SCIENCE, BACHELOR OF SCIENCE (B.S.) WITH A CONCENTRATION IN BIOLOGY

Learning outcomes
Upon completing this program, students will know and know how to do the following:

- Demonstrate broad and core science proficiency
- Demonstrate competency in at least two sciences or in a non-science area
- Apply learning to selection and pursuit of professional or graduate career objective
- Demonstrate proficiency in communication of scientific or research findings
- Demonstrate ability to apply the scientific method/approach to professional problems
- Demonstrate appreciation of the interrelation of core sciences to interdisciplinary problems

Special requirements
The Bachelor of Science in Science requires a minimum of 120 credits.

Along with the general education requirements of the undergraduate programs and the College of Humanities and Sciences for a Bachelor of Science degree, this curriculum requires 28 to 33 credits in foundation science and mathematics courses and 36 to 38 credits in supplemental courses in the concentration. In preparation for the required mathematical sciences courses, all students must take the Mathematics Placement Test. Science majors are strongly encouraged to select a minor in an area different from their area of concentration that will complement their career interests and contribute additional upper-level credits to their curriculum.

Science majors declaring the biology concentration may not simultaneously declare a major or minor in biology.

Grade requirements
A minimum grade of C is required in each prerequisite course:

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM 100</td>
<td>Introductory Chemistry (if required through placement test)</td>
<td>3</td>
</tr>
<tr>
<td>CHEM 101</td>
<td>General Chemistry I</td>
<td>3</td>
</tr>
<tr>
<td>CHEM 102</td>
<td>General Chemistry II</td>
<td>3</td>
</tr>
<tr>
<td>CHEM 301</td>
<td>Organic Chemistry</td>
<td>3</td>
</tr>
<tr>
<td>CHEM 302</td>
<td>Organic Chemistry</td>
<td>3</td>
</tr>
</tbody>
</table>

A minimum grade of C is required in the following courses before enrollment in advanced BIOL courses:

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOL 151 &amp; BIOZ 151</td>
<td>Introduction to Biological Sciences I and Introduction to Biological Science Laboratory I</td>
<td>4</td>
</tr>
<tr>
<td>BIOL 300</td>
<td>Cellular and Molecular Biology</td>
<td>3</td>
</tr>
</tbody>
</table>

Degree requirements for Science, Bachelor of Science (B.S.) with a concentration in biology

General education requirements

University Core Education Curriculum (minimum 21 credits)

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNIV 111</td>
<td>Focused Inquiry I</td>
<td>3</td>
</tr>
<tr>
<td>UNIV 112</td>
<td>Focused Inquiry II</td>
<td>3</td>
</tr>
<tr>
<td>UNIV 200</td>
<td>Inquiry and the Craft of Argument</td>
<td>3</td>
</tr>
<tr>
<td>Approved humanities/arts</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Approved natural/physical sciences</td>
<td>3-4</td>
<td></td>
</tr>
<tr>
<td>Approved quantitative literacy</td>
<td>3-4</td>
<td></td>
</tr>
<tr>
<td>Approved social/behavioral sciences</td>
<td>3-4</td>
<td></td>
</tr>
</tbody>
</table>

Total Hours: 21-24

Additional College of Humanities and Sciences requirements (11-23 credits)

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>HUMS 202</td>
<td>Choices in a Consumer Society</td>
<td>1</td>
</tr>
<tr>
<td>Approved H&amp;S diverse and global communities</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Approved H&amp;S human, social and political behavior (fulfills University Core social/behavioral sciences)</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Approved H&amp;S literature and civilization (fulfills University Core humanities/fine arts)</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Approved H&amp;S science and technology (fulfills University Core natural/physical sciences)</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Approved H&amp;S general education electives</td>
<td>6-8</td>
<td></td>
</tr>
<tr>
<td>Experiential fine arts</td>
<td>1-3</td>
<td></td>
</tr>
<tr>
<td>Foreign language through the 102 level (by course or placement)</td>
<td>0-8</td>
<td></td>
</tr>
</tbody>
</table>

Total Hours: 11-23

1 Course offered by the School of the Arts

Major requirements

Foundational courses

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOL 151 &amp; BIOZ 151</td>
<td>Introduction to Biological Sciences I and Introduction to Biological Science Laboratory I</td>
<td>4</td>
</tr>
<tr>
<td>CHEM 101 &amp; CHEZ 101</td>
<td>General Chemistry I and General Chemistry Laboratory I</td>
<td>4</td>
</tr>
<tr>
<td>ENVS 301</td>
<td>Introduction to Meteorology (or upper-level natural or health science elective from list below)</td>
<td>3</td>
</tr>
<tr>
<td>ENVS 310</td>
<td>Introduction to Oceanography (or upper-level natural or health science elective from list below)</td>
<td>2-3</td>
</tr>
</tbody>
</table>
INSC 490 Capstone Research Experience in Interdisciplinary Science (or an approved capstone from another natural science major from list below) 1-3

MATH 151 Precalculus Mathematics (or placement) 4

MATH 200 or SCMA 212 Calculus with Analytic Geometry 3-4
or STAT 314 Differential Calculus and Optimization for Business Applications of Statistics

PHYS 201 General Physics I 4-5
or PHYS 207 University Physics I

STAT 208 Statistical Thinking 3
or STAT 210 Basic Practice of Statistics

Supplemental courses
BIOL 152 Introduction to Biological Sciences II and Introduction to Biological Science Laboratory II 4
& BIOZ 152

BIOL 300 Cellular and Molecular Biology 3

BIOL 310 Genetics 3

BIOL 310 Laboratory in Genetics (or other upper-level biology laboratory) 1-2

BIOL 317 Ecology 3

CHEM 102 General Chemistry II 4
& CHEZ 102 and General Chemistry Laboratory II

Select one of the following: 4
ENVS 105 Physical Geology
& URSZ 204 and Physical Geography Laboratory: Geomorphology and Soils

