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/previouscatalogs/2023-2024/collegeofliberalartsandsciences/#lascollegerequirementstext) and University-wide requirements (http://catalog.iastate.edu/previouscatalogs/2023-2024/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 300/400 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 163 & 163L	College Chemistry and Laboratory in College Chemistry	
or		
CHEM 177 & 177L & CHEM 178	General Chemistry I and Laboratory in General Chemistry I and General Chemistry II	
or		
CHEM 201 & 201L	Advanced General Chemistry and Laboratory in Advanced General Chemistry	
A minimum of 4 credits from the following:		4-8

CHEM 231 & 231L	Elementary Organic Chemistry and Laboratory in Elementary Organic Chemistry	
or		
CHEM 331 & 331L	Organic Chemistry I and Laboratory in Organic Chemistry I	
and		
CHEM 332 & 332L	Organic Chemistry II and Laboratory in Organic Chemistry II	
5 credits from the following:		5
PHYS 115 & 115L	Physics for the Life Sciences and Laboratory in Physics for the Life Sciences	
or		
PHYS 131 & 131L	General Physics I and General Physics I Laboratory	
or		
PHYS 231 & 231L	Introduction to Classical Physics I and Introduction to Classical Physics I Laboratory	
STAT 330	Probability and Statistics for Computer Science	3
STAT 483	Empirical Methods for the Computational Sciences	3
BIOL 211 & 211L	Principles of Biology I and Principles of Biology Laboratory I	4
BIOL 212 & 212L	Principles of Biology II and Principles of Biology Laboratory II	4
BIOL 314	Principles of Molecular Cell Biology	3
or		
BIOL 315	Biological Evolution	
or		
GEN 409	Molecular Genetics	
Total Credits		**31-38**

Complementary courses note:The following other STAT courses may be substituted for STAT 330 and STAT 483, with permission of the BCBio Major.
STAT 330: STAT 101, 104, 201, 231, 305, or 341
STAT 483: STAT 301, 342, or 432

B. Core Courses Within the BCBio Major

GEN 313 & 313L	Principles of Genetics and Genetics Laboratory	4
COM S 227 & COM S 228	Object-oriented Programming and Introduction to Data Structures (recommended when developing course plan)	7
COM S 230	Discrete Computational Structures	3
COM S 311	Introduction to the Design and Analysis of Algorithms	3
MATH 165 & MATH 166	Calculus I and Calculus II (recommended when developing course plan)	8
BCBIO 110	BCBIO Orientation	0.5
BCBIO 322	Introduction to Bioinformatics and Computational Biology	3
BCBIO 401	Bioinformatics of Sequences	3
BCBIO 406	Bioinformatics of OMICS	3
BCBIO 490 or BCBIO 491	Independent Study Team Research Projects	1-5
Total Credits		**35.5-39.5**

Core courses note: The Com S 227/228 and Math 165/166 core course series is required for BCBio majors. However, students transferring into the major who have already earned credit for Com S 207/208 and/or the Math 181/182 can substitute those courses for the respective Com S 227/228 and/or Math 165/166 series. Students will need permission of the instructors to enroll in any upper level course that requires a pre-req in Com S 227/228 and/or Math 165/166.

C. Support Electives

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

BBMB 404	Biochemistry I	3
BBMB 405	Biochemistry II	3
BBMB 461	Molecular Biophysics	2
BIOL 328	Molecular and Cellular Biology of Human Diseases	3
BIOL 423	Developmental Biology	3
BIOL 451	Plant Evolution and Phylogeny	4
BIOL 462	Evolutionary Genetics	3
BIOL 487	Microbial Ecology	3
COM S 252	Linux Operating System Essentials	3
COM S 309	Software Development Practices	3
COM S 319	Construction of User Interfaces	3
COM S 327	Advanced Programming Techniques	3
COM S 363	Introduction to Database Management Systems	3
COM S 425	High Performance Computing for Scientific and Engineering Applications	3
COM S 426	Introduction to Parallel Algorithms and Programming	4
GEN 340	Human Genetics	3
GEN 410	Analytical Genetics	3
MATH 207 or MATH 317	Matrices and Linear Algebra Theory of Linear Algebra	3
MATH 265	Calculus III	4

