BIOINFORMATICS AND COMPUTATIONAL BIOLOGY

Undergraduate study in BCBIO is jointly administered by the Department of Computer Science, the Department of Genetics, Development, and Cell Biology, and the Department of Mathematics. The undergraduate B.S. degree is offered through the College of Liberal Arts and Sciences.

Bioinformatics and Computational Biology is an interdisciplinary science at the interfaces of the biological, informational and computational sciences. The science focuses on a variety of topics. These include gene identification, expression, and evolution; RNA, protein, and genome structure; and molecular and cellular systems and networks. The large group of participating faculty provides students with a multidimensional perspective on bioinformatics and computational biology and presents them with broad range of possibilities to get involved in research.

This major will prepare students for careers at the interfaces of biological, informational and computational sciences. BCBIO graduates with a B.S. seeking direct employment will find ready markets for their talents in agricultural and medical biotechnology industries, as well as in academia, national laboratories, and clinics. Although some students find employment directly after their baccalaureate training, many students will continue their education in one of the many excellent graduate programs in bioinformatics and computational biology that now exist.

Participation in this field requires that students achieve a high level of competence not only in biology, but also in mathematics, computer science, and statistics. As a result, the program includes required courses from many different disciplines. Graduates demonstrate an above-average ability to synthesize methods from these different disciplines to solve problems.

Student Learning Outcomes

By completing their studies, students earning the BS degree in BCBIO are expected to:

1. Develop critical thinking skills by implementing the scientific method through bioinformatics data analysis.

2. Explain and complete simple applications of the common bioinformatics and computational biology methods used for DNA, RNA, and protein analysis.

3. Understand the central dogma of biology and how bioinformatic analyses of high throughput biological next-generation sequencing proteomics datasets can help answer fundamental questions about the biology of DNA, RNA, and proteins.

4. Define systems biology and explain its importance in understanding biology; undertake basic data analyses in systems biology.

5. Identify common formats for biological data and be able to convert among different formats.

6. Summarize fundamental bioinformatics software tools, know when to apply them, and be able to use them.

7. Combine existing software tools into bioinformatic data processing pipelines.

8. Evaluate the limits of traditional algorithms and data analysis techniques as they apply to big data in biology.

9. Identify and appraise noise in high throughput biological datasets and uncertainty in the conclusions of data analysis.

10. Interpret bioinformatics and computational biology analyses individually and in collaborative learning environments.

As majors in the College of Liberal Arts and Sciences, Bioinformatics and Computational Biology students must meet College of Liberal Arts and Sciences (http://catalog.iastate.edu/collegeofliberalartsandsciences/#lascollegerequirements) and University-wide requirements (http://catalog.iastate.edu/collegescurricula/) for graduation in addition to those stated below for the major.

LAS majors require a minimum of 120 credits, including a minimum of 45 credits at the 3000/4000 level. You must also complete the LAS world language requirement and career proficiency requirement.

Students in all ISU majors must complete a three-credit course in U.S. diversity and a three-credit course in international perspectives. Check (http://www.registrar.iastate.edu/courses/div-ip-guide.html) for a list of approved courses. Discuss with your advisor how the two courses that you select can be applied to your graduation plan.

A. Complementary Courses for the BCBIO Major

A minimum of 5 credits from the following:

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<th>CHEM 1630 &amp; 1630L</th>
<th>College Chemistry and Laboratory in College Chemistry</th>
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| or
| CHEM 1770 & 1770L & 1780 | General Chemistry I and Laboratory in General Chemistry I and General Chemistry II |
| or
| CHEM 2010 & 2010L | Advanced General Chemistry and Laboratory in Advanced General Chemistry |

A minimum of 4 credits from the following:

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| or
| CHEM 1770 & 1770L & 1780 | General Chemistry I and Laboratory in General Chemistry I and General Chemistry II |
| or
| CHEM 2010 & 2010L | Advanced General Chemistry and Laboratory in Advanced General Chemistry |

A minimum of 4 credits from the following:
### Bioinformatics and Computational Biology

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<th>CHEM 2310 &amp; 2310L</th>
<th>Elementary Organic Chemistry and Laboratory in Elementary Organic Chemistry</th>
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<tr>
<td>CHEM 3310 &amp; 3310L</td>
<td>Organic Chemistry I and Laboratory in Organic Chemistry I</td>
</tr>
<tr>
<td>CHEM 3320 &amp; 3320L</td>
<td>Organic Chemistry II and Laboratory in Organic Chemistry II</td>
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5 credits from the following:

| PHYS 1150 | Physics for the Life Sciences and Laboratory in Physics for the Life Sciences |
| PHYS 1310 | General Physics I and General Physics I Laboratory |
| STAT 3300 | Probability and Statistics for Computer Science |
| STAT 4830 | Empirical Methods for the Computational Sciences |
| BIOL 2110 & 2110L | Principles of Biology I and Principles of Biology Laboratory I |
| BIOL 2120 & 2120L | Principles of Biology II and Principles of Biology Laboratory II |
| BIOL 3140 | Principles of Molecular Cell Biology |
| BIOL 3150 | Biological Evolution |
| GEN 4090 | Molecular Genetics |

**Total Credits**: 31-38

Complementary courses note: The following other STAT courses may be substituted for STAT 3300 and STAT 4830, with permission of the BCBIO Major.