URSP 204 Physical Geography: Geomorphology and Soils
& URSZ 204 and Physical Geography Laboratory: Geomorphology and Soils

Or a 200-level or higher natural science elective and a 200-level or higher natural science laboratory elective from the list below

PHYS 202 General Physics II 4-5
or PHYS 208 University Physics II

Select one upper-level animal or one upper-level plant course, with laboratory, from list below 4

Select two upper-level biology electives 6

Total Hours 64-71

Open electives
Select three to 24 open elective credits 3-24

Total Hours 3-24

Total minimum requirement 120 credits

Animal and plant courses

Animal group
BIOL 309 Entomology 1 4
BIOL 312 Invertebrate Zoology 3
BIOL 312 Invertebrate Zoology Laboratory 1
BIOL 313 Vertebrate Natural History 3
BIOL 313 Vertebrate Natural History Laboratory 1

BIOL 391 Topics in Biology (as approved) 1-4
BIOL 391 Topics in Biology Laboratory (as approved) 1-4
BIOL 402 Comparative Vertebrate Anatomy 5
BIOL 416 Ornithology 3
BIOL 416 Ornithology Laboratory 2
BIOL 417 Mammalogy 1 4
BIOL 435 Herpetology 1 3
BIOL 445 Neurobiology and Behavior 1 4
BIOL 503 Fish Biology 1 4

Plant group
BIOL 320 Biology of the Seed Plant 4
BIOL 321 Plant Development 3
BIOL 321 Plant Development Laboratory 2
BIOL 322 Economic Botany 3
BIOL 323 Plant Physiology 3
BIOL 391 Topics in Biology (as approved) 1-4
BIOL 391 Topics in Biology Laboratory (as approved) 1-4

1 These courses include laboratory hours and may be used to satisfy laboratory requirements.

Natural science electives
LFSC 301 Integrative Life Sciences Research 3
LFSC 401 Faith and Life Sciences 3
PHTX 400 Drugs and Their Actions 3

Any 200-level or higher BIOL, BNFO, CHEM, CLSE, EGRB, ENVS, FRSC, INSC or PHYS course, except:

BIOL 392 Introduction to Research
BIOL 475 Biology Capstone Seminar: ___
BIOL 477 Biology Capstone Experience
BIOL 489 Communicating Research
BIOL 490 Presenting Research
BIOL 492 Independent Study
BIOL 493 Biology Internship
BIOL 495 Research and Thesis
BIOL 496 Biology Preceptorship: ___
BNFO 292 Independent Study
BNFO 492 Independent Study
BNFO 496 Undergraduate Teaching Assistantship in Bioinformatics
FRSC 392 Directed Study
FRSC 492 Independent Study
FRSC 493 Chemistry Internship
ENGR 490 Engineering Seminar
ENGR 492 Independent Study in Engineering
ENVS 490 Research Seminar in Environmental Studies
ENVS 492 Independent Study
ENVS 493 Environmental Studies Internship
FRSC 490 Professional Practices in Forensic Science
FRSC 492 Forensic Science Independent Study
### Natural science laboratory electives

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
</table>
| BIOL 205     | Basic Human Anatomy
1                       | 4     |
| BIOL 309     | Entomology 1                               | 4     |
| BIOL 320     | Biology of the Seed Plant 1                | 4     |
| BIOL 402     | Comparative Vertebrate Anatomy 1           | 5     |
| BIOL 417     | Mammalogy 1                                | 4     |
| BIOL 435     | Herpetology 1                              | 3     |
| BIOL 445     | Neurobiology and Behavior 1                | 4     |
| BIOL 503     | Fish Biology 1                             | 4     |
| BIOZ: any 200-level or higher course |                            |       |
| BNFO 380     | Introduction to Mathematical Biology 1      | 4     |
| BNFO 420     | Applications in Bioinformatics 1            | 3     |
| BNFO 440     | Computational Methods in Bioinformatics 1   | 3     |
| CHEZ: any 200-level or higher course |                            |       |
| EGRB 307     | Biomedical Instrumentation 1               | 4     |
| EGRB 308     | Biomedical Signal Processing 1             | 4     |
| EGRB 310     | Biomechanics 1                            | 4     |
| ENVZ 335     | Environmental Geology Laboratory           | 1     |
| FRSZ: any 200-level or higher course |                            |       |
| PHIZ 260     | Human Physiology Laboratory                | 1     |
| PHYS 202     | General Physics II 1                       | 4     |
| PHYS 208     | University Physics II 1                   | 5     |
| PHYZ 320     | Modern Physics Laboratory                  | 1     |
| URSZ 203     | Physical Geography Laboratory              | 1     |
|               | Weather, Climate and Biogeography         |       |

1 Courses have a combined lecture and lab and will satisfy both natural science lecture and laboratory requirements.

### Health science electives

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFAM/ANTH/INTL/ GSWS 309</td>
<td>Global Women's Health</td>
<td>3</td>
</tr>
<tr>
<td>AFAM 310</td>
<td>Black Health Matters: Social Determinants of Health in the African American Community</td>
<td>3</td>
</tr>
<tr>
<td>AFAM 401</td>
<td>African-Americans and the U.S. Health Care System</td>
<td>3</td>
</tr>
<tr>
<td>HPEX 325</td>
<td>Pathology and Pharmacology in Athletic Training</td>
<td>3</td>
</tr>
<tr>
<td>HPEX 345</td>
<td>Nutrition for Health and Disease</td>
<td>3</td>
</tr>
<tr>
<td>HPEX 350</td>
<td>Nutrition</td>
<td>3</td>
</tr>
<tr>
<td>HPEX 353</td>
<td>Disease Trends, Prevention and Control</td>
<td>3</td>
</tr>
<tr>
<td>HPEX 373</td>
<td>Structural Kinesiology</td>
<td>3</td>
</tr>
<tr>
<td>HPEX 374</td>
<td>Musculoskeletal Structure and Movement</td>
<td>4</td>
</tr>
<tr>
<td>HPEX 375</td>
<td>Physiology of Exercise</td>
<td>3</td>
</tr>
<tr>
<td>HPEX 440</td>
<td>Chronic Disease and Exercise Management</td>
<td>3</td>
</tr>
</tbody>
</table>

