoing research. Topics include: neurodegenerative diseases, cancer, autoimmune diseases, infectious diseases.
Prerequisites: BIOS 115
Attribute/Distribution: NS
BIOS 342 Cellular Basis of Human Disease 3 Credits
Cell and molecular biological advanced topics relevant to human disease and/or health. Critical reading of the primary literature, discussion and student discussion required.
Prerequisites: BIOS 367 or BIOS 411
Attribute/Distribution: NS

BIOS 343 Personal Genomics 3 Credits
Contemporary methods and technologies for investigating human genetic variation and its use for inferring ancestry and risk for disease, along with discussions of relevant policy and ethics. Readings will include primary scientific literature in population and statistical genetics, government publications, and news reports. Final projects will involve development of outreach and education resources in this topic for non-experts.
Prerequisites: (BIOS 115 and BIOS 130) or BIOS 317
Attribute/Distribution: NS

BIOS 345 Molecular Genetics 3 Credits
The organization and replication of genetic material; mutagenesis; mechanisms of regulation; mechanisms of gene transmission involving prokaryotes and eukaryotes and their viruses; techniques for intervention into genetic organization and expression.
Prerequisites: BIOS 115
Attribute/Distribution: NS

BIOS 346 Molecular Genetics Laboratory 2 Credits
Laboratory experiments related to the topics covered in BIOS 345. Emphasis is on molecular characterization of DNA and the principles of gene isolation and transfer.
Prerequisites: BIOS 345
Can be taken Concurrently: BIOS 345
Attribute/Distribution: NS

BIOS 347 Advanced Topics in Genetics 3 Credits
Lectures and student projects on selected aspects of genetics such as the genetics and evolution of particular organisms, regulation of gene expression and transmission, human genetics, gene therapy, etc. Consent of department chair.
Prerequisites: BIOS 115 and BIOS 116
Attribute/Distribution: NS

BIOS 348 Marine Biology 3 Credits
Ecology and adaptations of marine species, populations and ecosystems. Studying life in the ocean requires a perspective that spans spatial and temporal scales from the planetary to the microscopic, from the geologic to the physiological, and from the surface to the deepest seafloor. Through this course, students develop a fundamental understanding of how the physical environment of planet earth shapes and is shaped by marine organisms.
Prerequisites: BIOS 041 and BIOS 042
Attribute/Distribution: NS

BIOS 353 Virology 3 Credits
An introduction to viruses and their interactions with host organisms. Topics include viral pathogenesis, from entry through release, viral immune evasion mechanisms, and viral evolution. Vaccines, antiviral strategies, as well as therapeutic uses of viruses for gene therapy will be emphasized.
Prerequisites: BIOS 115
Attribute/Distribution: NS

BIOS 365 Neurobiology of Sensory Systems 3 Credits
The fundamental features of sensory systems in a diverse array of animals. Focus on how nervous systems detect, compute, and internally represent aspects of the environment from the single cell to whole system level. Special attention to the way sensory processing influences how we think about the biological basis of perception and possible mechanisms for consciousness. Instructor permission required.
Prerequisites: BIOS 276
Attribute/Distribution: NS

BIOS 366 Diseases of the Nervous System 3 Credits
Neurobiological basis of CNS disorders, including affective, neurological and psychotic conditions. Emphasis on primary literature covering causes, diagnostic and treatment issues.
Prerequisites: BIOS 276 or BIOS 382
Attribute/Distribution: NS

BIOS 367 Cell Biology 3 Credits
Molecular aspects of cell biology. Emphasis on membrane structure and function, organelle biogenesis, cell motility, the cytoskeleton, and extracellular matrix.
Prerequisites: BIOS 115
Attribute/Distribution: NS

BIOS 368 Cell Biology Laboratory 2 Credits
Basic methods used in cell biology laboratories around the world and the opportunity to carry out an independent research project. Techniques include histology and microscopy (both white and fluorescent light), tissue culture and sterile procedures, cellular fractionation, nuclear import assays, and immunological probing. Consent of department required.
Prerequisites: BIOS 367
Can be taken Concurrently: BIOS 367
Attribute/Distribution: NS

