PCC Proposal to Establish a Master of Science in Bioinformatics and Computational Biology

PRESENTED BY Wendy Stickle, Chair, Senate Programs, Curricula, and Courses Committee

REVIEW DATES SEC – October 20, 2023 | SENATE – November 1, 2023

VOTING METHOD In a single vote

RELEVANT POLICY/DOCUMENT

NECESSARY APPROVALS Senate, President, USM Board of Regents, and the Maryland Higher Education Commission

ISSUE

The College of Computer, Mathematical, and Natural Sciences proposes to establish a Master of Science in Bioinformatics and Computational Biology. This program exists currently as an iteration of the Master of Professional Studies (MPS) program. The 30-credit MPS program was approved in 2022 and the first group of incoming students began in Fall 2023. Master of Professional Studies programs were first approved in 2005, when the University System of Maryland Board of Regents and Maryland Higher Education Commission approved an expedited review process for master’s and graduate certificate programs that respond quickly to the changing market needs of working professionals. Once a new iteration of the MPS is approved through campus PCC review, it only needs approval by the USM Chancellor to become official.

A limitation of offering this program as an MPS iteration is that all Professional Studies programs must use the same generic Federal Classification of Instructional Programs (CIP) code, rather than a CIP code that accurately describes the program content. Those who search for academic programs by using the CIP codes related to Bioinformatics or Computational Biology will not find this program. Moreover, some CIP codes are designated as “STEM” eligible by the US Department of Homeland Security, and international students with F1 visas who graduate from STEM designated programs may continue to work in the United States for two years longer than students in non-STEM designated programs. The generic CIP code for Professional Studies programs does not qualify as STEM-designated, even if the academic content of the Professional Studies program is STEM-related, as is the case with this program.

Consequently, the college proposes to transition the current program from a Master of Professional Studies program to a stand-alone Master of Science program in order to be classified more accurately. The 30-credit curriculum will remain the same.

The Master of Science in Bioinformatics and Computational Biology will provide students with an education in the theory and practice of the major current areas in the field including biological problem contexts, mathematical and statistical foundations, computational approaches, communication, and ethical, privacy and legal considerations. In addition to the fundamentals of bioinformatics and computational biology, the program covers relevant probability and statistics,
data structures and algorithms, and machine learning. The program consists of nine required 3-credit courses and one 3-credit elective requirement. The program is a non-thesis program and will have both an in-person and distance education version. Graduates of the program will be able to explain multiple problem-solving methods in bioinformatics and computational biology and apply these methods to problems in biology and biomedical research. Students will be able to interpret and infer results of bioinformatics and computational biology analyses to different audiences and communicate results with considerations of ethical, privacy, and legal issues.

The proposal was approved by the Graduate School PCC committee on September 27, 2023, and the Senate Programs, Curricula, and Courses committee on October 6, 2023.

RECOMMENDATION(S)

The Senate Committee on Programs, Curricula, and Courses recommends that the Senate approve this new academic program.

COMMITTEE WORK

The committee considered this proposal at its meeting on October 6, 2023. Michael Cummings, Amy Chester, and John Fourkas, from the College of Computer, Mathematical, and Natural Sciences, presented the proposal and answered questions from the committee. The committee unanimously approved the proposal.

ALTERNATIVES

The Senate could decline to approve this new academic program.

RISKS

If the Senate declines to approve this new degree program, the university will lose an opportunity to apply a more accurate Federal CIP code to an existing program thereby making the program more marketable.

FINANCIAL IMPLICATIONS

There are no significant financial implications with this proposal as the program already exists as a self-supported Master of Professional Studies program.
925: BIOINFORMATICS AND COMPUTATIONAL BIOLOGY

In Workflow
1. CMNS PCC Chair (jpresson@umd.edu; fourkas@umd.edu)
2. CMNS Dean (rinfanti@umd.edu)
3. Academic Affairs Curriculum Manager (mcolson@umd.edu)
4. Graduate School Curriculum Manager (jfarman@umd.edu)
5. Graduate PCC Chair (jfarman@umd.edu)
6. Dean of the Graduate School (jfarman@umd.edu; sroth1@umd.edu)
7. Senate PCC Chair (mcolson@umd.edu; wstickle@umd.edu)
8. University Senate Chair (mcolson@umd.edu)
9. President (mcolson@umd.edu)
10. Board of Regents (mcolson@umd.edu)
11. MHEC (mcolson@umd.edu)
12. Provost Office (mcolson@umd.edu)
13. Graduate Catalog Manager (bhernand@umd.edu; fantsao@umd.edu)

Approval Path
1. Thu, 27 Apr 2023 21:52:46 GMT
   John Fourkas (fourkas): Approved for CMNS PCC Chair
2. Fri, 28 Apr 2023 17:34:12 GMT
   Robert Infantino (rinfanti): Approved for CMNS Dean
3. Wed, 06 Sep 2023 18:17:26 GMT
   Michael Colson (mcolson): Approved for Academic Affairs Curriculum Manager
4. Fri, 29 Sep 2023 20:03:48 GMT
   Jason Farman (jfarman): Approved for Graduate School Curriculum Manager
5. Fri, 29 Sep 2023 20:08:50 GMT
   Jason Farman (jfarman): Approved for Graduate PCC Chair
   Stephen Roth (sroth1): Approved for Dean of the Graduate School
7. Sat, 07 Oct 2023 17:30:30 GMT
   Wendy Stickle (wstickle): Approved for Senate PCC Chair

New Program Proposal
Date Submitted: Thu, 27 Apr 2023 19:45:55 GMT

Viewing: 925: Bioinformatics and Computational Biology
Last edit: Mon, 31 Jul 2023 21:24:10 GMT
Changes proposed by: Michael Cummings (mcummin1)

Program Name
Bioinformatics and Computational Biology

Program Status
Proposed

Effective Term
Spring 2024

Catalog Year
2023-2024

Program Level
Graduate Program

Program Type
Master's
Delivery Method
On Campus

Departments
Department
Computer, Mathematical, and Natural Sciences

Colleges
College
Computer, Mathematical, and Natural Sciences

Degree(s) Awarded
Degree Awarded
Master of Science

Proposal Contact
Michael Cummings, Amy Chester

Proposal Summary
This proposal is to convert the existing MPS in Bioinformatics and Computational Biology to an MS in Bioinformatics and Computational Biology. Proposed CIP code: 26.1199 Biomathematics, Bioinformatics, and Computational Biology, Other
(PCC Log Number 23008)

Program and Catalog Information

Provide the catalog description of the proposed program. As part of the description, please indicate any areas of concentration or specializations that will be offered.