- STAT 3300: STAT 1010, 1040, 2010, 2310, 3050, or 3410
- STAT 4830: STAT 3010, 3420, or 4320

**B. Core Courses Within the BCBIO Major**

| GEN 3130 | Principles of Genetics and Genetics Laboratory |
| COMS 2270 & COMS 2280 | Object-oriented Programming and Introduction to Data Structures (recommended when developing course plan) |
| COMS 2300 | Discrete Computational Structures |
| COMS 3110 | Introduction to the Design and Analysis of Algorithms |
| MATH 1650 | Calculus I |
| & MATH 1660 | and Calculus II (recommended when developing course plan) |
| BCBIO 1100 | BCBIO Orientation |
| & BCBIO 4010 | Bioinformatics of OMICS |
| or BCBIO 4900 | Independent Study or BCBIO 4910 | Team Research Projects |

**Total Credits**: 35.5-39.5

Core courses note: The COMS 2270/2280 and MATH 1650/1660 core course series is required for BCBIO majors. However, students transferring into the major who have already earned credit for COMS 2070/2080 and/or the Math 1810/1820 can substitute those courses for the respective COMS 2270/2280 and/or MATH 1650/1660 series. Students will need permission of the instructors to enroll in any upper-level course that requires a pre-req in COMS 2270/2280 and/or MATH 1650/1660.

C. Support Electives

3-9 credits to be chosen from the following list:

- BBMB 4040 | Biochemistry I |
- BBMB 4050 | Biochemistry II |
- BBMB 4610 | Molecular Biophysics |
- BIOL 3280 | Molecular and Cellular Biology of Human Diseases |
- BIOL 4230 | Developmental Biology |
- BIOL 4510 | Plant Evolution and Phylogeny |
- BIOL 4620 | Evolutionary Genetics |
- BIOL 4870 | Microbial Ecology |
- COMS 2520 | Linux Operating System Essentials |
- COMS 3090 | Software Development Practices |
- COMS 3190 | Construction of User Interfaces |
- COMS 3270 | Advanced Programming Techniques |
- COMS 3630 | Introduction to Database Management Systems |
- COMS 4250 | High Performance Computing for Scientific and Engineering Applications |
- COMS 4260 | Introduction to Parallel Algorithms and Programming |
- GEN 3400 | Human Genetics |
- GEN 4100 | Analytical Genetics |
- MATH 2070 | Matrices and Linear Algebra |
- or MATH 3170 | Theory of Linear Algebra |
### Bioinformatics and Computational Biology, B.S.

#### Freshman

**Fall**
- **BCBIO 1100** 0 BIOL 2120 0.5 3
- **BIOL 2110** 3 1
- **BIOL 2110L** 1 3
- **CHEM 1630** 4 CHEM 2310 1
- **CHEM 1630L** 1 MATH 1660 4
- **MATH 1650** 4 LIB 1600 1

**Spring**
- **BCBIO 3220** 3 3
- **BIOL 3130** 3 3
- **BIOL 3130L** 1 BIOL 3140 3
- **BCBIO 3220** 3 PHYS 1150 4
- **COMS 2270** 4 PHYS 1150L 1
- **ENGL 2500** 3 3
- **International Perspectives or U.S. Diversity**

**Sophomore**

**Fall**
- **COMS 2300 (or CPRE 3100)** 3 COMS 3110 3
- **STAT 3300** 3 3
- **ENGL 3090 (or ENGL 3120 or ENGL 3140)** 3 3
- **Humanities Choice** 3 3

**Spring**
- **MATH 2650 (or other Support Elective)** 3 3
- **ENGL 1500** 3 3

**Junior**

**Fall**
- **COMS 2300 (or CPRE 3100)** 3 COMS 3110 3
- **STAT 3300** 3 3
- **ENGL 3090 (or ENGL 3120 or ENGL 3140)** 3 Bioinformatics Support Elective
- **MATH 2650 (or other Support Elective)** 4 3
- **Humanities Choice** 3 3
- **World Language if needed / Elective** 3 4
- **COMS 3630 (Recommended or other support elective)** 3 International Perspectives or US Diversity
- **Social Science choice** 3 3

**Senior**

**Fall**
- **BCBIO 4010 (or BCBIO 4440)** 3 BCBIO 4900 or 4910 1-5
- **Humanities choice** 3 3
- **World Language, if needed / Elective** 3-4
- **COMS 3630 (Recommended or other support elective)** 3
- **Social Science choice** 3 3

**Total Credits:** 121.5-132.5

### Minor in Bioinformatics and Computational Biology

The administering departments offer a minor in Bioinformatics and Computational Biology, which requires the following courses.

