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.

In addition to basic degree requirements listed in the Curriculum in Liberal Arts and Sciences, BCBio majors must satisfy the following requirements:

A. Complementary Courses for the BCBio Major

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	
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	
PHYS 111	General Physics	5
or		
PHYS 221	Introduction to Classical Physics I	
or		
PHYS 115 & 115L	Physics for the Life Sciences and Laboratory in Physics for the Life Sciences	
STAT 330	Probability and Statistics for Computer Science	3
STAT 430	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		**22**

Complementary courses note:The following other STAT courses may be substituted for STAT 330 and STAT 430, with permission of the BCBio Major.
STAT 330: STAT 101, 104, 105, 201, 231, 305, or 341
STAT 430: STAT 301, 401, or 432

B. Core Courses Within the BCBio Major

6-7 credits:		6-7
GEN 313 & 313L	Principles of Genetics and Genetics Laboratory	
COM S 227 & COM S 228	Introduction to Object-oriented Programming and Introduction to Data Structures (recommended when developing course plan)	
or		
COM S 207 & COM S 208	Fundamentals of Computer Programming and Intermediate Computer Programming (allowed for students entering major who took these courses)	
COM S 230	Discrete Computational Structures	3
COM S 311	Design and Analysis of Algorithms	3
MATH 165 & MATH 166	Calculus I and Calculus II (recommended when developing course plan)	8
or		
MATH 181 & MATH 182	Calculus and Mathematical Modeling for the Life Sciences I and Calculus and Mathematical Modeling for the Life Sciences II (allowed for students entering major who took these courses)	
BCBIO 110	BCBIO Orientation	0.5
BCBIO 322	Introduction to Bioinformatics and Computational Biology	3
BCBIO 401	Fundamentals of Bioinformatics and Computational Biology I	3
BCBIO 402	Fundamentals of Bioinformatics and Computational Biology II	3
BCBIO 490 or BCBIO 491	Independent Study Team Research Projects.	1-5
Total Credits		**30.5-35.5**

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 465	Morphometric Analysis	4
BIOL 487	Microbial Ecology	3
COM S 252	Linux Operating System Essentials	3
COM S 309	Software Development Practices	3
COM S 319	Software Construction and 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	Matrices and Linear Algebra	3
or MATH 317	Theory of Linear Algebra	
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	3
STAT 402	Statistical Design and the Analysis of Experiments	3
STAT 407	Methods of Multivariate Analysis	3
STAT 416	Statistical Design and Analysis of Gene Expression Experiments	3
STAT 444	Bayesian Data Analysis	3
STAT 480	Statistical Computing Applications	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	Biological Communication	
or		
ENGL 314	Technical Communication	

The lowest grade acceptable in ENGL 150 Critical Thinking and Communication, ENGL 250 Written, Oral, Visual, and Electronic Composition or ENGL 250H Written, Oral, Visual, and Electronic Composition: Honors is C-.

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	Introduction to Object-oriented Programming and Introduction to Data Structures	7
or		
COM S 207 & COM S 208	Fundamentals of Computer Programming and Intermediate Computer Programming	
STAT 330	Probability and Statistics for Computer Science	3
BCBIO 322	Introduction to Bioinformatics and Computational Biology	3
BCBIO 401	Fundamentals of Bioinformatics and Computational Biology I	3
BCBIO 402	Fundamentals of Bioinformatics and Computational Biology II	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, 105, 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. However, a total of 9 credits must be used only to fulfill the requirements of the minor.

Bioinformatics and Computational Biology B.S.

Freshman

Fall	Credits	Spring	Credits
BCBIO 110	0.5	BIOL 212	3
MATH 165	4	BIOL 212L	1
ENGL 150	3	Humanities choice	3
BIOL 211	3	MATH 166	4

BIOL 211L	1	LIB 160	1
CHEM 177	4	CHEM 178	3
CHEM 177L	1		
	16.5		**15**

Sophomore

Fall	**Credits**	**Spring**	**Credits**
CHEM 231L	1	GEN 409	3
BIOL 313L	1	COM S 228	3
COM S 227	4	MATH 265 (Recommended)	4
ENGL 250	3	Social Science choice	3
CHEM 231	3	BCBIO 322	3
BIOL 313	3		
	15		**16**

Junior

Fall	**Credits**	**Spring**	**Credits**
COM S 230 (or Cpr E 310)	3	Social Science choice	3
PHYS 221	5	Humanities choice	3
STAT 330***	3	COM S 311	3
Humanites Choice	3	Bioinformatics Support Elective**	3
		ENGL 309	3
		OR	
		ENGL 312 or 314	
	14		**15**

Senior

Fall	**Credits**	**Spring**	**Credits**
Elective*	3	BCBIO 402	3
Humanities choice	3	BCBIO 490 or 491	1-5
BCBIO 401	3	Social Science choice	3
COM S 363 (Recommended)	3	Elective*	3
STAT 430***	3		
	15		**10-14**

Total Credits: 116.5-120.5

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	3
COM S 207	Fundamentals of Computer Programming	3
COM S 208	Intermediate Computer Programming	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:

BCB 567	Bioinformatics I (Fundamentals of Genome Informatics)	3
BCB 568	Bioinformatics II (Advanced Genome Informatics)	3
BCB 569	Bioinformatics III (Structural Genome Informatics)	3
BCB 570	Bioinformatics IV (Computational Functional Genomics and Systems Biology)	3

And also should include

GDCB 511	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) .)