### Natural science capstones (approved for biology concentration)

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOL 475</td>
<td>Biology Capstone Seminar: ___</td>
<td>1-3</td>
</tr>
<tr>
<td>BIOL 477</td>
<td>Biology Capstone Experience (in conjunction with BIOL 492, BIOL 493, BIOL 495 or BIOL 497, as specified and approved by the biology department)</td>
<td>0</td>
</tr>
<tr>
<td>BIOZ 476</td>
<td>Molecular Capstone Laboratory</td>
<td>2</td>
</tr>
<tr>
<td>BNFO 420</td>
<td>Applications in Bioinformatics</td>
<td>3</td>
</tr>
<tr>
<td>CLSE 402</td>
<td>Senior Design Studio I (Laboratory/Project Time) and Senior Design Studio II (Laboratory/Project Time)</td>
<td>4</td>
</tr>
<tr>
<td>EGRB 402</td>
<td>Biomedical Engineering Senior Design Studio</td>
<td>3</td>
</tr>
</tbody>
</table>

What follows is a sample plan that meets the prescribed requirements within a four-year course of study at VCU. Please contact your adviser before beginning course work toward a degree.

### Freshman year

#### Fall semester

<table>
<thead>
<tr>
<th>Course</th>
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</tr>
</thead>
<tbody>
<tr>
<td>MATH 151</td>
<td>Precalculus Mathematics (or placement)</td>
<td>4</td>
</tr>
<tr>
<td>STAT 208</td>
<td>Statistical Thinking (or Basic Practice of Statistics)</td>
<td>3</td>
</tr>
<tr>
<td>STAT 210</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UNIV 101</td>
<td>Introduction to the University</td>
<td>1</td>
</tr>
<tr>
<td>UNIV 111</td>
<td>Focused Inquiry I</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Play course video for Focused Inquiry I</td>
<td></td>
</tr>
<tr>
<td>Approved science and technology</td>
<td></td>
<td>3-4</td>
</tr>
</tbody>
</table>

Term Hours: 14-15

#### Spring semester

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM 101</td>
<td>General Chemistry I</td>
<td>4</td>
</tr>
<tr>
<td>&amp; CHEZ 101</td>
<td>General Chemistry Laboratory I</td>
<td></td>
</tr>
<tr>
<td>HUMS 202</td>
<td>Choices in a Consumer Society</td>
<td>1</td>
</tr>
</tbody>
</table>
Science, Bachelor of Science (B.S.) with a concentration in biology

Math 200 or SCMA 212 or STAT 314
Calculus with Analytic Geometry or Differential Calculus and Optimization for Business or Applications of Statistics
3-4

UNIV 112
Focused Inquiry II
3

Play course video for
Focused Inquiry II

Approved human, social and political behavior
3-4

Term Hours: 14-16

Sophomore year
Fall semester
BIOL 151 & BIOZ 151
Introduction to Biological Sciences I and Introduction to Biological Science Laboratory I
4

CHEM 102 & CHEZ 102
General Chemistry II and General Chemistry Laboratory II
4

PHYS 201 or PHYS 207
General Physics I or University Physics I
4-5

UNIV 200
Inquiry and the Craft of Argument
3

Experiential fine arts (SPCH 321 or other upper-level option recommended)
1-3

Term Hours: 16-19

Spring semester
BIOL 152 & BIOZ 152
Introduction to Biological Sciences II and Introduction to Biological Science Laboratory II
4

PHYS 202 or PHYS 208
General Physics II or University Physics II
4-5

Approved diverse and global communities
3

Approved literature and civilization
3

Term Hours: 14-15

Junior year
Fall semester
BIOL 300
Cellular and Molecular Biology
3

BIOL 317
Ecology
3

ENVS 105 or URSP 204
Physical Geology or Physical Geography: Geomorphology and Soils
3

URSZ 204
Physical Geography Laboratory: Geomorphology and Soils
1

Foreign language (101) or upper-level minor elective
3-4

Open elective or upper-level minor elective
2-3

Term Hours: 15-17

Spring semester
BIOL 310
Genetics
3

ENVS 301
Introduction to Meteorology (or upper-level science elective)
3

Select one of the following:
1-2

BIOL 310
Laboratory in Genetics

Or other upper-level biology laboratory

Approved General Education elective
3

Foreign language (102) or upper-level minor elective
3-4

Open elective or upper-level minor elective
3

Term Hours: 16-18

Senior year
Fall semester
Select one of the following:
ENVS 310
Introduction to Oceanography
2-3

Or upper-level science elective

One upper-level animal or upper-level plant course, with laboratory
4

Open electives or upper-level minor electives
9

Term Hours: 15-16

Spring semester
Select one of the following:
INSC 490
Capstone Research Experience in Interdisciplinary Science
1-3

Or approved capstone from another science major
(biology, chemistry or physics)

Approved General Education elective
3-4

One upper-level animal or upper-level plant course, with laboratory
3-4

Open electives or upper-level minor electives, as needed
6

Upper-level biology elective
3

Term Hours: 16-20

Total Hours: 120-136

BIOL 101. Biological Concepts. 3 Hours.
Semester course; 3 lecture hours. 3 credits. A topical approach to basic biological principles. Topics include molecular aspects of cells, bioenergetics, photosynthesis, cellular respiration, cellular and organismal reproduction, genetics and evolution, and ecology. Not applicable for credit toward the major in biology.