- **BIOL 2110** Principles of Biology I 3
- **BIOL 2120** Principles of Biology II 3
- **GEN 3130** Principles of Genetics 3
- **COMS 2270** Object-oriented Programming 7
- **COMS 2280** and Introduction to Data Structures 2
- **STAT 3300** Probability and Statistics for Computer Science 3
Note: The following other STAT courses may be substituted for STAT 3300, with permission of the BCBIO Major: STAT 1010, 1040, 2010, 2310, 3050, or 3410.

2. The COMS 2270/2280 course series is required for the BCBIO minor. However, students transferring into the minor who have already earned credit for COMS 2070/2080 can substitute those courses for the COMS 2270/2280 series. Students will need permission of the instructors to enroll in any upper-level course that requires a pre-req in COMS 2270/2280.

Most students pursuing a minor in Bioinformatics and Computational Biology will be biology, genetics, computer science, computer engineering, statistics, or mathematics students who have already taken some of these courses for their major. The minor must include at least 9 credits that are not used to meet any other department, college, or university requirement.

Graduate Study

Work is offered for the Master of Science and Doctor of Philosophy degrees with a major in Bioinformatics and Computational Biology (BCB). Faculty are drawn from several departments: Agronomy; Animal Science; Astronomy and Physics; Biochemistry, Biophysics and Molecular Biology; Biomedical Sciences; Chemical and Biological Engineering; Chemistry; Computer Science; Ecology, Evolution, and Organismal Biology; Electrical and Computer Engineering; Entomology, Genetics, Development and Cell Biology; Materials Science and Engineering; Mathematics; Plant Pathology; Statistics; Veterinary Microbiology and Preventive Medicine; and Veterinary Pathology.

The BCB program emphasizes interdisciplinary training in nine related areas of focus: Bioinformatics, Computational Molecular Biology, Structural and Functional Genomics, Macromolecular Structure and Function, Metabolic and Developmental Networks, Integrative Systems Biology, information Integration and Data Mining, Biological Statistics, and Mathematical Biology. Additional information about research areas and individual faculty members is available at: www.bcb.iastate.edu (http://www.bcb.iastate.edu).

BCB students are trained to develop an independent and creative approach to science through an integrative curriculum and thesis research projects that include both computational and biological components. First year students are appointed as research assistants and participate in BCB 6970 Graduate Research Rotation, working with three or more different research groups to gain experience in both “wet” (biological) and “dry” (computer) laboratory environments. In the second year, students initiate a thesis research project under the joint mentorship of two BCB faculty mentors, one from the biological sciences and one from the quantitative/computational sciences. The M.S. and Ph.D. degrees are usually completed in two and five years, respectively.

Before entering the graduate BCB program, prospective BCB students should have taken courses in mathematics, statistics, computer science, biology, and chemistry. A course load similar to the following list would be considered acceptable:

- MATH 2650 Calculus III 4
- STAT 3410 Introduction to the Theory of Probability and Statistics I 4
- COMS 2270 Object-oriented Programming 4
- COMS 2280 Introduction to Data Structures 3
- COMS 2300 Discrete Computational Structures 3
- CPRE 3100 Theoretical Foundations of Computer Engineering 3
- CHEM 1630 College Chemistry 4
- CHEM 2310 Elementary Organic Chemistry 3
- BBMB 3010 Survey of Biochemistry 3
- BIOL 3130 Principles of Genetics 3
- BIOL 3150 Biological Evolution 3

During the first year, BCB students are required to address any background deficiencies in calculus, molecular genetics, computer science, statistics and discrete structures, with specific courses determined by prior training. Among the total course requirements for Ph.D. students are four core courses in Bioinformatics, three of which are mandatory in the BCB program:

- BCB 5670 Bioinformatics Algorithms 3
- BCB 5680 Statistical Bioinformatics 3
- BCB 5690 Structural Bioinformatics 3
- BCB 5700 Systems Biology 3

And also should include

- GDCB 5110 Advanced Molecular Genetics 3
- BCB 6900 Student Seminar in Bioinformatics and Computational Biology
- BCB 6910 Faculty Seminar in Bioinformatics and Computational Biology
- BCB 5930 Workshop in Bioinformatics and Computational Biology

M.S. students take the above background and core courses, take at least 6 credits of advanced coursework, and may elect to participate in fewer seminars and workshops. Additional coursework may be selected
to satisfy individual interests or recommendations of the Program of Study Committee. All graduate students are encouraged to teach as part of their training for an advanced degree. (For curriculum details and sample programs of study, see: www.bcb.iastate.edu (http://www.bcb.iastate.edu).)