The Master of Science in Bioinformatics and Computational Biology provides education in the theory and practice of the major current areas in the field including biological problem contexts, mathematical and statistical foundations, computational approaches, communication, and ethical, privacy and legal considerations. In addition to the fundamentals of bioinformatics and computational biology, the program covers relevant probability and statistics, data structures and algorithms, and machine learning. The program consists of 30-credit course work and is a non-thesis MS program.

Catalog Program Requirements:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIO601</td>
<td>Probability and Statistics</td>
<td>3</td>
</tr>
<tr>
<td>BIO602</td>
<td>Principles of Data Science</td>
<td>3</td>
</tr>
<tr>
<td>BIO603</td>
<td>Principles of Machine Learning</td>
<td>3</td>
</tr>
<tr>
<td>BIO604</td>
<td>Course BIO604 Not Found (Principles of Molecular Biology, Genetics, and Genomics)</td>
<td>3</td>
</tr>
<tr>
<td>BIO605</td>
<td>Course BIO605 Not Found (Data Sources and Data Management in Bioinformatics)</td>
<td>3</td>
</tr>
<tr>
<td>BIO606</td>
<td>Course BIO606 Not Found (Sequence and Alignment)</td>
<td>3</td>
</tr>
<tr>
<td>BIO607</td>
<td>Course BIO607 Not Found (Data Structures and Algorithms for Bioinformatics)</td>
<td>3</td>
</tr>
<tr>
<td>BIO610</td>
<td>Course BIO610 Not Found (Genome Annotation)</td>
<td>3</td>
</tr>
<tr>
<td>BIO611</td>
<td>Course BIO611 Not Found (Analysis of Gene Expression Data)</td>
<td>3</td>
</tr>
</tbody>
</table>

Elective Requirement (choose one of the following):

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIO621</td>
<td>Course BIO621 Not Found (Genome Assembly and Annotation)</td>
<td>3</td>
</tr>
<tr>
<td>BIO622</td>
<td>Course BIO622 Not Found (Metagenomics Data Analysis)</td>
<td>3</td>
</tr>
<tr>
<td>BIO699</td>
<td>Course BIO699 Not Found (Capstone Research)</td>
<td>3</td>
</tr>
</tbody>
</table>

Total Credits: 30

Sample plan. Provide a term by term sample plan that shows how a hypothetical student would progress through the program to completion. It should be clear the length of time it will take for a typical student to graduate. For undergraduate programs, this should be the four-year plan.

SAMPLE PLAN OF STUDY (PART-TIME, TWO 3-CREDIT COURSES PER SEMESTER)

UPDATED JULY 2023
List the intended student learning outcomes. In an attachment, provide the plan for assessing these outcomes.

<table>
<thead>
<tr>
<th>Learning Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explain multiple problem-solving methods in bioinformatics and computational biology.</td>
</tr>
<tr>
<td>Apply bioinformatics and computational biology methods to problems in biology and biomedical research.</td>
</tr>
<tr>
<td>Interpret and infer results of bioinformatics and computational biology analyses to different audiences.</td>
</tr>
<tr>
<td>Communicate results of analyses with considerations of ethical, privacy and legal issues</td>
</tr>
</tbody>
</table>

New Program Information

Mission and Purpose

Describe the program and explain how it fits the institutional mission statement and planning priorities.

Bioinformatics and computational biology are critical areas at the nexus of life sciences, computer science, and data science. Maryland is among the top locations in the nation for biomedical research, the home of the National Institutes of Health, and home to numerous pharmaceutical and biotechnology companies. There is a tremendous need for graduate-level training at the local, national, and international levels. The program will serve a student population mostly consisting of experienced professionals that fall in the categories of "Career Advancers" who work in a related discipline,
and “Career Crossers” working in an unrelated discipline. Professionals in these categories place priority on flexible delivery, professional development, and interdisciplinary pathways.

This proposed self-supported graduate program allows the University of Maryland to serve additional students above and beyond the resources provided by the state while fulfilling demonstrated higher education and workforce needs. This program aligns with the missions of the University of Maryland; College of Computer, Mathematical, and Natural Sciences; and the Science Academy within the College.

Program Characteristics

What are the educational objectives of the program?

Students from this program should be able to identify, choose, describe, explain, and apply bioinformatics and computational biology methods to problems in biology and biomedical research, and to interpret, infer, and communicate results of bioinformatics and computational biology analyses to different audiences, with consideration of ethical, privacy and legal issues.

Our curriculum design philosophy is that ethical, privacy and legal considerations are integrated throughout the program, with specific topical coverage relevant to other material being taught. For example, the Health Insurance Portability and Accountability Act (HIPAA) and other privacy concerns are covered in courses dealing with analyses of personal identifying information, or analyses of data where identification might be inferred (e.g., some DNA data). Whereas ethical considerations related to samples (e.g., tissue) and informed consent are covered in courses related to data collection and subsequent analyses. Thus, these and related topics are reinforced in a context-specific manner throughout the curriculum.

Describe any selective admissions policy or special criteria for students interested in this program.

Applicants must have earned a four-year baccalaureate degree from a regionally accredited U.S. institution, or an equivalent degree from a non-U.S. institution.

Applicants must have earned a 3.0 GPA (on a 4.0 scale) in all prior undergraduate and graduate coursework.

Applicants must provide an official copy of a transcript for all post-secondary work.

International applicants must fulfill all requirements relating to international academic credentials, evidence of English proficiency, financial certification, and visa documentation.