BIOS 369 Comparative Physiology of Vertebrate Systems 3-4 Credits
Functional analysis of energy balance in vertebrate animal models. Digestion, respiration, circulation, and excretion, across aquatic and terrestrial vertebrates. Homeostatic mechanisms of salt, water, and gas exchange. Ionotropic and metabotropic signal transduction. Hormonal and electrical cellular communication among muscles, glands, and neurons. Sensory systems, movement and reproduction. Physiological adaptations to extreme environments. When offered for 4 credits, the course includes one laboratory meeting per week.
Prerequisites: BIOS 044 and BIOS 045
Attribute/Distribution: NS

BIOS 371 (CHM 371) Elements of Biochemistry I 0.3 Credits
A general study of carbohydrates, proteins, lipids, nucleic acids and other biological substances and their importance in life processes. Protein and enzyme chemistry are emphasized. Must have completed one year of organic chemistry.
Prerequisites: CHM 112
Attribute/Distribution: NS

BIOS 372 (CHM 372) Elements of Biochemistry II 3 Credits
Dynamic aspects of biochemistry; enzyme reactions including energetics, kinetics and mechanisms; metabolism of carbohydrates, lipids, proteins and nucleic acids; photosynthesis, electron transport mechanisms, coupled reactions, phosphorylations, and the synthesis of biological macromolecules.
Prerequisites: BIOS 473 or ((BIOS 371 or CHM 371) and BIOS 041)
Attribute/Distribution: NS

BIOS 374 Sex Determination and Differentiation 3 Credits
An examination of the primary scientific literature on how sex is conferred to a zygote. Hormonal and non-hormonal mechanisms of sexual differentiation. Neural correlates of sex, gender, and sexual orientation.
Prerequisites: BIOS 367 or BIOS 371 or BIOS 382
Attribute/Distribution: NS

BIOS 375 Methods in Developmental Biology Lab 2 Credits
Detection of gene expression and protein expression in vivo or in vitro. Mutants and/or transgenics examined. Students address research questions of instructor.
Prerequisites: BIOS 376
Attribute/Distribution: NS

BIOS 376 Developmental Biology 3 Credits
Differentiation of multicellular organisms from a single cell. Axis determination; gradients; induction and pattern formation viewed through modern analysis of regulated gene expression. Lecture topics on organ formation paired with discussions on birth defects and human diseases.
Prerequisites: BIOS 115 and BIOS 116
Attribute/Distribution: NS
BIOS 377 (CHM 377) Biochemistry Laboratory 0.3 Credits
Laboratory studies of the properties of chemicals of biological origin and the influence of chemical and physical factors on these properties. Laboratory techniques used for the isolation and identification of biochemicals.
Prerequisites: (BIO 371 or CHM 371) and (BIO 041)
Can be taken Concurrently: BIOS 371, CHM 371
Attribute/Distribution: ND

BIOS 378 Biochemical Preparations 1-3 Credits
A laboratory course involving the preparation or isolation, purification and identification of chemicals of biological origin.
Prerequisites: (BIOS 377 or CHM 377) and (BIOS 372 or CHM 372)
Attribute/Distribution: ND

BIOS 380 (BIOE 380) Molecular and Cellular Biophysics 3-4 Credits
Prerequisites: (BIO 115) and (PHY 013 or PHY 021)

BIOS 381 Physical Biochemistry 3 Credits
Topics include: thermodynamics of biological systems; Forces acting on and between biological molecules; Principles of macromolecular structure; Physical methods used to characterize biomolecules; and other topics to be determined.
Prerequisites: (BIO 371 or CHM 371) and (BIO 041)
Attribute/Distribution: NS

BIOS 382 (PSYC 382) Endocrinology of Behavior 3 Credits
Hormonal effects upon animal and human behavior. Emphasis on neuroendocrinology of steroid hormone involvement in reproductive behaviors.
Prerequisites: BIO 044
Attribute/Distribution: NS

BIOS 383 Biological Sciences Colloquia 0.1 Credits
Analysis of weekly colloquia in the biological sciences.
Repeat Status: Course may be repeated.
Prerequisites: BIO 044
Attribute/Distribution: NS

