BIOINFORMATICS

Director: Debra T. Burhans, PhD

Introduction
Bioinformatics is an exciting field that involves the application of techniques from computer science, mathematics, statistics and information technology to problems in biology. Bioinformatics is a truly interdisciplinary science that teaches students both practical and conceptual tools for the understanding of biological information. Bioinformatics is important in all areas of biology, from human genetics to ecology, evolutionary biology, epidemiology and structural biology. Bioinformatics is transforming drug discovery, medical diagnostics and other biotechnology related areas. This major is academically rigorous, requiring challenging course work in biology, chemistry, mathematics and computer science. The major is ideal for students interested in learning about and applying mathematical and computational techniques to problem solving in biology.

A degree in bioinformatics from Canisius College provides you with the experience and background required for graduate study or employment in bioinformatics or computer science. Graduates of the program have pursued advanced degrees in bioinformatics, biology, biostatistics, and computer science as well as going on to medical school. They have also found employment in academic and industrial settings. The foundational courses in the major provide a strong general background in computing, biology, and chemistry. Elective courses in the major allow students to specialize in the area of greatest interest to them, whether it is computer science, mathematics, or biology.

For a more detailed description of the program, faculty, facilities, academic and co-curricular opportunities please go to the Bioinformatics website (https://www.canisius.edu/academics/programs/bioinformatics).

Qualifications
Students must maintain a 2.0 GPA in their major and a 2.0 overall average to graduate with a degree in Bioinformatics. In order to proceed in the computer science course sequence students must earn a C or better in CSC 111/CSC 111L. Similar requirements are found for the introductory biology and chemistry sequences.

Advisement
All students should have an advisor in the major and should contact the department directly to have an advisor assigned if they do not already have one. Major advisors are normally assigned in the sophomore year, but may be requested in the freshman year to supplement a student’s freshman advisor (their GRIF 101 facilitator). Meetings with academic advisors are required prior to students receiving their PIN for course registration each semester. All majors should work closely with their advisor in discussing career expectations, choosing their major electives, developing their entire academic program and planning their co-curricular or supplemental academic experiences.

Dual Majors
Students who wish to expand their educational opportunities may decide to declare a dual major. The decision may be based on career goals or planned graduate studies. Before a student declares a dual major, it is important to meet with the appropriate academic departments for advisement. Some dual major combinations can be completed within the minimum 120 credit hour degree requirement, but in some cases additional course work may be required. In order to declare a dual major, the student must complete the appropriate dual major request form and get the signature of each department chairperson and the appropriate associate dean.

Some bioinformatics majors have elected a second major in Computer Science. If all bioinformatics elective courses are taken in computer science, students will need an additional 4 courses in Computer Science for the double major. Careful consultation with the advisor is important if this is of interest.

Minors
Minors provide students the opportunity to pursue additional interests but generally do not require as many courses as a major. Minors generally range from five to eight required courses. The minors page (http://catalog.canisius.edu/undergraduate/minors) provides a complete list of minors and provides links to each minor. Some majors and minors can be completed within the minimum 120 credit hour degree requirement, but in some cases additional coursework may be required. Students must complete the appropriate minor request form.

Students with a strong background in mathematics are encouraged to consider a math minor. Please consult as soon as possible with your advisor regarding course selections if you are interested in this possibility. Minimally, students will elect MAT 230 instead of MAT 191 and MAT 351 instead of MAT 141. This major is most suitable for students with AP credit for calculus.

General Education Requirements
All undergraduate students must complete either the Canisius Core Curriculum (http://catalog.canisius.edu/undergraduate/academics/curricular-information/core-curriculum) or the All-College Honors Curriculum (http://catalog.canisius.edu/undergraduate/academics/curricular-information/all-college-honors-program).

Free Electives
Free electives are courses in addition to the Core Curriculum or Honors Curriculum and major requirements sufficient to reach the minimum of 120 credit hours required for graduation. Students may graduate with more but not less than 120 credit hours.

Major Requirements

<table>
<thead>
<tr>
<th>Bioinformatics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>BIF 101L</td>
<td>1</td>
</tr>
<tr>
<td>BIF 400</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Computer Science</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CSC 111 &amp; 111L</td>
<td>4</td>
</tr>
<tr>
<td>CSC 112 &amp; 112L</td>
<td>4</td>
</tr>
<tr>
<td>CSC 213 &amp; 213L</td>
<td>4</td>
</tr>
<tr>
<td>CSC 310 &amp; 310L</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mathematics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>MAT 111</td>
<td>4</td>
</tr>
</tbody>
</table>
MAT 141  Inferential Statistics and Computers for Science  4
MAT 191  Introduction to Discrete Mathematics  4

