# 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

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<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>CHEM 163</td>
<td>College Chemistry</td>
<td></td>
</tr>
<tr>
<td>&amp; 163L</td>
<td>and Laboratory in College Chemistry</td>
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<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
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<tbody>
<tr>
<td>CHEM 177</td>
<td>General Chemistry I</td>
<td></td>
</tr>
<tr>
<td>&amp; 177L</td>
<td>and Laboratory in General Chemistry I</td>
<td></td>
</tr>
<tr>
<td>&amp; CHEM 178</td>
<td>and General Chemistry II</td>
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<tr>
<th>Course Code</th>
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<th>Credits</th>
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<tbody>
<tr>
<td>CHEM 201</td>
<td>Advanced General Chemistry</td>
<td></td>
</tr>
<tr>
<td>&amp; 201L</td>
<td>and Laboratory in Advanced General Chemistry</td>
<td></td>
</tr>
<tr>
<td>CHEM 231</td>
<td>Elementary Organic Chemistry</td>
<td></td>
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<tr>
<td>&amp; 231L</td>
<td>and Laboratory in Elementary Organic Chemistry</td>
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or

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<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>CHEM 331</td>
<td>Organic Chemistry I</td>
<td></td>
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<tr>
<td>&amp; 331L</td>
<td>and Laboratory in Organic Chemistry I</td>
<td></td>
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<tr>
<td>and</td>
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</tr>
<tr>
<td>CHEM 332</td>
<td>Organic Chemistry II</td>
<td></td>
</tr>
<tr>
<td>&amp; 332L</td>
<td>and Laboratory in Organic Chemistry II</td>
<td></td>
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or

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<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
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<tbody>
<tr>
<td>PHYS 111</td>
<td>General Physics</td>
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or

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<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>PHYS 221</td>
<td>Introduction to Classical Physics I</td>
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## B. Core Courses Within the BCBio Major

### 6-7 credits:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>GEN 313</td>
<td>Principles of Genetics</td>
<td></td>
</tr>
<tr>
<td>&amp; 313L</td>
<td>and Genetics Laboratory</td>
<td></td>
</tr>
<tr>
<td>COM S 227</td>
<td>Introduction to Object-oriented Programming</td>
<td></td>
</tr>
<tr>
<td>&amp; COM S 228</td>
<td>and Introduction to Data Structures</td>
<td></td>
</tr>
<tr>
<td>(recommended when developing course plan)</td>
<td></td>
<td></td>
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</table>

or

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>COM S 207</td>
<td>Fundamentals of Computer Programming</td>
<td></td>
</tr>
<tr>
<td>&amp; COM S 208</td>
<td>and Intermediate Computer Programming (allowed for students entering major who took these courses)</td>
<td></td>
</tr>
<tr>
<td>COM S 230</td>
<td>Discrete Computational Structures</td>
<td></td>
</tr>
<tr>
<td>COM S 311</td>
<td>Design and Analysis of Algorithms</td>
<td></td>
</tr>
<tr>
<td>MATH 165</td>
<td>Calculus I</td>
<td></td>
</tr>
<tr>
<td>&amp; MATH 166</td>
<td>and Calculus II</td>
<td></td>
</tr>
<tr>
<td>(recommended when developing course plan)</td>
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</table>

or

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>MATH 181</td>
<td>Calculus and Mathematical Modeling for the Life Sciences I</td>
<td></td>
</tr>
<tr>
<td>&amp; MATH 182</td>
<td>and Calculus and Mathematical Modeling for the Life Sciences II (allowed for students entering major who took these courses)</td>
<td></td>
</tr>
<tr>
<td>BCBIO 110</td>
<td>BCBIO Orientation</td>
<td>0.5</td>
</tr>
<tr>
<td>BCBIO 322</td>
<td>Introduction to Bioinformatics and Computational Biology</td>
<td>3</td>
</tr>
<tr>
<td>BCBIO 401</td>
<td>Fundamentals of Bioinformatics and Computational Biology</td>
<td>3</td>
</tr>
<tr>
<td>BCBIO 402</td>
<td>Fundamentals of Bioinformatics and Computational Biology II</td>
<td>3</td>
</tr>
<tr>
<td>BCBIO 490</td>
<td>Independent Study</td>
<td>1-5</td>
</tr>
<tr>
<td>or BCBIO 491</td>
<td>Team Research Projects.</td>
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**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 3
- MATH 265 Calculus III 4
- MATH 266 Elementary Differential Equations 3
- or MATH 267 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 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 3
- or
- ENGL 314 Technical Communication 3

