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

A minimum of 4 credits from the following:		4-8
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	
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 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		**30-38**

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, 105, 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
A minimum of 6 credits from the following:		6-7
COM S 227 & COM S 228	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	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	Fundamentals of Bioinformatics and Computational Biology	4
BCBIO 402	Fundamentals of Systems Biology and Network Science	3
BCBIO 490 or BCBIO 491	Independent Study Team Research Projects.	1-5
Total Credits		**35.5-40.5**

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 or MATH 267	Elementary Differential Equations Elementary Differential Equations and Laplace Transforms	3
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 or ENGL 250H	Written, Oral, Visual, and Electronic Composition Written, Oral, Visual, and Electronic Composition: Honors	3
And one of the following:		
ENGL 309	Proposal and Report Writing	3
or		
ENGL 312	Biological Communication	
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.

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
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	4
BCBIO 402	Fundamentals of Systems Biology and Network Science	3
Total Credits		**29**

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. The minor must include at least 9 credits that are not used to meet any other department, college, or university requirement.

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		
	17		**14**

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)	4	BCBIO 402	3
Humanities choice	3	BCBIO 490 or 491	1-5
World Language if neeeded	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		
	17		**11-15**

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 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, 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).)

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, similarity search, identification of sequence patterns, construction of phylogenetic trees, and comparative genomics.

BCBIO 401: Fundamentals of Bioinformatics and Computational Biology
(Cross-listed with BIOL, COM S, GEN). (4-0) Cr. 4. F.
Prereq: BCBIO 322, basic programming experience (e.g. COM S 127, COM S 227 or permission of instructor). MATH 160 or MATH 165; and STAT 101 or STAT 104; and MATH 166 or STAT 301.
Application of computer science and statistics to molecular biology with a significant problem-solving component, including hands-on programming using Python to solve a variety of biological problems. String algorithms, sequence alignments, homology search, pattern discovery, genotyping, genome assembly, genome annotation, comparative genomics, protein structure.

BCBIO 402: Fundamentals of Systems Biology and Network Science
(3-0) Cr. 3. S.
Prereq: BIOL 212
Technologies: transcriptome, proteome, metabolome; Networks: Gene regulatory network, Protein-protein interaction network, Literature network; Theories: Graph theory, random network, scale-free network, evolving network, network robustness; Tools: Jmol, MeV, Cytoscape, Citespace.

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 490: Independent Study
Cr. 1-5. Repeatable, maximum of 9 credits. F.S.SS.
Prereq: BCBIO 322, junior or senior classification, permission of instructor
Independent research projects for undergraduate students in bioinformatics and computational biology. 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. F.S.SS.
Prereq: BCBIO 322, 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.

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. Alt. F., offered odd-numbered years.
Prereq: MATH 165 or STAT 401 or equivalent
A practical, hands-on overview of how to apply bioinformatics to biological research. Recommended for biologists desiring to gain computational molecular biology skills. Topics include: sequence analysis, genomics, proteomics, phylogenetic analyses, ontology enrichment, systems biology, data visualization and emergent technologies.

BCB 546: Computational Skills for Biological Data
(Cross-listed with EEOB). Cr. 3. F.
Prereq: Graduate student status or permission of the instructor
Computational skills necessary for biologists working with big data sets. UNIX commands, scripting in R and Python, version control using Git and GitHub, and use of high performance computing clusters. Combination of lectures and computational exercises.

BCB 567: Bioinformatics Algorithms
(Cross-listed with COM S, CPR E). (3-0) Cr. 3.
Prereq: COM S 228; COM S 330; credit or enrollment in BIOL 315, STAT 430
Biology as an information science. A review of the algorithmic principles that are driving the advances in bioinformatics and computational biology.

BCB 568: Statistical Bioinformatics
(Cross-listed with COM S, GDCB, STAT). (3-0) Cr. 3. S.
Prereq: BCB 567 or (BIOL 315 and one of STAT 430 or STAT 483 or STAT 583), credit or enrollment in GEN 409
Statistical models for sequence data, including applications in genome annotation, motif discovery, variant discovery, molecular phylogeny, gene expression analysis, and metagenomics. Statistical topics include model building, inference, hypothesis testing, and simple experimental design, including for big data/complex models.

BCB 569: Structural Bioinformatics
(Cross-listed with BBMB, COM S, CPR E, GDCB). (3-0) Cr. 3. F.
Prereq: BCB 567, BBMB 316, GEN 409, STAT 430
Molecular structures including genes and gene products: protein, DNA and RNA structure. Structure determination methods, structural refinement, structure representation, comparison of structures, visualization, and modeling. Molecular and cellular structure from imaging. Analysis and prediction of protein secondary, tertiary, and higher order structure, disorder, protein-protein and protein-nucleic acid interactions, protein localization and function, bridging between molecular and cellular structures. Molecular evolution.

BCB 570: 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 or STAT 483 or STAT 583
Algorithmic and statistical approaches in computational functional genomics and systems biology. Analysis of high throughput biological data obtained using system-wide measurements. Topological analysis, module discovery, and comparative analysis of gene and protein networks. Modeling, analysis, and inference of transcriptional regulatory networks, protein-protein interaction networks, and metabolic networks. Dynamic systems and whole-cell models. Ontology-driven, network based, and probabilistic approaches to information integration.

BCB 585: Fundamentals of Predictive Plant Phenomics
(Cross-listed with GDCB, M E). Cr. 4. F.
Principles of engineering, data analysis, and plant sciences and their interplay applied to predictive plant phenomics. Transport phenomena, sensor design, image analysis, graph models, network data analysis, fundamentals of genomics and phenomics. Multidisciplinary laboratory exercises.

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.