BIOS 384 Eukaryotic Signal Transduction 3 Credits
Signal transduction between cells of multicellular eukaryotic organisms examined in the context of specialized functions that include: nutrition, hormones and neurotransmitters, vision, muscle contraction, adhesion, and the immune system. The evolution of cancer based on mutations in these signaling systems.
Prerequisites: BIOS 367 or BIOS 372 or CHM 372 or BIOS 382 or BIOS 365

BIOS 385 Synapses, Plasticity and Learning 3 Credits
Communication between neurons. Physiology of synaptic transmission; varying forms of neuronal plasticity; acquisition, encoding, and retrieval of memory.
Prerequisites: BIOS 276
Attribute/Distribution: NS

BIOS 386 Genes and the Brain 3 Credits
Modern molecular genetics techniques applied to complex brain processes. Emphasis on DNA and RNA manipulation strategies to elucidate mechanisms of complex behaviors. Animal models of learning, behavioral plasticity, and neuropsychiatric diseases.
Prerequisites: BIOS 276
Attribute/Distribution: NS

BIOS 387 Biological Sciences Honors Seminar 1 Credit
Development, presentation and implementation of research proposals, and discussions of research. Required for senior biology, molecular biology, biochemistry, and behavioral neuroscience majors pursuing departmental honors. Departmental permission required.
Attribute/Distribution: ND

BIOS 388 Biological Sciences Honors Seminar 1 Credit
Continuation and extension of BIOS 387. Departmental permission required.
Attribute/Distribution: ND

BIOS 389 Honors Project 1-6 Credits
Repeat Status: Course may be repeated.

BIOS 391 Undergraduate Research 1-3 Credits
Laboratory research under tutorial with a faculty member. Must have junior standing. Consent of instructor required.
Repeat Status: Course may be repeated.
Attribute/Distribution: ND

BIOS 393 Thesis 3 Credits
Literature review and design of project in selected area, execution of the project, final report and presentation. Consent of department required. Intended for senior majors in BIOS only. Consent of instructor required.
Repeat Status: Course may be repeated.
Attribute/Distribution: ND

BIOS 401 Professional Skills for Biological Sciences Graduate Students 3 Credits
Students learn expectations and fundamental skills related to success in the biological sciences. The course is designed to help students make the most out of their graduate education. Students learn the principles underlying fundable, publishable research, and how these general principles can be applied to their specific research area. They learn to write and review manuscripts and grant proposals by serving on a mock editorial board and scientific review panel. They gain experience in giving oral presentations. Readings are from texts on scientific writing and research styles, and from original journal articles and grant proposals written by the faculty. Required of all Integrative Biology graduate students.

BIOS 402 Ethics and Rigor in Research 1 Credit
This course covers material critical to the responsible conduct of science, in addition to data reproducibility, rigor, research ethics, and misconduct.

BIOS 404 (PSYC 404) Behavioral Neuroscience 3 Credits
Theoretical and empirical issues in biopsychology. Must have graduate standing.

BIOS 405 Special Topics in Molecular Biology 1-3 Credits
Research, conferences, and reports on selected topics not covered in the general graduate offerings.
Repeat Status: Course may be repeated.

BIOS 406 Biological Sciences Seminar 0.1 Credits
An advanced seminar in current developments including departmental research. Required for candidates for graduate degrees in molecular biology.
Repeat Status: Course may be repeated.

BIOS 407 Research in Biological Science 1-9 Credits
Laboratory investigations in one of the department's research areas.

BIOS 408 Responsible Conduct of Science 0 Credits
Responsible practice in research. Training in general laboratory methods; human subjects concerns; radiation safety; chemical hazards; aseptic technique; physical, mechanical, biological, and fire hazards; animal welfare. Occupational and workplace considerations. Recombinant DNA guidelines; patent and proprietary rights; controversies over applications of science. Appropriate aspects required of investigators in all departmental research projects.

BIOS 409 Evolutionary and Functional Morphology 3 Credits
Readings in the current literature, demonstrations and laboratory exercises exploring the applications of comparative methods to the analysis of evolutionary patterns at a range of morphological levels (molecular and macroscopic). Students will also learn experimental approaches to testing relationships between form and function in vertebrates. Emphasis will be on the musculoskeletal and nervous systems.
BIOS 410 Special Topics in Behavioral and Evolutionary Bioscience 1-3 Credits
Readings and discussions on selected topics not covered in the general graduate offerings.