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 Introduction to Object-oriented Programming 3
- & COM S 228 Introduction to Data Structures 3
- or
- COM S 207 Fundamentals of Computer Programming and Intermediate Computer Programming 3
- & COM S 208 Probability and Statistics for Computer Science 3
- STAT 330 Introduction to Bioinformatics and Computational Biology 3
- BCBIO 322 Fundamentals of Bioinformatics and Computational Biology I 3
- BCBIO 401 Fundamentals of Bioinformatics and Computational Biology II 3
- or
- BCBIO 402 Fundamentals of Bioinformatics and Computational Biology III 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

<table>
<thead>
<tr>
<th>Fall</th>
<th>Credits</th>
<th>Spring</th>
<th>Credits</th>
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<tbody>
<tr>
<td>BCBIO 110</td>
<td>0.5 BIOL 212</td>
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<td>3</td>
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<tr>
<td>MATH 165</td>
<td>4 BIOL 212L</td>
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<td>1</td>
</tr>
<tr>
<td>ENGL 150</td>
<td>3 Humanities choice</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>BIOL 211</td>
<td>3 MATH 166</td>
<td></td>
<td>4</td>
</tr>
</tbody>
</table>
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:

- **Fall**
  - 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)
  - BIOL 313: Principles of Genetics (3)
  - BIOL 315: Biological Evolution (3)

- **Spring**
  - MATH 341: Linear Algebra (3)
  - STAT 430: Introduction to Mathematical Statistics (3)
  - STAT 435: Introduction to Probability (3)
  - COM S 311: Computer Organization and Architecture (3)
  - CPR E 310: Theoretical Foundations of Computer Engineering (3)
  - CHEM 231: Elementary Organic Chemistry (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:

- **Fall**
  - BIOL 313: Principles of Genetics (3)
  - BIOL 315: Biological Evolution (3)
  - BIOL 569: Bioinformatics I (Fundamentals of Genome Informatics) (3)
  - BIOL 570: Bioinformatics IV (Computational Functional Genomics and Systems Biology) (3)
  - GDCB 511: Molecular Genetics (3)

And also should include:

- **Spring**
  - 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)
  - BCB 593: Workshop in Bioinformatics and Computational Biology (3)

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.S.
Prereq: Permission of instructor

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.

BCB 568: Bioinformatics II (Advanced Genome Informatics)
(Cross-listed with COM S, GDCB, STAT). (3-0) Cr. 3. S.

BCB 569: Bioinformatics III (Structural Genome Informatics)
(Cross-listed with BBMB, COM S, CPR E). (3-0) Cr. 3. F.

BCB 570: Bioinformatics IV (Computational Functional Genomics and Systems Biology)
(Cross-listed with COM S, CPR E, GDCB, STAT). (3-0) Cr. 3. S.

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.S.
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 primarily for graduate students:

BCB 660: Selected Topics in Bioinformatics and Computational Biology
(3-0) Cr. 1-4. Repeatable, maximum of 4 times. F.S.S.
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
Cr. arr. Repeatable. F.S.
Faculty research series.

BCB 697: Graduate Research Rotation
Cr. 1. Repeatable. F.S.S.
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, and computational systems biology. 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

BCBIO 442: Bioinformatics and Computational Biology Techniques
(0.2-0.5) Cr. 0.5. Repeatable, maximum of 2 credits. S.SS.
Prereq: BCBIO 401
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: BCBIO 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: BCBIO 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: BCBIO 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.