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/#lascollegerequirementstext) 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:		5-8
CHEM 1630 & 1630L	College Chemistry and Laboratory in College Chemistry	
or		
CHEM 1770 & 1770L & CHEM 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:		4-8

CHEM 2310 & 2310L	Elementary Organic Chemistry and Laboratory in Elementary Organic Chemistry	
or		
CHEM 3310 & 3310L	Organic Chemistry I and Laboratory in Organic Chemistry I	
and		
CHEM 3320 & 3320L	Organic Chemistry II and Laboratory in Organic Chemistry II	
5 credits from the following:		5
PHYS 1150 & 1150L	Physics for the Life Sciences and Laboratory in Physics for the Life Sciences	
or		
PHYS 1310 & 1310L	General Physics I and General Physics I Laboratory	
or		
PHYS 2310 & 2310L	Introduction to Classical Physics I and Introduction to Classical Physics I Laboratory	
STAT 3300	Probability and Statistics for Computer Science	3
STAT 4830	Empirical Methods for the Computational Sciences	3
BIOL 2110 & 2110L	Principles of Biology I and Principles of Biology Laboratory I	4
BIOL 2120 & 2120L	Principles of Biology II and Principles of Biology Laboratory II	4
BIOL 3140	Principles of Molecular Cell Biology	3
or		
BIOL 3150	Biological Evolution	
or		
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 & 3130L	Principles of Genetics and Genetics Laboratory	4
COMS 2270 & COMS 2280	Object-oriented Programming and Introduction to Data Structures (recommended when developing course plan)	7
COMS 2300	Discrete Computational Structures	3
COMS 3110	Introduction to the Design and Analysis of Algorithms	3
MATH 1650 & MATH 1660	Calculus I and Calculus II (recommended when developing course plan)	8
BCBIO 1100	BCBIO Orientation	0.5
BCBIO 3220	Introduction to Bioinformatics and Computational Biology	3
BCBIO 4010	Bioinformatics of Sequences	3
BCBIO 4060	Bioinformatics of OMICS	3
BCBIO 4900	Independent Study	1-5
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	3
BBMB 4050	Biochemistry II	3
BBMB 4610	Molecular Biophysics	2
BIOL 3280	Molecular and Cellular Biology of Human Diseases	3
BIOL 4230	Developmental Biology	3
BIOL 4510	Plant Evolution and Phylogeny	4
BIOL 4620	Evolutionary Genetics	3
BIOL 4870	Microbial Ecology	3
COMS 2520	Linux Operating System Essentials	3
COMS 3090	Software Development Practices	3
COMS 3190	Construction of User Interfaces	3
COMS 3270	Advanced Programming Techniques	3
COMS 3630	Introduction to Database Management Systems	3
COMS 4250	High Performance Computing for Scientific and Engineering Applications	3
COMS 4260	Introduction to Parallel Algorithms and Programming	4
GEN 3400	Human Genetics	3
GEN 4100	Analytical Genetics	3
MATH 2070	Matrices and Linear Algebra	3
or MATH 3170	Theory of Linear Algebra	

MATH 2650	Calculus III	4
MATH 2660	Elementary Differential Equations	3
or MATH 2670	Elementary Differential Equations and Laplace Transforms	
MATH 3040	Combinatorics	3
MATH 3140	Graph Theory	3
MATH 3730	Introduction to Scientific Computing	3
MICRO 4020	Microbial Genetics and Genomics	3
STAT 3420	Introduction to the Theory of Probability and Statistics II	4
STAT 4710	Introduction to Experimental Design	3
STAT 4740	Introduction to Bayesian Data Analysis	3
STAT 4750	Introduction to Multivariate Data Analysis	3
STAT 4860	Introduction to Statistical Computing	3
STAT 5810	Analysis of Gene Expression Data for the Biological Sciences	3

D. The communications and English proficiency requirements of the LAS college are met by:

ENGL 1500	Critical Thinking and Communication	3
ENGL 2500	Written, Oral, Visual, and Electronic Composition	3
or ENGL 2500H	Written, Oral, Visual, and Electronic Composition: Honors	
And one of the following:		
ENGL 3090	Proposal and Report Writing	3
or		
ENGL 3120	Communicating Science and Public Engagement	
or		
ENGL 3140	Technical Communication	

BCBIO majors must earn a minimum grade of C in ENGL 2500 Written, Oral, Visual, and Electronic Composition or ENGL 2500H Written, Oral, Visual, and Electronic Composition: Honors.

Bioinformatics and Computational Biology, B.S.

Freshman

Fall	Credits	Spring	Credits
BCBIO 1100	0.5	BIOL 2120	3
BIOL 2110	3	BIOL 2120L	1
BIOL 2110L	1	CHEM 2310	3
CHEM 1630	4	CHEM 2310L	1
CHEM 1630L	1	MATH 1660	4
MATH 1650	4	LIB 1600	1
ENGL 1500	3	Humanities choice	3
	16.5		**16**

Sophomore

Fall	Credits	Spring	Credits
BIOL 3130	3	COMS 2280	3
BIOL 3130L	1	BIOL 3140	3
BCBIO 3220	3	PHYS 1150	4
COMS 2270	4	PHYS 1150L	1
ENGL 2500	3	Social Science choice	3
International Perspectives or U.S. Diversity	3	LAS 2030	1
	17		**15**

Junior

Fall	Credits	Spring	Credits
COMS 2300 (or CPRE 3100)	3	COMS 3110	3
STAT 3300	3	STAT 4830	3
ENGL 3090 (or ENGL 3120 or ENGL 3140)	3	Bioinformatics Support Elective	3-9
MATH 2650 (or other Support Elective)	4	Humanities choice	3
Humanites Choice	3	Social Science choice	3
	16		**15-21**

Senior

Fall	Credits	Spring	Credits
BCBIO 4010 (or BCBIO 4440)	3	BCBIO 4900 or 4910	1-5
Humanities choice	3	BCBIO 4060	3
World Language, if needed / Elective	3-4	World Language if needed or elective	4
COMS 3630 (Recommended or other support elective)	3	International Perspectives or US Diversity	3
Social Science choice	3		
	15-16		**11-15**

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 & COMS 2280	Object-oriented Programming and Introduction to Data Structures	7
STAT 3300	Probability and Statistics for Computer Science	3

BCBIO 3220	Introduction to Bioinformatics and Computational Biology	3
BCBIO 4010	Bioinformatics of Sequences	3
BCBIO 4060	Bioinformatics of OMICS	3
Total Credits		**28**

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).)