BIOS 411 Advanced Cell Biology 3 Credits
Cell structure and biochemistry, as related to specialized cell functions.

BIOS 412 Metabolic Influences on Behavior 3 Credits
Sensory systems that detect metabolic energy availability and affect the behavior of humans and other animals: food intake and body weight regulation, sexual and parental behavior, aggression, learning, and body temperature regulation.

BIOS 414 Sexual Differentiation 3 Credits
Genetic and hormonal events mediating the development and expression of sexual dimorphisms in physiology and behavior. Current theoretical models; emphasis on biochemical, neuroanatomical and molecular biological considerations.

BIOS 415 Synapses, Plasticity and Learning 3 Credits
Communication between neurons. Physiology of synaptic transmission; varying forms of neuronal plasticity; acquisition, encoding and retrieval of memory.

BIOS 420 Pheromonal Communication 3 Credits
Mechanisms of pheromone synthesis, biochemistry, sensory transduction, neuroanatomy/neuroendocrinology, and adaptive significance.

BIOS 421 Molecular Cell Biology I 3 Credits
Molecular aspects of cell structure, cell motility, intracellular transport; and biomembrane dynamics.
Prerequisites: BIOS 411

BIOS 422 Molecular Cell Biology II 3 Credits
Molecular aspects of gene expression, including genome structure and replication, RNA synthesis/processing, and protein synthesis.
Prerequisites: BIOS 345 or BIOS 345

BIOS 423 Evolution of Development 3 Credits
This course examines how changes in the blueprint that describes the development of a multicellular animal from a single fertilized egg lead to the evolution of new species or new forms within a species.
Prerequisites: BIOS 317 or BIOS 376 or BIOS 327
Can be taken Concurrently: BIOS 317, BIOS 376, BIOS 327

BIOS 424 Advanced Neurobiology of Sensory Systems 3 Credits
This course is designed to provide an overview of core principles of neuroscience through exploration of sensory systems. The course will provide an intensive review of fundamental neural signaling followed by a broad introduction to the major sensory pathways. Focus will be on major organizing principles of neural systems, and information processing. Student discussions and presentations will incorporate current literature and concepts.

BIOS 426 Coevolution 3 Credits
Discussion-based seminar course covering readings from the primary literature. Course will examine evolutionary consequences of species interactions, interactions between the sexes, and genetic interactions. Topics will include predator-prey interactions, host-parasite interactions, sexual conflict, genomic conflict, mutualism, and more. Consequences of coevolution for biodiversity and human health will also be examined.

BIOS 427 Techniques in Cell and Molecular Biology 1-3 Credits
Laboratory experiences in three or more cell and molecular biological techniques: gel electrophoresis of nucleic acids/proteins; polymerase chain reaction; DNA/RNA sequencing; molecular hybridization techniques; fluorescence microscopy; confocal microscopy; flow cytometry; electron microscopy tissue preparation; immunological detection methods; molecular cloning techniques; oocyte microinjection techniques; tissue culture methods; and autoradiography.

BIOS 428 Molecular Evolution 3 Credits
Evolution at the level of individual genes, proteins, and genomes. Lectures and discussion of papers from the recent primary literature. Topics include pathways for adaptive evolution, directionality in evolution, epistasis, evolvability, genome rearrangements and speciation, gene duplication, and evolutionary dynamics. Examples of molecular evolution in nature, laboratory model systems, and human pathogens.
Prerequisites: BIOS 317 or BIOS 345
Can be taken Concurrently: BIOS 317, BIOS 345

BIOS 429 Advances in Herpetology 3 Credits
Lectures and readings from the primary literature on current research in amphibian and reptilian biology. Two lectures, one discussion session and one laboratory or field trip. Not open to students who have received credit for BIOS 329.

BIOS 431 Advanced Topics in Cell Biology 3 Credits
Current research problems in cell biology.
Repeat Status: Course may be repeated.
Prerequisites: BIOS 367 or BIOS 367 or BIOS 411

BIOS 432 Advanced Topics in Molecular Genetics 3 Credits
Current research in molecular genetics.
Repeat Status: Course may be repeated.
Prerequisites: BIOS 345 or BIOS 345

BIOS 433 Advanced Topics in Developmental Biology 3 Credits
Current research problems in developmental biology.
Repeat Status: Course may be repeated.
Prerequisites: BIOS 345 or BIOS 345

BIOS 434 Speciation 3 Credits
Discussion-based seminar course covering readings from classical and current literature, including both theoretical and empirical contributions. Topics will be included species concepts, reproductive isolation, mechanisms and modes of speciation, and current approaches to studying speciation.