Personal statement including such elements as relevant experience. The admissions criteria will include education or work experience in biological/biomedical sciences, mathematics, statistics, and computer science deemed sufficient for success in the program. These criteria, apart from those related to biological/biomedical sciences, are like those for the MS programs in Data Science, and Machine Learning. Students also can submit an optional essay during the admissions process to explain any deficient areas or to share additional context to their previous academic performances. This will ensure all applicants have a chance to be considered and share how/why they are prepared for academic success in the program.

Summarize the factors that were considered in developing the proposed curriculum (such as recommendations of advisory or other groups, articulated workforce needs, standards set by disciplinary associations or specialized-accrediting groups, etc.).

The motivation for the program is based on the perceived need for the training the program is designed to provide. The faculty within the Center for Bioinformatics and Computational Biology is very frequently contacted about available positions, the qualifications for which would be provided by the program. These perceived needs comport with the market analysis (attached), and success of similar programs in the state, region, and country more broadly. There is a shortage of qualified professionals in bioinformatics and computational biology. Maryland is home to over 2000 life science businesses, and the DMV region has the third largest concentration of biotech and bio-pharmaceuticals companies in the country.

The proposed curriculum was developed through extensive discussions with the faculty in the Center for Bioinformatics and Computational Biology, each of whom has domain science expertise in different areas of the field and extensive collaborative research experience including with non-academic partners. Furthermore, many of our PhD students have been placed in various academic, government and industry settings and we are familiar with the training relevant for those positions.

Select the academic calendar type for this program (calendar types with dates can be found on the <a href="https://www.provost.umd.edu/calendar">Academic Calendar</a> page)

Traditional Semester

For Master’s degree programs, describe the thesis requirement and/or the non-thesis requirement.

master’s non-thesis

Identify specific actions and strategies that will be utilized to recruit and retain a diverse student body.

The primary recruitment activities will be via the CMNS Science Academy. The Science Academy uses a diverse, targeted approach when recruiting students. This digital strategy focuses on UMD alumni, current UMD graduating seniors, and working professionals in the DMV area. The admissions review process reviews for not only academic readiness but also diversity in experiences, industries, backgrounds, and career aspirations to recruit a diverse student body.

To attract a diverse student population, we will engage in the following activities:

- Representing the program in educational fairs, conferences and events, e.g. the National Leadership Conference of the National Society of Black Engineers, GEM Grad Labs.
• Advertising the program to the National Society of Black Engineers (NSBE), the Society of Women Engineers (SWE), and the Association for Women in Computing (AWC).
• Direct mailing and email campaigns to domestic and international colleges
• Outreach to UMD Campus organizations and clubs
• Holding online (virtual) open houses, information sessions and career panels
• Outreach to US Military to attract veterans
• Social media and online advertising
• Establishing graduate scholarships to provide financial aid to underrepresented minority applicants

Once enrolled, the Science Academy staff, and faculty are committed to creating and fostering a supportive environment for all students to thrive. We regularly share resources and opportunities for counseling, support, and funding. All students are expected to complete and honor the TerrapinSTRONG orientation and initiatives. Students are encouraged to take part in Grad School programs that address diversity and inclusion in higher education, build communities of support and success, and create meaningful dialogue among graduate students. Such programs include "Cultivating Community Conversations" and the "Annual Office of Graduate Diversity and Inclusions Spring Speaker Services." Faculty that are involved in the Science Academy represent many departments, have a diversity of appointments (both tenure track, professional track, and adjunct) exposing students to many future career paths. The Science Academy and faculty provide student advising, academic support, and career guidance to students to retain all students and support timely graduation.

Our student retention efforts will consist of:
• Holding "Women in Engineering, Computing and STEM" seminars to address the obstacles faced by women in today's technical workplace and guide our women students to maneuver through the internship and job application process
• Requiring students to attend mandatory advising sessions with the program adviser to ensure that the students' study plans are in line with their interests and career goals, and that the students make satisfactory progress toward meeting the degree requirements
• Implementing an early warning system that detects students struggling with core courses and alerts the academic advisor, who meets with the students and designs a study plan to get them back on track

Relationship to Other Units or Institutions

If a required or recommended course is offered by another department, discuss how the additional students will not unduly burden that department's faculty and resources. Discuss any other potential impacts on another department, such as academic content that may significantly overlap with existing programs. Use space below for any comments. Otherwise, attach supporting correspondence.

None of the courses in the program are currently offered by any department, nor do existing courses target the intended student population. Apart from the three courses shared with current programs with the CMNS Science Academy, all courses for the program will be new, and thus should not burden department faculty and resources. Instructors for the program courses will be a combination of tenure-track or professional-track faculty teaching on overload, and adjuncts. There is no substantial programmatic overlap with any existing program, and no existing program targets the specific student population for which this program and degree are designed.

Three of the proposed courses are to be co-listed versions of courses in common with the MS programs in Data Science, and Machine Learning: BIOI/DATA/MSML 601, Probability and Statistics; BIOI/DATA/MSML 602, Principles of Data Science; and BIOI/DATA/MSML 603, Principles of Machine Learning. These three courses are foundational to modern quantitative and computational-based science, and thus are common to the existing programs and the proposed program. All the remaining core courses will be new to the program, and some electives may be accepted from other programs. All programs are managed by the Science Academy.

Accreditation and Licensure. Will the program need to be accredited? If so, indicate the accrediting agency. Also, indicate if students will expect to be licensed or certified in order to engage in or be successful in the program's target occupation.

No accreditation or licensure is required for the program.

Describe any cooperative arrangements with other institutions or organizations that will be important for the success of this program.

No formal cooperative arrangements with other institutions or organizations are important for the success of the proposed program.

Faculty and Organization

Who will provide academic direction and oversight for the program? In an attachment, please indicate the faculty involved in the program. Include their titles, credentials, and courses they may teach for the program.