BIOL 103. Environmental Science. 4 Hours.
Hybrid semester course taught mostly online; 3 lecture and 2 laboratory hours. 4 credits. Online presentations, assignments, debates and exams require students to understand situations and ideas that involve scientific, social and economic concepts associated with Earth's environment. Laboratory exercises reinforce major course concepts. Integrates aspects of biology, chemistry, geology, physics and sociology. Topics include ecology, evolution, natural resources, air and water resources, energy and recycling, population biology, and sustainable global societies. Not applicable as a prerequisite for any biology course at the 200 level or above, nor for credit toward the B.S. in Biology. Crosslisted as: ENVS 103.

BIOL 151. Introduction to Biological Sciences I. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Pre- or corequisites: MATH 151 and CHEM 101. Introduction to core biological concepts including cell structure, cellular metabolism, cell division, DNA replication, gene expression and genetics. Designed for biology majors.
BIOL 152. Introduction to Biological Sciences II. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: BIOL 151 and CHEM 101, both with a minimum grade of C. Focuses on evolutionary principles, the role of natural selection in the evolution of life forms, taxonomy and phylogeny, biological diversity in the context of form and function of organisms, and basic principles of ecology. Designed for biology majors.

BIOL 200. Quantitative Biology. 3 Hours.
Semester course; 3 lecture hours (delivered online). 3 credits. Prerequisites: BIOL 151 and BIOZ 151 with minimum grades of C; and MATH 151, MATH 200, MATH 201, STAT 210 or satisfactory score on the VCU Mathematics Placement Test within a one-year period immediately preceding the beginning of the course. Enrollment restricted to biology majors and biology minors. An introduction to the application of the scientific method, experimental design and quantitative aspects of biology.

BIOL 201. Human Biology. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: BIOL 101, 151, or 152, or BIOL/ENVS 103. Fundamentals of human biology, including the structure, function and disorders of human body systems, principles of human genetics and inheritance, human evolution, and the interaction of humans with the environment. Not applicable for credit toward the B.S. in Biology.

BIOL 205. Basic Human Anatomy. 4 Hours.
Semester course; 3 lecture and 2 laboratory hours, plus online component. 4 credits. Prerequisites: BIOL 101 and BIOZ 101, BIOL 151 and BIOZ 151, or BIOL 152 and BIOZ 152, each with a minimum grade of C. Restricted to communication arts majors; health, physical education and exercise science majors; pre-health majors in clinical laboratory sciences, clinical radiation sciences, dental hygiene and nursing; students enrolled in the health sciences certificate program; and students in the advising tracks for pre-nursing, pre-occupational therapy, pre-pharmacy and pre-physical therapy and pre-nursing accelerated. Human specimens, models and interactive software are used to study human body structures; emphasis is on the skeletal-muscular aspects. Not applicable for credit toward the B.S. in Biology.

BIOL 209. Medical Microbiology. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: BIOL 101 and BIOZ 101, BIOL 151 and BIOZ 151, or BIOL 152 and BIOZ 152, each with a minimum grade of C. General principles of microbiology and immunology to provide a thorough understanding of the host-microbe relationship in disease. Not applicable for credit toward the B.S. in Biology.

BIOL 217. Principles of Nutrition. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: BIOL 101, 151 or 152 with a minimum grade of C, or BIOL/ENVS 103 with a minimum grade of C. An introduction to basic principles of nutrition and their application in promoting growth and maintaining health throughout the life cycle. Not applicable for credit toward the B.S. in Biology.

BIOL 291. Topics in Biology. 1-4 Hours.
Semester course; variable hours. Variable credit. Prerequisites: BIOL 151, 152 and BIOZ 151, 152, with minimum grades of C. A study of a selected topic in biology. See the Schedule of Classes for specific topics to be offered each semester and prerequisites.

BIOL 300. Cellular and Molecular Biology. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: BIOL 151 and 152; BIOL 151 or LFSC/BNFO 251; BIOZ 152 or LFSC/BNFO 252; CHEM 101 and CHEZ 101, all with a minimum grade of C; BIOL 200, MATH 200, MATH 201, STAT 210, STAT 212, STAT 314 or satisfactory score on the VCU Mathematics Placement Test within the one-year period immediately preceding the beginning of the course. Biology majors must have completed BIOL 200. Pre- or corequisites: CHEM 102 and CHEZ 102. A study of the molecular biology of the cell as it relates to gene expression, cell signaling, and cell growth and differentiation.

BIOL 303. Microbiology. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: BIOL 300 with a minimum grade of C. The morphological, biochemical, taxonomic, genetic and evolutionary characteristics of microorganisms with a primary focus on bacteria. Focuses on the structural, mechanical and biochemical adaptations employed by microorganisms in their interactions with host cells and substrates.

BIOL 304. Biology Skills. 2 Hours.
Semester course; 1 lecture hour (delivered online) and 3 laboratory hours. 2 credits. Prerequisites: BIOL 151 and BIOZ 151 and permission of instructor. This course provides a hands-on experience in laboratory techniques, emphasizes the development of library and informational fluency skills, and uses current biological and/or biomedical research topics to aid in development of critical-thinking and problem-solving skills.