MATH 266	Elementary Differential Equations	3
or MATH 267	Elementary Differential Equations and Laplace Transforms	
MATH 304	Combinatorics	3
MATH 314	Graph Theory	3
MATH 373	Introduction to Scientific Computing	3
MICRO 402	Microbial Genetics and Genomics	3
STAT 342	Introduction to the Theory of Probability and Statistics II	4
STAT 471	Introduction to Experimental Design	3
STAT 474	Introduction to Bayesian Data Analysis	3
STAT 475	Introduction to Multivariate Data Analysis	3
STAT 486	Introduction to Statistical Computing	3
STAT 581	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 150	Critical Thinking and Communication	3
ENGL 250	Written, Oral, Visual, and Electronic Composition	3
or ENGL 250H	Written, Oral, Visual, and Electronic Composition: Honors	

And one of the following:

ENGL 309	Proposal and Report Writing	3
or		
ENGL 312	Communicating Science and Public Engagement	
or		
ENGL 314	Technical Communication	

BCBio majors must earn a minimum grade of C in ENGL 250 Written, Oral, Visual, and Electronic Composition or ENGL 250H Written, Oral, Visual, and Electronic Composition: Honors.

Bioinformatics and Computational Biology, B.S.

Freshman

Fall	Credits	Spring	Credits
BCBIO 110	0.5	BIOL 212	3
BIOL 211	3	BIOL 212L	1
BIOL 211L	1	CHEM 231	3
CHEM 163	4	CHEM 231L	1
CHEM 163L	1	MATH 166	4
MATH 165	4	LIB 160	1
ENGL 150	3	Humanities choice	3
	16.5		**16**

Sophomore

Fall	Credits	Spring	Credits
BIOL 313	3	COM S 228	3
BIOL 313L	1	BIOL 314	3
BCBIO 322	3	PHYS 115	4
COM S 227	4	PHYS 115L	1
ENGL 250	3	Social Science choice	3
International Perspectives or U.S. Diversity	3	LAS 203	1
	17		**15**

Junior

Fall	Credits	Spring	Credits
COM S 230 (or Cpr E 310)	3	COM S 311	3
STAT 330	3	STAT 483	3
ENGL 309 (or ENGL 312 or ENGL 314)	3	Bioinformatics Support Elective	3-9
MATH 265 (or other Support Elective)	4	Humanities choice	3
Humanites Choice	3	Social Science choice	3
	16		**15-21**

Senior

Fall	Credits	Spring	Credits
BCBIO 401 (or BCBIO 444)	3	BCBIO 490 or 491	1-5
Humanities choice	3	BCBIO 406	3
World Language, if needed / Elective	3-4	World Language if needed or elective	4
COM S 363 (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 211	Principles of Biology I	3
BIOL 212	Principles of Biology II	3
GEN 313	Principles of Genetics	3
COM S 227 & COM S 228	Object-oriented Programming and Introduction to Data Structures	7
STAT 330	Probability and Statistics for Computer Science	3
BCBIO 322	Introduction to Bioinformatics and Computational Biology	3

BCBIO 401	Bioinformatics of Sequences	3
BCBIO 406	Bioinformatics of OMICS	3
Total Credits		**28**

Note: The following other STAT courses may be substituted for STAT 330, with permission of the BCBio Major: STAT 101, 104, 201, 231, 305, or 341

2. The Com S 227/228 course series is required for the BCBio minor. However, students transferring into the minor who have already earned credit for Com S 207/208 can substitute those courses for the Com S 227/228 series. Students will need permission of the instructors to enroll in any upper level course that requires a pre-req in Com S 227/228.

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 697 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 265	Calculus III	4
STAT 341	Introduction to the Theory of Probability and Statistics I	4
COM S 227	Object-oriented Programming	4
COM S 228	Introduction to Data Structures	3
COM S 230	Discrete Computational Structures	3
CPR E 310	Theoretical Foundations of Computer Engineering	3
CHEM 163	College Chemistry	4
CHEM 231	Elementary Organic Chemistry	3
BBMB 301	Survey of Biochemistry	3
BIOL 313	Principles of Genetics	3
BIOL 315	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 567	Bioinformatics Algorithms (mandatory)	3
BCB 568	Statistical Bioinformatics (mandatory)	3
BCB 569	Structural Bioinformatics	3
BCB 570	Systems Biology (mandatory)	3
And also should include		
GDCB 511	Advanced Molecular Genetics	
BCB 690	Student Seminar in Bioinformatics and Computational Biology	
BCB 691	Faculty Seminar in Bioinformatics and Computational Biology	
BCB 593	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).)