The Oversight Committee will be composed of the following individuals: Graduate Director, Professor Michael P. Cummings (approved by Dean and departmental chair); Professor Najib El-Sayed (approved by departmental chair); and Amy Chester, Director of the Science Academy, CMNS. Academic coordination of the program will be the responsibility of the Director, Master of Professional Studies Program in Bioinformatics and Computational Biology.

Indicate who will provide the administrative coordination for the program

The Science Academy in the College of Computer, Mathematics and Natural Science will provide administrative coordination for the program, in collaboration with the Office of Extended Studies. The Office of Extended Studies provides program development support (budget development and
Resource Needs and Sources

Each new program is required to have a library assessment prepared by the University Libraries in order to determine any new library resources that may be required. This assessment must be done by the University Libraries. Add as an attachment.

The library assessment is attached

Discuss the adequacy of physical facilities, infrastructure and instructional equipment.

No additional physical facilities, infrastructure and instructional equipment is required for this program. Existing facilities (e.g., classrooms) and resources (e.g., instructional equipment) will be used, and these are demonstrably adequate for the proposed program. It is anticipated that most of the instruction will be in the evenings, as befitting the target student population of working adults. Thus, the use of classrooms will be outside the hours used for instruction by most other programs.

Discuss the instructional resources (faculty, staff, and teaching assistants) that will be needed to cover new courses or needed additional sections of existing courses to be taught. Indicate the source of resources for covering these costs.

Instructional resources for the program will comprise current tenure track faculty, professional track faculty, and adjunct instructors, as is the case with the Graduate programs in Data Science and Analytics, and Machine Learning. These instructional personnel will come from the Center for Bioinformatics and Computational Biology, departments listed elsewhere in this proposal, and outside the university (e.g., National Institutes of Health, industry). The funding source of covering instructional costs will come from tuition both from the program and the Science Academy if needed. No state resources will be used to support the program.

Discuss the administrative and advising resources that will be needed for the program. Indicate the source of resources for covering these costs.

The CMNS Science Academy will provide the academic and advising oversight to incoming and admitted students. Revenue generated from the program will be used to support administrative and advising resources including a Program Manager. No state resources will be used to support the program.

Use the Maryland Higher Education Commission (MHEC) commission financial tables to describe the program's financial plan for the next five years. See help bubble for financial table template. Use space below for any additional comments on program funding.

The Office of Extended Studies (OES) has prepared a five-year financial projection, which is attached.

Implications for the State (Additional Information Required by MHEC and the Board of Regents)

Explain how there is a compelling regional or statewide need for the program. Argument for need may be based on the need for the advancement of knowledge and/or societal needs, including the need for “expanding educational opportunities and choices for minority and educationally disadvantaged students at institutions of higher education.” Also, explain how need is consistent with the Maryland State Plan for Postsecondary Education.

See support document attachment, Market Analysis, for a full analysis of the market as of March 2023. Our research indicates a faster than average growth in bioinformatic scientist positions in the field with Maryland is the second highest employment level and the second highest top paying state for Bioinformatics Scientists. Other similar programs in the State of Maryland are all MS degrees. Our program will be differentiated and attractive to the professional learner in its applied nature. Lastly, following the enrollment trends at other Maryland programs, coupled with the projected job growth in this area, the program anticipates enrollment greater than 10 students per year, recovering costs no later than 2 years of operation.

Present data and analysis projecting market demand and the availability of openings in a job market to be served by the new program. Possible sources of information include industry or disciplinary studies on job market, the Occupational Outlook Handbook, or Maryland state projections. Add as an attachment.

See help bubble for financial table template. Use space below for any additional comments on program funding.

The Office of Extended Studies (OES) has prepared a five-year financial projection, which is attached.

Present data and analysis projecting market demand and the availability of openings in a job market to be served by the new program. Possible sources of information include industry or disciplinary studies on job market, the US Bureau of Labor Statistics indicate a much faster than average growth in health information technologists and mathematicians/statisticians occupations, 17% and 31% respectively. These positions are found across the federal government, professional and technical services, hospitals, higher education, and other employment locations.
Identify similar programs in the state. Discuss any differences between the proposed program and existing programs. Explain how your program will not result in an unreasonable duplication of an existing program (you can base this argument on program differences or market demand for graduates). The MHEC website can be used to find academic programs operating in the state: [http://mhec.maryland.gov/institutions_training/pages/HEPrograms.aspx](http://mhec.maryland.gov/institutions_training/pages/HEPrograms.aspx)

While other programs in the state do exist, most are either clinical focused and or only available in an online or blended space. The UMD program will be available both in person and online with an applied and experiential approach.

Discuss the possible impact on Historically Black Institutions (HBIs) in the state. Will the program affect any existing programs at Maryland HBIs? Will the program impact the uniqueness or identity of a Maryland HBI?

Our research indicated that Morgan State has a small MS program in Bioinformatics. The UMD program would complement the Morgan State program and provide an opportunity to strengthen the offerings in the state rather than competing. The State of Maryland is seeing tremendous growth in this area and our offering will expand opportunities for state and regional professionals.

Morgan State University MS in Bioinformatics is a 5-course plus thesis degree program, whereas the UMD program is a 10-course program. The UMD program is further distinguished by having a much broader topical coverage within bioinformatics and computational biology, and provides a stronger and broader foundation in data science, machine learning, data structures, and other areas, which are increasingly important in the field.