BIOL 307. Aquatic Ecology. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: BIOL 317, CHEM 102 and CHEZ 102, with minimum grades of C. The physical, chemical and especially the biological aspects of freshwater ecosystems.

BIOL 308. Vertebrate Histology. 4 Hours.
Semester course; 3 lecture and 3 laboratory hours. 4 credits. Prerequisite: BIOL 300 with a minimum grade of C. Microanatomy of vertebrate cells, tissues and organs and the relationship of structure to function. Laboratory work involves an in-depth study of vertebrate microanatomy at the light microscope level as well as an introduction to techniques used for the preparation of materials for histological study.

BIOL 309. Entomology. 4 Hours.
Semester course; 3 lecture and 3 laboratory hours. 4 credits. Prerequisites: BIOL 151, 152 and BIOZ 151, 152, with minimum grades of C. A field-based course that focuses on insect diversification, identification, natural history and basic biology.

BIOL 310. Genetics. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: BIOL 152; BIOZ 152 or LFSC/BNFO 252; CHEM 101; and CHEZ 101, each with a minimum grade of C; and BIOL 200, MATH 200, MATH 201, STAT 210, STAT 212, STAT 314 or satisfactory score on the VCU Mathematics Placement Test within the one-year period immediately preceding the beginning of the course. Biology majors must have completed BIOL 200. Pre- or corequisites: CHEM 102 and CHEZ 102. The basic principles of molecular and applied genetics of plants, animals and microorganisms.

BIOL 312. Invertebrate Zoology. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: BIOL 151, 152 and BIOZ 151, 152, with minimum grades of C. A survey of the invertebrate animals with emphasis on environmental interactions. A weekend trip to a marine environment is required.
BIOL 313. Vertebrate Natural History. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: BIOL 151, 152 and BIOZ 151, 152, with minimum grades of C. The natural history of vertebrates with emphasis on the species native to Virginia.

BIOL 314. Animal Reproduction. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: BIOL and BIOZ 151, BIOL and BIOZ 152, and BIOL 300, each with a minimum grade of C. Introduction to basic reproductive anatomy and physiology. Examination of the basic factors that affect reproductive performance and how these factors are used to regulate the reproductive processes of domestic animals and humans.

BIOL 317. Ecology. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: BIOL and BIOZ 151 and BIOL and BIOZ 152, each with a minimum grade of C; and BIOL 200, MATH 200, MATH 201, STAT 210, STAT 212, STAT 314 or satisfactory score on the VCU Mathematics Placement Test within the one-year period immediately preceding the beginning of the course. Biology majors must have completed BIOL 200. An introduction to the basic principles of ecology, including interactions among organisms and influences of the physical environment.

BIOL 318. Evolution. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: BIOL and BIOZ 151 and BIOL and BIOZ 152, each with a minimum grade of C; and BIOL 200, MATH 200, MATH 201, STAT 210, STAT 212, STAT 314 or satisfactory score on the VCU Mathematics Placement Test within the one-year period immediately preceding the beginning of the course. Biology majors must have completed BIOL 200. An exploration of the theoretical and empirical foundations of evolutionary biology with a focus on the processes driving evolutionary change across all of life.

BIOL 320. Biology of the Seed Plant. 4 Hours.
Semester course; 3 lecture and 3 laboratory hours. 4 credits. Prerequisites: BIOL and BIOZ 151 and BIOL and BIOZ 152, each with a minimum grade of C. The physiology, structure and adaptation of seed plants.

BIOL 321. Plant Development. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: BIOL 300 and 310, each with a minimum grade of C. A survey of the developmental changes that take place during the life cycle of lower and higher plants. Emphasis is placed on the control factors that are involved in regulating the ordered changes which take place during development.

BIOL 322. Economic Botany. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: BIOL 151 and 152 and BIOZ 151 and 152, or equivalents, with minimum grades of C. This class focuses on plant morphology, anatomy, phytochemistry, growth and reproduction through an examination of the biology of economically and culturally important plants, including crops used for foods and beverages, medicines and drugs, fibers, and timber.

BIOL 323. Plant Physiology. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: BIOL and BIOZ 151, BIOL and BIOZ 152, and BIOL 300, or equivalents, with minimum grades of C. An introduction to basic plant physiology, including transport processes, energy production and secondary metabolism with emphasis on adaptations to stress.

BIOL 325. Fungal Biology. 3 Hours.
Semester course; 2 lecture and 3 laboratory hours. 3 credits. Prerequisite: BIOL 300 with a minimum grade of C. The basic biology of fungi, including growth, structure, genetics, diversity, the commercial uses of fungi and their importance as model organisms. Also discusses the interactions between fungi and plants and fungi and humans.

BIOL 332. Environmental Pollution. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: eight credits in biology. The study of pollution in the environment with emphasis on the procedures for detection and abatement. Crosslisted as: ENVS 330.

BIOL 333. Evolution of the Angiosperms. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: BIOL 151, BIOL 152, BIOZ 151 and BIOZ 152, all with minimum grade of C. Application of evolutionary concepts to flowering plants. Topics include speciation concepts, evolution of vegetative and sexual characteristics and an overview of angiosperm diversity to the level of family.

BIOL 335. Global Change Biology. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: BIOL 151, BIOL 152, BIOZ 151 and BIOZ 152, all with minimum grade of C. Examines how humans influence biological systems and explores what can be done to adapt to or to mitigate future global change, emphasizing anthropogenic climate change.

BIOL 341. Human Evolution. 4 Hours.
Semester course; 3 lecture and 2 laboratory hours. 4 credits. Prerequisite: UNIV 200 or HONR 200 with a minimum grade of C. Introduces the range of human diversity as well as a broad understanding of evolution and evolutionary biology, particularly as it applies to hominid evolution. Specific topics include basic genetics, primatology, paleontology and the hominin fossil record. Crosslisted as: ANTH 301.