**Biology**
BIO 111  Introductory Biology I  4
& 111L  and Introductory Biology Laboratory I  4
BIO 112  Introductory Biology II  4
& 112L  and Introductory Biology Laboratory II  4
BIO 211  Biochemistry and Cell Biology I  4
& 211L  and Biochemistry and Cell Biology Lab I  4
BIO 212  and Biochemistry and Cell Biology II  4
& 212L  and Biochemistry and Cell Biology Lab II  4

**Chemistry**
CHM 111  General Chemistry I  4
& 111L  and General Chemistry I Laboratory  4
CHM 112  General Chemistry II  4
& 112L  and General Chemistry II Laboratory  4
CHM 227  Organic Chemistry I  4
& 227L  and Organic Chemistry I Laboratory  4

Total Credits  60

**Note:** The BIF 400 course is offered once every two years, and students should plan accordingly. The BIF 400 course carries the Advanced Writing-intensive attribute. If all of the other core courses elected by students have no overlap of attributes students will need to elect 11 additional core courses after taking the four foundational courses. With this in mind, it is important to plan schedules carefully to ensure timely completion of the program. Upper-level Computer Science courses are offered once every other year, and students must ensure that they take CSC 310 as soon as it is offered after their sophomore year.

**Elective Courses**
Students choose 3 elective courses for the major at the 300-400 level from the list below. Note that as new courses are developed this list may be revised to include additional courses, and that additional courses may be approved on a case by case basis by the program director. Note also that some of these courses may have additional prerequisites not included in the required BIF courses.

**Biology**
BIO 404  Genetics  3
BIO 408  Biotechnology, Theory in Practice  4
BIO 419  Cell Biology  3
BIO 432  Developmental Biology  3
BIO 450  Molecular Biology  3

**Chemistry**
CHM 301  Classical Physical Chemistry  4
& 301L  and Classical Physical Chemistry Laboratory  4
CHM 302  Modern Physical Chemistry  4
& 302L  and Modern Physical Chemistry Laboratory  4

**Computer Science (all courses with lab)**
CSC 330  Distributed Computing  4
& 330L  and Distributed Computing Laboratory  4
CSC 351  Comparative Programming Languages  4
& 351L  and Comparative Programming Languages Laboratory  4
CSC 360  Intelligent Systems  4
& 360L  and Intelligent Systems Laboratory  4
CSC 380  Web Development  4
& 380L  and Web Development Laboratory  4
CSC 395  Software Engineering  4
& 395L  and Software Engineering Lab  4

**Mathematics**
MAT 341  Numerical Analysis  3
MAT 351  Probability & Statistics I  4
& MAT 352  and Probability & Statistics II  4
MAT 354  Experimental Design and Statistical Computing  3

**Additional Course Considerations**
Students interested in medical or dental school or in advanced study in biology should take the second semester of organic chemistry and a year of physics.

CHM 228  Organic Chemistry II  4
& 228L  and Organic Chemistry II Laboratory  4
Select one of the following:  4
PHY 201  College Physics I  4
& PHY 202  and College Physics II (does not require calculus)  4
PHY 223  General Physics for Physical Science Majors I  4
& PHY 224  and General Physics for Physical Science Majors II (requires Calculus I)  4

**Additional recommended math courses for majors include**
MAT 112  Calculus II  4
MAT 211  Calculus III  4
MAT 219  Linear Algebra  4
MAT 222  Differential Equations  3

**Recommended Semester Schedule for Major Course Requirements**

<table>
<thead>
<tr>
<th>Semester</th>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshman</td>
<td>BIF 101L</td>
<td>BIF 101L</td>
<td></td>
</tr>
<tr>
<td>Fall</td>
<td>BIF 101L</td>
<td>BIF 101L</td>
<td></td>
</tr>
<tr>
<td>Spring</td>
<td>CSC 112</td>
<td>CSC 112</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&amp; 112L</td>
<td>&amp; 112L</td>
<td></td>
</tr>
<tr>
<td>Sophomore</td>
<td>CSC 213</td>
<td>CSC 213</td>
<td></td>
</tr>
<tr>
<td>Fall</td>
<td>&amp; 213L</td>
<td>&amp; 213L</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BIO 211</td>
<td>BIO 211</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&amp; 211L</td>
<td>&amp; 211L</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CHM 227</td>
<td>CHM 227</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&amp; 227L</td>
<td>&amp; 227L</td>
<td></td>
</tr>
<tr>
<td>Junior</td>
<td>MAT 141</td>
<td>MAT 141</td>
<td></td>
</tr>
<tr>
<td>Fall</td>
<td>BIF 400</td>
<td>BIF 400</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(or BIF elective)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: The BIF 400 course is offered once every two years, and students should plan accordingly. The BIF 400 course carries the Advanced Writing-intensive attribute. If all of the other core courses elected by students have no overlap of attributes students will need to elect 11 additional core courses after taking the four foundational courses. With this in mind, it is important to plan schedules carefully to ensure timely completion of the program. Upper-level Computer Science courses are offered once every other year, and students must ensure that they take CSC 310 as soon as it is offered after their sophomore year.
BIF elective