**Supporting Documents**

**Attachments**
- Bioinformatics_Market_Research_2023 (1).xlsx
- MS in Bioinformatics and Computational Biology Budget.xlsx
- Library_Collection_Assessment_Computational_Biology.docx
- Faculty List Template-Bioinformatics.docx
- Appendix 2 Summary of Learning Outcome Assessments 7-31-2023.pdf
- Appendix 6 Bioinformatics Course Descriptions.pdf

Key: 925
<table>
<thead>
<tr>
<th>Institution</th>
<th>Website</th>
<th>Delivery Method</th>
<th>Degree Name &amp; Type (MPS, MA, MS, MPH, etc.)</th>
<th># of Credits</th>
<th>Program Duration</th>
<th>Tuition (course or credit)</th>
<th>Target Population</th>
<th>Prior Education/Pre-Requisites</th>
</tr>
</thead>
<tbody>
<tr>
<td>University of Illinois Urbana-Champaign</td>
<td><a href="https://illinois.edu/colleges/programmes/bioinformatics">https://illinois.edu/colleges/programmes/bioinformatics</a></td>
<td>F2F</td>
<td>Bioinformatics, M.S., Information Sciences</td>
<td>36</td>
<td>Program can be completed in 1 year</td>
<td>$14,578/year</td>
<td>$26,900/year</td>
<td>Students seeking a promising career in managing information produced in a range of biomedicine settings and in creating health care systems that connect the available data and analytics to improve medicine and public health.</td>
</tr>
<tr>
<td>Indiana University Bloomington</td>
<td><a href="https://www.indiana.edu/programmes/bioinformatics">https://www.indiana.edu/programmes/bioinformatics</a></td>
<td>F2F</td>
<td>Bioinformatics, M.S.</td>
<td>30</td>
<td>Program can be completed in 2 years</td>
<td>$10,630/year</td>
<td>$30,704/year</td>
<td>Designed for students interested in learning how to model, analyze and manage massive amounts of biological data.</td>
</tr>
<tr>
<td>University of Iowa</td>
<td><a href="https://informatics.purdue.edu/academic-programs/ms-bioinformatics">https://informatics.purdue.edu/academic-programs/ms-bioinformatics</a></td>
<td>F2F</td>
<td>Bioinformatics, MS.</td>
<td>31</td>
<td></td>
<td>$605/credit</td>
<td>This program provides competency in fundamental biological sciences as well as computing, math, and statistics that are essential in pursuing a career, academic or otherwise, that depends on bioinformatics and/or computational analyses of biological information. Some academic background in at least two of the following areas or strong academic background in one – molecular biology, biochemistry, mathematics, statistics, computer science – are highly considered. Proven interest in bioinformatics by taking classes, attending workshops or conferences, or working on research projects that relate to biological data analysis is also highly considered.</td>
<td></td>
</tr>
<tr>
<td>University of Michigan Ann Arbor</td>
<td><a href="https://medicine.umich.edu/academic-programs/bioinformatics/accelerated-master-program">https://medicine.umich.edu/academic-programs/bioinformatics/accelerated-master-program</a></td>
<td>F2F</td>
<td>Bioinformatics, Accelerated Master's Program</td>
<td>30</td>
<td>Students complete B.A. and M.S in five years</td>
<td>$2,033/credit</td>
<td>$3,473/credit</td>
<td>The Accelerated Master's Degree Program is an excellent way for UM undergraduates to acquire applicable knowledge and skills in bioinformatics as they complete their studies, plus explore overlapping interests. Students start taking Bioinformatics graduate-level courses while in their junior year of UM undergraduate study.</td>
</tr>
<tr>
<td>Michigan State University</td>
<td><a href="https://cmse.msu.edu/academic-programs/bioinformatics-program">https://cmse.msu.edu/academic-programs/bioinformatics-program</a></td>
<td>F2F</td>
<td>Bioinformatics Program- Not a degree program</td>
<td>N/A</td>
<td></td>
<td>$938/credit</td>
<td>The Bioinformatics modules are a set of introductory courses that help life science students learn basic skills in computation and bioinformatics. These modules are 5 graduate credit, one month long, and flippable classroom (students watch video lectures online for homework and then come to class to solve problems and ask questions).</td>
<td>Some academic background in at least two of the following areas or strong academic background in one – molecular biology, biochemistry, mathematics, statistics, computer science – are highly considered. Proven interest in bioinformatics by taking classes, attending workshops or conferences, or working on research projects that relate to biological data analysis is also highly considered.</td>
</tr>
<tr>
<td>University of Minnesota Twin Cities</td>
<td><a href="https://www.umn.edu/academics/programs/biocomputing">https://www.umn.edu/academics/programs/biocomputing</a> programmes/master</td>
<td>F2F</td>
<td>Bioinformatics and Computational Biology, M.S.</td>
<td>30</td>
<td></td>
<td>$1,539/credit</td>
<td>The graduate program trains graduate students in the development and applications of computational methods and to work in interdisciplinary teams of life scientists and computational scientists. The program offers industrial and clinical internships and training in business leadership, technology management, and ethics to prepare students for the workforce.</td>
<td>The program expects incoming graduate students to have a strong background in the quantitative sciences and varied backgrounds in the life/health sciences. Including: Data Science, Intro Programming, Intro Bio, Multivariate calc, algorithms and data structures, statistics, biochemistry, and health sciences.</td>
</tr>
<tr>
<td>University of Nebraska Lincoln</td>
<td><a href="https://cse.unl.edu/academic-programs/biocomputing-specialization">https://cse.unl.edu/academic-programs/biocomputing-specialization</a></td>
<td>F2F</td>
<td>Computer Science M.S.-Bioinformatics Specialization</td>
<td>Thesis – 30</td>
<td>Non-Thesis – 36</td>
<td>$472/credit</td>
<td>To prepare graduate students for advanced professional practice as bioinformaticians or to prepare graduate students for doctoral studies in bioinformatics. Offers a thesis or non-thesis option.</td>
<td>Applicants must have a Bachelor of Science degree in Bioinformatics or a Bachelor of Science degree in Computer Science and a minor in Biology, or a Bachelor of Science degree in Biology (or Master of Science in a related field, e.g. Agronomy) and a minor in Computer Science. However, students with background in only one of the two areas will also be considered for provisional admission if they have a good academic record.</td>
</tr>
<tr>
<td>Northwestern University</td>
<td><a href="https://qph.northwestern.edu/online-health-informatics">https://qph.northwestern.edu/online-health-informatics</a></td>
<td>Online</td>
<td>Health Informatics, M.S.</td>
<td>36</td>
<td>1 Year</td>
<td>$4,883/course</td>
<td>The program expects incoming graduate students to have a strong background in the quantitative sciences.</td>
<td>Undergraduate GPA of 3.0 or higher on a 4.0 scale.</td>
</tr>
<tr>
<td>Ohio State University</td>
<td><a href="https://medicine.osu.edu/academic-programs/biomedical-informatics">https://medicine.osu.edu/academic-programs/biomedical-informatics</a></td>
<td>F2F</td>
<td>Biomedical Informatics, M.S.</td>
<td>48</td>
<td>2 Years</td>
<td>$30,124/year (Within Medical College) $35,048/year (Within Medical College)</td>
<td>Our degree programs are designed to cultivate biomedical informaticians expertise in public health and clinical practitioners and researchers. Intended for students whose interests are academically oriented rather than directed toward professional practice.</td>
<td>Undergraduate GPA of 3.0 or higher on a 4.0 scale.</td>
</tr>
<tr>
<td>Purdue University</td>
<td><a href="https://portal.purdue.edu/departmental-programs/computer-and-information-technology">https://portal.purdue.edu/departmental-programs/computer-and-information-technology</a></td>
<td>F2F</td>
<td>Computer Science and Information Technology - Bioinformatics and Healthcare computing Specialization</td>
<td>33</td>
<td></td>
<td>$4,859/semester $9,401/semester</td>
<td>When you pursue your advanced degree in computer and information technology, your studies and research will prepare you for an exciting new technology, enterprise-scale computing, and solving the challenges of society and industry. You will be at the forefront of emerging areas such as information security, healthcare informatics, computing applications, and data management.</td>
<td>A relevant, earned baccalaureate degree in computer science, information technology, computer engineering, mathematics, or other computer-related field of study. Minimally, students should have earned 15-18 credit hours of computational coursework.</td>
</tr>
</tbody>
</table>
The Masters in Health Informatics degree program is specifically designed to provide an in-depth knowledge of the appropriate systems, software and analytical techniques for use in Hospitals, Pharmaceutical Organizations, Health Insurance Companies and such. The program curriculum provides ample knowledge and practice of the use of state of the art analytical techniques and technologies.