BIOL 351. Introduction to Bioinformatics. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: BNFO 201 and BNFO 300 or permission of instructor. The course will present a practical and theoretical introduction to the tools and techniques needed to obtain and interpret a variety of genome-related data types. The course will include several bioinformatic methods underlying nucleotide and protein sequence alignment, statistical methods for data visualization in R, the types of experimental results commonly encountered in bioinformatics data analysis and the public databases where these data can be accessed. Crosslisted as: BNFO 301.

BIOL 380. Introduction to Mathematical Biology. 4 Hours.
Semester course; 3 lecture and 2 laboratory hours. 4 credits. Prerequisites: MATH 200 and BIOL 151, or permission of instructor. An introduction to mathematical biology. Various mathematical modeling tools will be covered and implemented in a range of biological areas. Additionally, the collaborative research process will be presented and discussed. Crosslisted as: BNFO 380/MATH 380.

BIOL 391. Topics in Biology. 1-4 Hours.
Semester course; 1-4 lecture hours. 1-4 credits. Prerequisites: BIOL 152 and BIOZ 152; and BIOL 300, BIOL 310, BIOL 317 or BIOL 318, each with a minimum grade of C. A study of a selected topic in biology. See the Schedule of Classes for specific topics to be offered each semester and prerequisites.
BIOL 392. Introduction to Research. 2 Hours.
Semester course; 1 lecture and 1 demonstration hour. 2 credits. Prerequisite: BIOL 300, BIOL 310, BIOL 317 or BIOL 318 with a minimum grade of C. An introduction to the scientific process, including the mechanics of problem definition, information gathering and experimental design. Experimentation is discussed in context with methods of data collection and analysis. Aims are to prepare the student for future research experiences and to have the student write detailed research proposals.

BIOL 395. Directed Study. 1-2 Hours.
Semester course; variable hours. 1-2 credits. Maximum of 2 credits per semester; maximum total of 6 credits for all independent study courses (BIOL 395, BIOL 492, BIOL 495 and/or BIOZ 395). Prerequisites: BIOL 151 and BIOL 152 with minimum grades of C, permission of the Department of Biology and research mentor. Mentors are not limited to faculty members within the Department of Biology, but the context of the research study must be applicable to the biological sciences as determined by the department. Studies should include directed readings, directed experimentation or advanced guided inquiry — all under the direct supervision of a faculty member. A minimum of three hours of supervised activity per week per credit hour is required. Graded as pass/fail.

BIOL 401. Applied and Environmental Microbiology. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: 300 and 317, each with a minimum grade of C. The biology and chemical activities of microorganisms (bacteria, algae, virus and fungi) of industrial, pharmaceutical and agricultural importance.

BIOL 402. Comparative Vertebrate Anatomy. 5 Hours.
Semester course; 3 lecture and 4 laboratory hours. 5 credits. Prerequisites: BIOL 300 and BIOL 318, each with a minimum grade of C. The evolution of vertebrate forms as demonstrated by anatomical studies of selected vertebrate types.

BIOL 403. Primatology. 4 Hours.
Semester course; 3 lecture and 2 laboratory hours. 4 credits. Prerequisite: ANTH 210 or ANTH 301/BIOL 341. Primatology investigates the taxonomic relationships among primates through comparative anatomy, comparative behavior and comparative biochemistry. Study of primate evolution, demography, subsistence, reproduction, social organization, communication systems and ecology. Crosslisted as: ANTH 403.

BIOL 411. Animal Physiology. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: BIOL 300 and CHEM 301, each with a minimum grade of C. Physiological principles of animal cells, tissues and organs from the viewpoint of chemical and physical phenomena.

BIOL 413. Parasitology. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: BIOL 300 with a minimum grade of C. The epidemiology and pathological effects of eukaryotic parasites, including parasite life cycles and host-parasite relationships.

BIOL 415. Mangrove Avian Field Ecology. 4 Hours.
Semester course; two weeks abroad in Panama (or other tropical location with mangrove forests) followed by class meetings two days per week throughout most of spring semester. 4 credits. Prerequisite: BIOL 317. An immersive study of tropical ecology with a focus on bird ecology and conservation of mangrove ecosystems through a unique blend of rigorous science and community engagement. Two weeks of study abroad, including engagement with local conservation organizations and participation in education outreach with local schools, followed by discussion, data analysis and presentation of progress and research in a public symposium on campus.

BIOL 416. Ornithology. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: BIOL 317 with a minimum grade of C. Provides an integrative study of birds, including avian evolution and diversity, general anatomy and physiology, behavior, and ecology.

BIOL 417. Mammalogy. 4 Hours.
Semester course; 3 lecture and 3 laboratory hours. 4 credits. Prerequisites: BIOL 218 and 317 with minimum grades of C. Study of the characteristics, adaptive radiation and distribution of mammals, with emphasis on North American forms.

BIOL 420. Yeast and Fermentation. 3 Hours.
Semester course; 2 lecture and 3 laboratory hours. 3 credits. Prerequisite: BIOL 300 with a minimum grade of C. Corequisites: BIOL 303 and BIOL 310. Addresses the basic biology of yeast used in brewing beer and briefly in wine production. Topics will include yeast properties such as growth, structure, genetics, biodiversity and natural habitats. The process of wine and beer production will be discussed. Laboratory sessions include basic microbiology techniques, yeast isolations and characterization using DNA and biochemical methods, as well as the study of factors that affect fermentation. At the end of the course the students will give a presentation on other fermentation products of their interest such as vinegar, bread, etc., providing an expanded version of this important process.