BIOS 435 Epigenetics 3 Credits
Foundational concepts in environmental epigenetics. Course will be centered around presentations and discussions of studies that address current issues, such as the mechanisms behind heritable health effects of acute malnourishment in human populations across multiple generations, or the potential for extremely fast evolutionary adaptation in species threatened by environmental change.

BIOS 437 (CHM 437) Pathophysiological Chemistry 3 Credits
Biochemical basis of human diseases involving abnormal metabolism of proteins, nucleic acids, carbohydrates, and lipids. Emphasis on the correlation of the clinical presentation of disease processes seen as physiological dysfunctions with clinical laboratory methods. Lectures, student presentations, and clinical case discussions. Consent of department required.

BIOS 438 Neurodegenerative Diseases in Model Organisms 3 Credits
Discussion-based seminar course on the use of model systems to investigate neurodegenerative diseases. The primary focus will be on invertebrate model systems, including Drosophila. Critical reading of primary scientific literature and student discussion is required.
Prerequisites: BIOS 115

BIOS 439 Advanced Behavioral Ecology 3 Credits
Critical evaluation of the theoretical foundation in sociobiology. Emphasis placed on kinship, altruism, mate choice, parental investment, parent-offspring conflict, etc. Lectures and seminars. Not open to students who have taken BIOS 337.
Prerequisites: BIOS 317 or BIOS 317

BIOS 442 Cellular Basis of Human Disease 3 Credits
Cell and molecular biological advanced topics relevant to human disease and/or health. Critical reading of the primary literature, discussion and student discussion required.
Prerequisites: BIOS 367 or BIOS 411
BIOS 443 Personal Genomics 3 Credits
Contemporary methods and technologies for investigating human genetic variation and its use for inferring ancestry and risk for disease, along with discussions of relevant policy and ethics. Readings will include primary scientific literature in population and statistical genetics, government publications, and news reports. Final projects will involve development of outreach and education resources in this topic for non-experts.

BIOS 445 Systematics and Evolution 3 Credits
Theoretical, philosophical and methodological foundations of the classification of eukaryotic organisms and the manner in which systematic theory and method relate to evolutionary theory. Two lectures and one lab/recitation/discussion session.

BIOS 448 Marine Biology 3 Credits
Ecology and adaptations of marine species, populations, and ecosystems. With an average depth of more than two miles, the ocean makes up more than 95% of the habitable space on our planet. Ocean ecosystems are essential life support systems for the entire earth. Studying life in the ocean requires a perspective that spans spatial and temporal scales from the planetary to the microscopic, from the geologic to the physiological, and from the surface to the deepest seafloor. Through this course.

BIOS 450 Developmental Neurobiology 3 Credits
Fundamental mechanisms underlying neural development. Early events leading to the induction of the neuroectoderm and the reorganization of the vertebrate central nervous system during adulthood and aging. Major developmental events such as phenotype commitment, cell migration, differentiation and growth cone guidance. Emphasis on the interplay between concepts emerging from organismal and molecular levels of analyses.

BIOS 453 General Neuroanatomy 3 Credits
Graduate level study of the neuroanatomy and neurochemistry of systems that underlie behavior in vertebrates. Emphasis will be on the traditional and novel methodologies used to reveal neuroanatomical pathways as well as the function of these pathways. Consent of department required.

BIOS 457 Advanced Behavioral Neuroendocrinology 3 Credits
A seminar course that covers current primary literature on the hormone-nervous system interactions that underlie physiology and behavior. The course covers the neuroendocrinology of reproduction, sex behavior, parental behavior, social behavior, agonistic and territorial behavior, learning and memory, homeostasis (caloric, nutritional, water and salt balance, temperature regulation), circadian rhythms and seasonality in a variety of vertebrates.