Bachelor’s degree or higher with a minimum GPA of 3.0. Complete application form online and select either Piscataway (Off Campus) option for On Campus MS HI Program or Online (Distance) for MS HI Online Program. Since the On Campus classes are held during daytime hours nearly all of our students who are working professionals choose the MS HI Online Program. Three letters of recommendation from individuals who can assess your professional ability and potential for successful completion of the program are required. Candidates who have completed at least two semesters of college calculus will be given preference.

Potential students include both those with bachelor’s degrees in an area of data science (e.g., computer science, statistics), as well as health professionals and clinicians (e.g., M.D., Ph.D., P.H.); it is expected that admitted candidates will have demonstrated an aptitude for computer science and math, fundamental programming skills, knowledge of data structures and algorithms, and at least two semesters of college calculus. We will however consider candidates who have a wide...
<table>
<thead>
<tr>
<th>State of Maryland System Institutions: Overseen by MHEC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hood College</strong></td>
</tr>
<tr>
<td><strong>Johns Hopkins University</strong></td>
</tr>
<tr>
<td><strong>Morgan State University</strong></td>
</tr>
<tr>
<td><strong>Mount Saint Mary's University</strong></td>
</tr>
<tr>
<td><strong>UMD, Baltimore</strong></td>
</tr>
<tr>
<td><strong>UMGC</strong></td>
</tr>
</tbody>
</table>

State of Maryland System Institutions: Overseen by MHEC
<table>
<thead>
<tr>
<th>Institution</th>
<th>Program</th>
<th>Duration</th>
<th>Tuition</th>
</tr>
</thead>
<tbody>
<tr>
<td>American University</td>
<td>Biotechnology, M.S. - Bioinformatics Track</td>
<td>30</td>
<td>$1,866/credit</td>
</tr>
<tr>
<td>Catholic University of America</td>
<td>Biotechnology, M.S.</td>
<td>18 month accelerated option or 24 months regular option</td>
<td>$2,075/credit</td>
</tr>
<tr>
<td>George Mason</td>
<td>Bioinformatics and Computational Biology, M.S.</td>
<td>31</td>
<td>$703/credit and $1,681/credit</td>
</tr>
<tr>
<td>Georgetown University</td>
<td>Bioinformatics, M.S.</td>
<td>30</td>
<td>$2,360/credit</td>
</tr>
<tr>
<td>Liberty University</td>
<td>Health Informatics, M.S.</td>
<td>42</td>
<td>$565/credit</td>
</tr>
<tr>
<td>Arizona State University</td>
<td>Bioinformatics, M.S.</td>
<td>32</td>
<td>$1,144/credit and $1,565/credit</td>
</tr>
<tr>
<td>Columbia University</td>
<td>Computer Science, M.S.-Computational Biology Track</td>
<td>30</td>
<td>$2,196/credit</td>
</tr>
<tr>
<td>Harvard University</td>
<td>Computational Biology and Quantitative Genetics, M.S.</td>
<td>80</td>
<td>$65,460/year</td>
</tr>
<tr>
<td>Stanford University</td>
<td>Biomedical Informatics, M.S.</td>
<td>45</td>
<td>$1,400/credit</td>
</tr>
<tr>
<td>University of Delaware</td>
<td>Biocomputational Biology, M.S.</td>
<td>31</td>
<td>$979/credit</td>
</tr>
<tr>
<td>Virginia Commonwealth University</td>
<td>Bioinformatics, M.S. (Or Bioinformatics, MPS)</td>
<td>34</td>
<td>$524/credit and $1,132/credit</td>
</tr>
<tr>
<td>Boston University</td>
<td>Bioinformatics, M.S.</td>
<td>32</td>
<td>$81,050/year</td>
</tr>
<tr>
<td>Northeastern University</td>
<td>Bioinformatics, M.S.</td>
<td>32</td>
<td>$55,400/year</td>
</tr>
</tbody>
</table>