BIOL 422. Forest Ecology. 4 Hours.
Semester course; 3 lecture hours and 3 laboratory hours. 4 credits. Prerequisite: BIOL 317 with a minimum grade of C. Covers the fundamentals of forest ecology, with a particular emphasis on Virginia’s diverse forest ecosystems. Students gain an understanding of the principal controls on forest structure, growth and distribution and relate these principles to sustainable forest management.

BIOL 425. Field Botany. 3 Hours.
Semester course; 2 lecture hours and 3 laboratory hours. (60 percent online, 40 percent field/laboratory) 3 credits. Prerequisites: BIOL 310 and BIOL 317, both with minimum grades of C. Online lectures, discussions, reflections and assessments in conjunction with field experience. Explores the effects of environmental conditions on plant morphology and adaptations, with emphasis on plant anatomy, plant physiology and ecology.

BIOL 430. Invasion Biology. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: BIOL 151, BIOL 152, BIOZ 151, BIOZ 152 and BIOL 317, all with minimum grade of C. A comprehensive view of the ecology and impacts of invasive species. Integrates the effects of historical human demography, ecological disturbance, natural history, species interactions, barriers to invasion, invasive species management and impacts on natural communities and ecosystems.
BIOL 431. Introduction to Marine Biology. 3 Hours. Semester course; 3 lecture hours. 3 credits. Prerequisites: BIOL 317, CHEM 102 and CHEZ 102, with minimum grades of C. An introduction to physical, chemical and geological oceanography and a more detailed treatment of the organisms and ecological processes involved in the pelagic and benthic environments of the world's oceans and estuaries.

BIOL 435. Herpetology. 3 Hours. Semester course; 3 lecture hours. 3 credits. Prerequisite: BIOL 317 with a minimum grade of C. The evolution, ecology, structure, taxonomy and behavior of reptiles and amphibians.

BIOL 438. Forensic Molecular Biology. 3 Hours. Semester course; 3 lecture hours. 3 credits. Prerequisites: CHEM 302, CHEZ 302, and BIOL 310 or equivalent, each with a minimum grade of C. Provides an understanding of molecular biology testing methodologies as applied to analysis of forensic samples. Current topics in forensic DNA analysis will include quality assurance, DNA databanking, contemporary research and population genetics. Crosslisted as: FRSC 438.

BIOL 440. Developmental Biology. 3 Hours. Semester course; 3 lecture hours. 3 credits. Prerequisites: BIOL 300 and 310, each with a minimum grade of C. Basic principles of developmental biology focused on vertebrate model organisms with an emphasis on the underlying cellular and molecular mechanisms that guide development.

BIOL 445. Neurobiology and Behavior. 4 Hours. Semester course; 3 lecture and 3 laboratory hours. 4 credits. Prerequisite: BIOL 317 with a minimum grade of C. The study of animal behavior stressing ecological, evolutionary and neurobiological approaches.

BIOL 448. Neuroscience. 3 Hours. Semester course; 3 lecture hours. 3 credits. Prerequisite: BIOL 300 with a minimum grade of C. Pre- or corequisite: BIOL 310. An examination of the basic structure of the nervous system, nervous system operation on a cellular and molecular level and the formation of the nervous system during development.

BIOL 450. Biology of Cancer I. 3 Hours. Semester course; 3 lecture hours. 3 credits. Prerequisites: BIOL 300 with a minimum grade of C or PHIS 309. An examination of the cellular, molecular and clinical aspects of cancer development, progression and treatment.

BIOL 451. Biology of Cancer II. 4 Hours. Semester course; 1 lecture and 12 laboratory hours. 4 credits. Prerequisites: BIOL 450 and instructor's permission. An examination of the cellular, molecular and clinical aspects of cancer development, progression and treatment.

BIOL 452. Biology of Drugs. 3 Hours. Semester course; 3 lecture hours. 3 credits. Prerequisite: BIOL 300 with a minimum grade of C. Explores how drugs modulate biological signaling pathways to study, cure, enhance and intoxicate organisms. An introduction to basic pharmacology that largely focuses on human pathways and diseases. Topics include major drug classes (cardiovascular, gastrointestinal, etc.) and drugs of abuse (alcohol, marijuana, etc.).

BIOL 455. Immunology. 3 Hours. Semester course; 3 lecture hours. 3 credits. Prerequisite: BIOL 300 with a minimum grade of C or PHIS 309. A comprehensive introduction to the immune system of higher animals, emphasizing the molecular and cellular basis for antibody-mediated immunity.

BIOL 459. Infectious Disease Ecology. 3 Hours. Semester course; 3 lecture hours. 3 credits. Prerequisites: BIOL 151, BIOL 152, BIOZ 151, BIOZ 152 and BIOL 317, all with minimum grade of C. A comprehensive and up-to-date overview of the causes and consequences of infectious disease at levels from individual organisms to global scale. Examines the history of infectious disease ecology in human and nonhuman populations. Students learn about the roles of transmission and coevolution in infectious disease ecology and how population models are used to inform management of epidemics and emerging infectious diseases.

BIOL 460. Human Evolutionary Genetics. 3 Hours. Semester course; 3 lecture hours. 3 credits. Prerequisite: BIOL 318 or BIOL 341 with a minimum grade of C. The origin and genetic history of modern humans, our historic colonization and migration, the utility of the Human Genome Project, our differences from other primates, adaptation to our environment and disease, and the ethical implications of genetic research in our society.

BIOL 475. Biology Capstone Seminar: ____. 1-3 Hours. Semester course; 1-3 seminar hours. 1-3 credits. Prerequisites: BIOL 300, BIOL 310, BIOL 317 and BIOL 318, each with a minimum grade of C. Enrollment is restricted to biology majors with senior standing. Students read assigned topical papers before class, prepare critical analyses, discuss and debate selected positions. See Schedule of Classes for specific topics.