Courses primarily for undergraduates:

BCB 490: Independent Study
Cr. 1-5. Repeatable, maximum of 9 credits. F.S.SS.
Prereq: Permission of instructor

Courses primarily for graduate students, open to qualified undergraduates:

BCB 544: Fundamentals of Bioinformatics
(Cross-listed with COM S, CPR E, GDCB). (4-0) Cr. 4. F.
Prereq: MATH 165 or STAT 401 or equivalent
Survey of key bioinformatics methods, including hands-on use of computational tools to solve various biological problems. Topics include: database searching, sequence alignment, gene prediction, RNA and protein structure prediction, construction of phylogenetic trees, comparative and functional genomics, and systems biology.

BCB 567: Bioinformatics I (Fundamentals of Genome Informatics)
(Cross-listed with COM S, CPR E). (3-0) Cr. 3. F.
Prereq: COM S 228; COM S 330; credit or enrollment in BIOL 315, STAT 430
Biology as an information science. Review of algorithms and information processing. Generative models for sequences. String algorithms. Pairwise sequence alignment. Multiple sequence alignment. Searching sequence databases. Genome sequence assembly.

BCB 568: Bioinformatics II (Advanced Genome Informatics)
(Cross-listed with COM S, GDCB, STAT). (3-0) Cr. 3. S.
Prereq: BCB 567 or (BIOL 315 and STAT 430), credit or enrollment in GEN 409
Advanced sequence models. Basic methods in molecular phylogeny. Hidden Markov models. Genome annotation. DNA and protein motifs. Introduction to gene expression analysis.

BCB 569: Bioinformatics III (Structural Genome Informatics)
(Cross-listed with BBMB, COM S, CPR E). (3-0) Cr. 3. F.
Prereq: BCB 567, BBMB 316, GEN 409, STAT 430
Algorithmic and statistical approaches in structural genomics including protein, DNA and RNA structure. Structure determination, refinement, representation, comparison, visualization, and modeling. Analysis and prediction of protein secondary and tertiary structure, disorder, protein cores and surfaces, protein-protein and protein-nucleic acid interactions, protein localization and function.

BCB 570: Bioinformatics IV (Computational Functional Genomics and Systems Biology)
(Cross-listed with COM S, CPR E, GDCB, STAT). (3-0) Cr. 3. S.
Prereq: BCB 567 or COM S 311, COM S 228, GEN 409, STAT 430
Algorithmic and statistical approaches in computational functional genomics and systems biology. Elements of experiment design. Analysis of high throughput gene expression, proteomics, and other datasets obtained using system-wide measurements. Topological analysis, module discovery, and comparative analysis of gene and protein networks. Modeling, analysis, simulation and inference of transcriptional regulatory modules and networks, protein-protein interaction networks, metabolic networks, cells and systems: Dynamic systems, Boolean, and probabilistic models. Multi-scale, multi-granularity models. Ontology-driven, network based, and probabilistic approaches to information integration.

BCB 590: Special Topics
Cr. arr. Repeatable.
Prereq: Permission of instructor

BCB 593: Workshop in Bioinformatics and Computational Biology
(1-0) Cr. 1. Repeatable. F.S.
Current topics in bioinformatics and computational biology research. Lectures by off-campus experts. Students read background literature, attend preparatory seminars, attend all lectures, meet with lecturers.

BCB 598: Cooperative Education
Cr. R. Repeatable. F.S.SS.
Prereq: Permission of the program chair
Off-campus work periods for graduate students in the field of bioinformatics and computational biology.

BCB 599: Creative Component
Cr. arr.

Courses for graduate students:

BCB 660: Selected Topics in Bioinformatics and Computational Biology
(3-0) Cr. 1-4. Repeatable, maximum of 4 times. F.S.SS.
Prereq: Permission of Instructor
Topics of interest in the major research areas of computational molecular biology, including genomics, structural genomics, functional genomics, and computational systems biology.

BCB 690: Student Seminar in Bioinformatics and Computational Biology
Cr. 1. Repeatable. S.
Student research presentations.

BCB 691: Faculty Seminar in Bioinformatics and Computational Biology
(1-0) Cr. 1. Repeatable.
Faculty research series.

BCB 697: Graduate Research Rotation
Cr. arr. Repeatable. F.S.SS.
Graduate research projects performed under the supervision of selected faculty members in the Bioinformatics and Computational Biology major.

BCB 699: Research
Cr. arr. Repeatable.