**Program Descriptions:**

- **American University:** Designed to transform your understanding of science and prepare you to be a leader in the biotechnology industry.
- **Catholic University of America:** Designed for students interested in medical genomics, proteomics, and bioinformatics. After graduating, students work as bioinformatics professionals in the field.
- **George Mason:** Designed for students interested in scientific research in both Biochemistry, Molecular Biology, and Bioinformatics. Graduates have gained knowledge and experience in both Biochemistry, Molecular Biology, and Bioinformatics, making them great candidates for job positions in the D.C. biotechnology lab. Graduates often pursue a career in industry, government, and academia.
- **Liberty University:** Online health informatics programs train people to combine the use of healthcare and information technology to organize, manage and access health information. People in this field use various classification systems to code and categorize patient information.
- **Arizona State University:** The program is designed to prepare students for employment in the biotech industry and other career options.
- **Columbia University:** The Computational Biology Track is intended for students who want to develop working knowledge of computational techniques and their applications to biomedical research.
- **Harvard University:** The SMS in Computational Biology and Quantitative Genetics is intended as a terminal professional degree which will enable you to launch your career in bioinformatics.
- **Stanford University:** The mission is to train future research leaders to design and implement novel quantitative and computational methods to solve challenging problems across the entire spectrum of biology and medicine.
- **University of Delaware:** The thesis-based MS degree prepares students for advanced research.
- **Virginia Commonwealth University:** Students enter the program from a variety of academic backgrounds and will have an effective exposure to the fields of healthcare and information technology to organize, manage and access health information.
- **Boston University:** The program is intended to prepare students for employment in the biotech industry and other career options.
- **Northeastern University:** The program is designed to transform your understanding of science and prepare you to be a leader in the biotechnology industry.

**Application Requirements:**

- **Strategic planning requirements:**
  - Personal statement
  - 2 letters of recommendation
  - GPA 3.0 or above
  - English language proficiency

**Online Application:**

- Application fee
- Transcripts from all institutions attended

**Requirements:**

- A regionally or nationally accredited bachelor’s degree with a 3.0 or above GPA is required for admission.

**Other Major Institutions Offering Similar Programs:**

- **Columbia University:**
  - F2F Biotechnology, M.S.
  - Program can be completed in 10 to 15 months.
  - Tuition: $2,075/credit

- **George Washington University:**
  - F2F Bioinformatics, M.S.
  - Program can be completed in 2-3 semesters.
  - Tuition: $2,360/credit

- **George Mason:**
  - Online Bioinformatics and Computational Biology, M.S.
  - Program can be completed in 2 years.
  - Tuition: $703/credit and $1,681/credit

- **Liberty University:**
  - Online Health Informatics, M.S.
  - Program can be completed in 2 years.
  - Tuition: $565/credit

- **Arizona State University:**
  - Biotechnology, M.S.
  - Program can be completed in 2 years.
  - Tuition: $1,144/credit and $1,565/credit

- **Columbia University:**
  - Computer Science, M.S.-Computational Biology Track
  - Program can be completed in 2 years.
  - Tuition: $2,196/credit

- **Harvard University:**
  - Computational Biology and Quantitative Genetics, M.S.
  - Program can be completed in 2 years.
  - Tuition: $65,460/year

- **Stanford University:**
  - Biomedical Informatics, M.S.
  - Program can be completed in 2-5 years.
  - Tuition: $1,400/credit

- **University of Delaware:**
  - Biocomputational Biology, M.S.
  - Program can be completed in 2 years.
  - Tuition: $979/credit

- **Virginia Commonwealth University:**
  - Bioinformatics, M.S. (Or Bioinformatics, MPS)
  - Program can be completed in 2 years.
  - Tuition: $524/credit and $1,132/credit

- **Boston University:**
  - Bioinformatics, M.S.
  - Program can be completed in 2 years.
  - Tuition: $81,050/year

- **Northeastern University:**
  - Bioinformatics, M.S.
  - Program can be completed in 2 to 3 years.
  - Tuition: $55,400/year

**Applicants:**

- Applicable to eligible students who have earned a bachelor’s or master’s degree in biology, computer science, engineering, nursing or statistics from a regionally accredited institution.
- Applicants must have completed a bachelor’s degree in biology or a related field.
- Applicants must have completed a bachelor’s degree in biology or a related field.
- Applicants should have a bachelor’s degree with a strong background in biology, chemistry and mathematics.
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<table>
<thead>
<tr>
<th>Occupation</th>
<th># of Jobs in the Field</th>
<th>Where Professionals are Employed</th>
<th>Professional Salary Information</th>
<th>Projected Job Growth</th>
</tr>
</thead>
</table>
| **Bioengineers and Biomedical Engineers**     | 17,900                 | Research and development in the physical, engineering, and life sciences 28%  
Medical Equipment and supplies manufacturing 14%  
Healthcare and social assistance 8%  
Navigational, measuring, electromedical, and control instruments manufacturing 7%  
Colleges, universities, and professional schools; state, local and private 5% | $97,410 per year  
$46.83 per hour  
Job Outlook 2021-31: 10% (Faster than average) |                                                                                                               |
| **Health Information Technologists and Medical Registrars** | 39,900                 | Hospitals; state, local, and private 46%  
Offices of physicians 11%  
Professional, scientific, and technical services 7%  
Management of companies and enterprises 6%  
Administrative and support services 6% | $55,560 per year  
$26.71 per hour  
Job Outlook 2021-31: 17% (Much faster than average) |                                                                                                               |
| **Mathematicians and Statisticians**          | 36,100                 | Federal government 62%  
Professional, scientific, and technical services 13%  
Colleges, universities, and professional schools; state, local and private 13% | $96,280 per year  
$46.29 per hour  
Job Outlook 2021-31: 31% (Much faster than average) |                                                                                                               |