BIOS 464 Molecular Biology of Eukaryotic Organisms 3 Credits
Comparative analysis of several eukaryotes as model systems in cell biology, developmental biology, genetics, and molecular biology.

BIOS 466 Structure and Function of RNAs and Ribonucleoprotein Complexes 3 Credits
Biochemistry and function of small nuclear RNPs, RNase P, ribosomes, self-splicing introns, signal recognition particle, RNA viruses. Functions of RNA in DNA replication, in regulation, as an enzyme, and as a repressor.

BIOS 467 (CHM 467) Principles of Nucleic Acid Structure 3 Credits
An examination of the principles underlying nucleic acid structure including stereochemistry, electrostatics, hydration, torsional constraints, sequence specific effects, and interaction with nuclear proteins. Special emphasis will be placed on DNA structure. Must have completed one year of biochemistry and one year of physical chemistry or consent of department required.

BIOS 468 (CHM 468) Principles of Protein Structure 3 Credits
An examination of the principles underlying protein structure including stereochemistry, preferred tertiary structures, protein homology, excluded volume effects, time dependent structural fluctuations, and prediction of protein structure from sequence information. Must have completed one year of biochemistry and one year of physical chemistry or consent of department required.

BIOS 469 (CHM 469) Biochemical Problem Solving I 1 Credit
Applications of material covered in BIOS 371 or CHM 371 including techniques used in research.

BIOS 470 (CHM 470) Biochemical Problem Solving II 1 Credit
Applications of concepts covered in BIOS 372 or CHM 372 including techniques used in research.

BIOS 471 Eukaryotic Signal Transduction 3 Credits
Signal transduction between and within cells of multicellular organisms examined in the context of specialized functions that include: nutrition, hormones and neurotransmitters, vision, muscle contraction, adhesion and the immune system. The evolution of cancer based on mutations in these signaling systems. Lecture, discussion, and student presentations.

Prerequisites: (BIOS 372 or CHM 372 or BIOS 411)

BIOS 472 (CHM 472) Lipids and Membranes 3 Credits
The study of lipids and lipid membranes similar to those found in mammalian cells including methods of synthesis, surface activity, bilayer and micellar structures, lipid mixing, fluidity, permeability and membrane stability. Special emphasis will be given to the current evidence for and against the lipid raft hypothesis.

Prerequisites: BIOS 372 or CHM 372

BIOS 473 (CHM 473) Principles of Biochemistry I 3 Credits
Study of proteins, carbohydrates, lipids, nucleic acids and other biological substances. Protein and enzyme chemistry are emphasized. Must have completed one year each of general chemistry and organic chemistry.

BIOS 477 (CHM 477) Topics in Biochemistry 1-3 Credits
Selected areas of biochemistry, such as mechanisms of enzyme action, new developments in the chemistry of lipids, nucleic acids, carbohydrates and proteins.

Repeat Status: Course may be repeated.

BIOS 479 (CHM 479) Biochemical Techniques 3 Credits
Laboratory studies of the techniques and principles involved in the isolation, identification, and biochemical transformation of carbohydrates, lipids, nucleic acids and proteins.

Prerequisites: (BIOS 371)

Can be taken Concurrently: BIOS 371

BIOS 480 (CHM 480) Advanced Biochemical Preparations 1-3 Credits
An advanced laboratory course in the preparation, isolation, purification, and identification of biochemically produced materials. Emphasis is placed on materials and procedures of current interest in biochemistry. Consent of department required.

BIOS 483 Special Topics in Behavioral Neuroscience 3 Credits
Examination of the biological substrates of behavior. Topics may include animal communication, sociobiology, behavioral endocrinology, or behavior genetics.

Repeat Status: Course may be repeated.

BIOS 486 Genes and the Brain 3 Credits
Modern molecular genetics techniques applied to complex brain processes. Emphasis on DNA and RNA manipulation strategies to elucidate mechanisms of complex behaviors. Animal models of learning, behavioral plasticity, and neuropsychiatric diseases.

Attribute/Distribution: NS

BIOS 488 Seminar in Neuroscience, Behavior, and Evolution 1 Credit
Advanced seminar in current research developments.

BIOS 490 Thesis 1-6 Credits
Repeat Status: Course may be repeated.

BIOS 499 Dissertation 1-15 Credits