CSC 310 & 310L

Senior

Fall

Spring

BIF elective (or BIF 400 if not taken in junior year)

Learning Goals & Objectives

Student Learning Goal 1

Majors will effectively develop and implement computational solutions to problems.

Students will:

• Specify and design acceptable computational solutions;
• Implement and test acceptable computational solutions;
• Describe which data structures would be appropriate to use and explain why, given a problem;
• Describe which algorithms would be appropriate to use and explain why, given a problem;
• Design effective data representations for the storage and manipulation of large datasets where needed;
• Utilize and understand statistical methods for the analysis of large datasets where appropriate.

Student Learning Goal 2

Majors will be competent with respect to biology and biotechnology:

Students will:

• Describe information transfer within cells and between generations;
• Understand high-throughput laboratory technologies used in biology to generate large datasets.

Student Learning Goal 3

Majors will analyze legal, social, and ethical considerations related to bioinformatics.

Students will:

• Understand and analyze issues using different ethical frameworks;
• Understand social, legal, and privacy implications of electronic storage and sharing of biological information.

A minor in Bioinformatics is offered. There are 6 required courses (20 credits) that will also meet the Field 6 and Field 7 (BIO and CSC courses) requirements in the Core Curriculum. The courses are listed below. All of the following courses must include the accompanying laboratory section.

Minor Courses

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIF 101L</td>
<td>Introduction to Bioinformatics</td>
<td>1</td>
</tr>
<tr>
<td>BIO 111</td>
<td>Introductory Biology I</td>
<td>4</td>
</tr>
<tr>
<td>&amp; 111L</td>
<td>and Introductory Biology Laboratory I</td>
<td></td>
</tr>
<tr>
<td>BIO 112</td>
<td>Introductory Biology II</td>
<td>4</td>
</tr>
<tr>
<td>&amp; 112L</td>
<td>and Introductory Biology Laboratory II</td>
<td></td>
</tr>
<tr>
<td>CSC 111</td>
<td>Introduction to Programming</td>
<td>4</td>
</tr>
<tr>
<td>&amp; 111L</td>
<td>and Introduction to Programming Laboratory</td>
<td></td>
</tr>
<tr>
<td>CSC 112</td>
<td>Data Structures</td>
<td>4</td>
</tr>
<tr>
<td>&amp; 112L</td>
<td>and Data Structures Laboratory</td>
<td></td>
</tr>
<tr>
<td>BIF 400</td>
<td>Bioinformatics Senior Seminar</td>
<td>3</td>
</tr>
</tbody>
</table>

Total Credits 20

BIF 101L Introduction to Bioinformatics 1 Credit
This 1 credit course provides an introduction to the field of bioinformatics. Web sites, tools, video, discussions, and visiting speakers will help students learn about the major and current opportunities in terms of jobs and research.
Offered: fall.

BIF 400 Bioinformatics Senior Seminar 3 Credits
This course provides a culminating experience for bioinformatics majors. Students work on several projects where they learn about and use a variety of bioinformatics software as well as building their own tools and pipelines. Students will contribute to a bioinformatics research project about which they will write a scientific article. The writing component introduces skills such as reading primary literature, the development of writing skills appropriate to the field and information literacy techniques.
Restriction: must be junior or senior bioinformatics major.
Fulfills College Core: Advanced Writing-Intensive
Offered: spring of even-numbered years.

BIF 400L Bioinformatics Senior Seminar Lab 1 Credit
This course provides a culminating experience for bioinformatics majors. Students work on several projects where they learn about and use a variety of bioinformatics software as well as building their own tools and pipelines. Students will contribute to a bioinformatics research project about which they will write a scientific article. The writing component introduces skills such as reading primary literature, the development of writing skills appropriate to the field and information literacy techniques. Instruction is carried out through both lecture and lab components.
Restriction: must be junior or senior bioinformatics major.
Offered: spring of even-numbered years.

BIF 499 Bioinformatics Internship 3-4 Credits
Students are strongly encouraged to take part in a bioinformatics internship, which typically would take place in a research laboratory or biotechnology firm. Application and faculty advisor approval required. Note that this course cannot count as a bioinformatics elective for the major.