Courses primarily for undergraduates:

BCBIO 110: BCBIO Orientation
(1-0) Cr. 0.5. F.
First 8 weeks. Orientation to the area of bioinformatics and computational biology. For students considering a major in BCBIO. Specializations and career opportunities. Offered on a satisfactory-fail basis only.

BCBIO 322: Introduction to Bioinformatics and Computational Biology
(Cross-listed with BIOL, GEN). (3-0) Cr. 3. F.
Prereq: BIOL 212
Genome sequencing, assembly, structural and functional annotation, and comparative genomics. Investigating these topics will develop skills in programming and scripting (Perl and/or Python), the use of biological databases, sequence alignment, homology search, identification of sequence patterns, construction of phylogenetic trees, and comparative genomics.

BCBIO 401: Fundamentals of Bioinformatics and Computational Biology I
(3-0) Cr. 3. F.
Prereq: BCBIO 211 and basic programming experience (e.g. COM S 207, COM S 208, COM S 227 or permission of instructor)
Application of computer science to molecular biology. String algorithms, sequence alignments, indexing data structures, homology search methods, pattern recognition, fragment assembly, genome annotation, construction of bioinformatics databases, and gathering and distribution of biological information with the Internet.

BCBIO 402: Fundamentals of Bioinformatics and Computational Biology II
(3-0) Cr. 3. S.
Prereq: BCBIO 401
Genomics: Gene structure prediction, gene function prediction and comparative genomics. Post-genomics: Gene expression studies, DNA microarrays, next-generation sequencing of transcriptome. Structural biology: Protein and RNA structure predictions, structure representation, comparison and visualization. Systems biology: Signal transduction pathway inference, biological networks and systems.

BCBIO 442: Bioinformatics and Computational Biology Techniques
(0.2-0.5) Cr. 0.5. Repeatable, maximum of 2 credits. S.SS.
Prereq: BIOL 314 recommended
Modular minicourses consisting of guided tutorials and hands-on computer software exercises focused on fundamental problems, approaches, and software applications in bioinformatics and computational biology. Offered on a satisfactory-fail basis only.

BCBIO 442A: Bioinformatics and Computational Biology Techniques: Sequence Database Searching
(0.2-0.5) Cr. 0.5. Repeatable, maximum of 2 credits. S.SS.
Prereq: BIOL 314 recommended
Modular minicourses consisting of guided tutorials and hands-on computer software exercises focused on fundamental problems, approaches, and software applications in bioinformatics and computational biology. Offered on a satisfactory-fail basis only.

BCBIO 442B: Bioinformatics and Computational Biology: Protein Structure Databases, Visualization, and Prediction
(0.2-0.5) Cr. 0.5. Repeatable, maximum of 2 credits. S.SS.
Prereq: BIOL 314 recommended
Modular minicourses consisting of guided tutorials and hands-on computer software exercises focused on fundamental problems, approaches, and software applications in bioinformatics and computational biology. Offered on a satisfactory-fail basis only.

BCBIO 442C: Bioinformatics and Computational Biology Techniques: Phylogenetic Analysis
(0.2-0.5) Cr. 0.5. Repeatable, maximum of 2 credits. S.SS.
Prereq: BIOL 314 recommended
Modular minicourses consisting of guided tutorials and hands-on computer software exercises focused on fundamental problems, approaches, and software applications in bioinformatics and computational biology. Offered on a satisfactory-fail basis only.

BCBIO 442D: Bioinformatics and Computational Biology Techniques: Microarray Analysis
(0.2-0.5) Cr. 0.5. Repeatable, maximum of 2 credits. S.SS.
Prereq: BIOL 314 recommended
Modular minicourses consisting of guided tutorials and hands-on computer software exercises focused on fundamental problems, approaches, and software applications in bioinformatics and computational biology. Offered on a satisfactory-fail basis only.

BCBIO 444: Bioinformatic Analysis
(Cross-listed with BCB, BIOL, COM S, CPR E, GEN). (4-0) Cr. 4. F.
Prereq: MATH 165 or STAT 401 or equivalent.
Broad overview of bioinformatics with a significant problem-solving component, including hands-on practice using computational tools to solve a variety of biological problems. Topics include: bioinformatic data processing, Perl programming, genome assembly, database search, sequence alignment, gene prediction, next-generation sequencing, comparative and functional genomics, and systems biology.

BCBIO 490: Independent Study
Cr. 1-5. Repeatable, maximum of 9 credits. F.S.SS.
Prereq: BCBIO 211, junior or senior classification, permission of instructor
Students in the College of Liberal Arts and Sciences may use no more than 9 credits of BCBIO 490 and 491 toward graduation.

BCBIO 491: Team Research Projects.
Cr. 1-5. Repeatable, maximum of 9 credits.
Prereq: BCBIO 211, junior or senior classification, permission of instructor
Research projects in bioinformatics and computational biology done by teams of students. Students in the College of Liberal Arts and Sciences may use no more than 9 credits of BCBIO 490 and 491 toward graduation.