BIOL 477. Biology Capstone Experience. 0 Hours. Semester course; variable hours. 0 credits. Prerequisites: BIOL 300, BIOL 310, BIOL 317 and BIOL 318, each with a minimum grade of C and 90 hours of undergraduate course work. The following courses qualify as a capstone experience if taken concurrently with this course: BIOL 492, BIOL 493, BIOL 495, BIOL 497 or other courses, including topics courses, which include the core competencies required for a capstone experience and are approved by the chair of the Department of Biology. Graded as pass/fail.

BIOL 480. Animal-Plant Interactions. 3 Hours. Semester course; 3 lecture hours. 3 credits. Prerequisite: BIOL 317 or BIOL 318 with a minimum grade of C, or permission of the instructor. Ecological and evolutionary consequences of interactions among animals and plants.

BIOL 489. Communicating Research. 1 Hour. Semester course; 1 lecture hour. 1 credit. Prerequisite: Completion of the Biocore with minimum grades of C. Corequisite: BIOL 495, senior standing. An opportunity for students to develop skills necessary for effective communication of their research in writing. Includes a variety of seminar discussions and activities including preparation of figures for publication and the crafting of a research paper with correct usage of the primary literature. Students will use this as an opportunity to aid the writing of their thesis for BIOL 495.

BIOL 490. Presenting Research. 1 Hour. Semester course; 1 credit. Prerequisite: Completion of the Biocore with minimum grades of C. Pre- or corequisites: BIOL 492 or 495, and senior standing. Opportunity for students to develop skills necessary for effective oral presentation of their research work. Includes a variety of seminar discussions and activities such as preparation of visual materials and statistical analysis of data. Students will make several oral presentations directly related to their specific BIOL 492 or 495 projects.

BIOL 491. Topics in Biology. 1-4 Hours. Semester course; variable hours. Variable credit. Prerequisite: BIOL 300. A study of a selected topic in biology. See the Schedule of Classes for specific topics to be offered each semester and prerequisites.
BIOL 492. Independent Study. 1-4 Hours.
Semester course; 1-4 variable hours. 1-4 credits. Maximum of 4 credits per semester; maximum total of 6 credits for all independent study courses (BIOL 395, BIOL 492, BIOL 495 and/or BIOZ 395). A minimum of 2 credits is required for the course to count as a laboratory experience. Prerequisites: BIOZ 151 and BIOZ 152, each with a minimum grade of C; and permission of the chair of the Department of Biology. Projects should include data collection and analysis, learning field and/or laboratory techniques, and/or mastering experimental procedures, all under the direct supervision of a faculty member. A minimum of three hours of supervised activity per week per credit hour is required. A final report must be submitted at the completion of the project.

BIOL 493. Biology Internship. 1-3 Hours.
Semester course; variable hours. Variable credit. Maximum of 3 credits per semester; maximum total of 6 credits for all independent study and internship courses. 1 credit awarded for each 100 hours of work experience in professional biology setting. Prerequisites: BIOL 310 or 317 with minimum grades of C; and permission of the chair of the Department of Biology and of the agency, company or organization in which internship will be held. Internship designed to provide laboratory or field experience in an off-campus professional biology setting. A final report must be submitted upon completion of the internship. Graded as pass/fail.

BIOL 495. Research and Thesis. 1-4 Hours.
Semester course; 1-4 variable hours. 1-4 credits. Maximum of 4 credits per semester; maximum total of 6 credits for all undergraduate research in biology (BIOL 395, BIOL 492, BIOL 495 and/or BIOZ 395). A minimum of 2 credits is required for the course to count as a laboratory experience. A minimum of 4 credits is required for honors in biology. Prerequisites: BIOL 392, permission of the supervising faculty member and a research proposal acceptable to the departmental chair. Corequisite: BIOL 489 or BIOL 490, depending on term offering. Activities include field and/or laboratory research under the direct supervision of a faculty mentor. A minimum of three hours of supervised activity per week per credit hour is required. Research projects must include experimental design and analysis of data. This course must be taken for two consecutive semesters starting in the fall. A written thesis of substantial quality is required upon completion of the research.

BIOL 496. Biology Preceptorship: ____. 2 Hours.
Semester course; 2 practicum hours. 2 credits. May be repeated with a different course for a maximum of 4 credits. Enrollment restricted to students who have completed the relevant course with a minimum grade of B and who have a minimum cumulative GPA of 3.0. Permission of instructor and departmental chair required prior to registration. Preceptors assist instructors in lecture (BIOL) or laboratory (BIOZ) courses. Responsibilities vary and may include, but are not are limited to, attending class, conducting review sessions and preparing course study/review materials. Graded as pass/fail.

BIOL 497. Ecological Service Learning. 1 Hour.
Semester course; 1 lecture hour. 1 credit. Prerequisite: BIOL 317 with a minimum grade of C. A service-learning course coupled to course content and material taught in BIOL 317. Students will seek out ecologically relevant opportunities with local, state and federal community partners who will provide experiences to enhance academic enrichment and personal growth and will help foster a sense of civic responsibility. Students must complete a minimum of 20 service-learning hours with community partner(s).

BIOL 498. Insects and Plants Service-learning. 2 Hours.
Semester course; 2 field experience hours. 2 credits. Prerequisites: BIOL 317 or BIOL 318 with a minimum grade of C, and permission of the instructor. A service-learning course related to insect-plant interactions. Field experience with community partners, including public parks, botanical gardens and organic farms. Designed to expand academic instruction, enhance personal growth and foster a sense of civic responsibility. Students must complete a minimum of 40 service-learning hours with a community partner.