**Maryland has the second highest employment level in this occupation in the United States. (Only CA is higher).**

**Maryland has the third highest concentration of jobs in this occupation in the United States.**

**Maryland is the second highest top paying state for this occupation.**

**Maryland is the fifth highest top paying state for this occupation.**
## Five-Year Enrollment Trends

<table>
<thead>
<tr>
<th>Year</th>
<th>Hood College</th>
<th>Johns Hopkins University</th>
<th>Morgan State University</th>
<th>Mount Saint Mary's University</th>
<th>UMB</th>
<th>UMGC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bioinformatics, M.S.</td>
<td>Bioinformatics, M.S.</td>
<td>Bioinformatics, M.S.</td>
<td>Biotechnology and Management</td>
<td></td>
<td>Biotechnology, M.S.-Bioinformatics Specialization</td>
</tr>
<tr>
<td></td>
<td>Approved in 2016</td>
<td>Approved in 2003</td>
<td>Approved in 2002</td>
<td>Approved in 2012</td>
<td>Approved 2021</td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td>5</td>
<td>141</td>
<td>5</td>
<td>23</td>
<td>395</td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td>15</td>
<td>169</td>
<td>3</td>
<td>10</td>
<td>446</td>
<td></td>
</tr>
<tr>
<td>2018</td>
<td>24</td>
<td>174</td>
<td>3</td>
<td>14</td>
<td>498</td>
<td></td>
</tr>
<tr>
<td>2019</td>
<td>32</td>
<td>173</td>
<td>6</td>
<td>13</td>
<td>543</td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td>28</td>
<td>183</td>
<td>9</td>
<td>17</td>
<td>597</td>
<td></td>
</tr>
<tr>
<td>2021</td>
<td>25</td>
<td>207</td>
<td>11</td>
<td>29</td>
<td>598</td>
<td></td>
</tr>
</tbody>
</table>

## Five-Year Degree Recaps

<table>
<thead>
<tr>
<th>Year</th>
<th>Hood College</th>
<th>Johns Hopkins University</th>
<th>Morgan State University</th>
<th>Mount Saint Mary's University</th>
<th>UMB</th>
<th>UMGC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bioinformatics, M.S.</td>
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<td></td>
<td>Biotechnology, M.S.-Bioinformatics Specialization</td>
</tr>
<tr>
<td></td>
<td>Approved in 2016</td>
<td>Approved in 2003</td>
<td>Approved in 2002</td>
<td>Approved in 2012</td>
<td>Approved 2021</td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td>36</td>
<td>1</td>
<td>1</td>
<td>9</td>
<td>92</td>
<td></td>
</tr>
<tr>
<td>2018</td>
<td>1</td>
<td>32</td>
<td>3</td>
<td>15</td>
<td>91</td>
<td></td>
</tr>
<tr>
<td>2019</td>
<td>3</td>
<td>39</td>
<td>1</td>
<td>5</td>
<td>113</td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td>10</td>
<td>51</td>
<td>0</td>
<td>6</td>
<td>137</td>
<td></td>
</tr>
<tr>
<td>2021</td>
<td>5</td>
<td>43</td>
<td>5</td>
<td>8</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td>2022</td>
<td>7</td>
<td>59</td>
<td>3</td>
<td>6</td>
<td>154</td>
<td></td>
</tr>
</tbody>
</table>
The learning outcomes for the program will be assessed using a combination of formative and summative assessments during and at the completion of each semester. Each course in the program will have homework assignments, practice sets, and other assessments that will be graded with feedback to help assess the student’s learning. Midterms and final exams or projects will be cumulative assessments to determine if and to what level the student mastered the learning outcomes for each course.

The assessments will be appropriate to the nature of the course content and the course learning objectives. Both individual assessments and group assessments will be required in the program. This type of variation best mimics the work and industry expectations. The assessments of the program will mirror work products in the industry and prepare students for jobs in industry. For example, many of the elective courses include final projects, presentations and assignments where students have to work with real data sets. Students will be expected to process the data, and perform tasks and make recommendations that are expected of an entry level data scientist/AI engineer.

Lastly, students will also be challenged to complete reflective assessments to apply knowledge and skills in their future professional work. This work will assist students in the job search process and enable them to identify, apply to, and earn positions in this field. The assessments will all follow best practices for adult and professional students. As the student progresses through the curriculum and satisfies learning objectives, they will align with and accomplish the program-level learning outcomes.
# Five-Year Program Budget

## Tuition Revenue

<table>
<thead>
<tr>
<th></th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Total enrolled students</td>
<td>9</td>
<td>19</td>
<td>20</td>
<td>21</td>
<td>23</td>
</tr>
<tr>
<td>1. First year enrollment</td>
<td>9</td>
<td>10</td>
<td>10</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>2. Second year enrollment</td>
<td>9</td>
<td>10</td>
<td>10</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>B. Total # of 3-credit Courses (by enrollment year)</td>
<td>8</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>1. # of courses offered for students in year one of the program</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>2. # of courses offered for students in year two of the program</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>C. Per Course Rate</td>
<td>$4,000</td>
<td>$4,120</td>
<td>$4,244</td>
<td>$4,371</td>
<td>$4,502</td>
</tr>
</tbody>
</table>

**Total Tuition Revenue**: $288,000, $403,760, $424,360, $472,058, $531,240

## Direct Expenses

<table>
<thead>
<tr>
<th></th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Instructor Salaries and Fringe</td>
<td>$134,927</td>
<td>$173,936</td>
<td>$179,154</td>
<td>$184,529</td>
<td>$190,065</td>
</tr>
<tr>
<td>1. Subtotal: Instructor salaries</td>
<td>$103,870</td>
<td>$133,900</td>
<td>$137,917</td>
<td>$142,055</td>
<td>$146,316</td>
</tr>
<tr>
<td>Average 3-credit course salary</td>
<td>$13,000</td>
<td>$13,390</td>
<td>$13,792</td>
<td>$14,205</td>
<td>$14,632</td>
</tr>
<tr>
<td>Program specific courses (100% FTE)</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Shared courses (33% FTE)</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>2. Fringe Benefits: 29.9%</td>
<td>$31,057</td>
<td>$40,036</td>
<td>$41,237</td>
<td>$42,474</td>
<td>$43,749</td>
</tr>
<tr>
<td><strong>Total Direct Expenses</strong></td>
<td>$134,927</td>
<td>$173,936</td>
<td>$179,154</td>
<td>$184,529</td>
<td>$190,065</td>
</tr>
</tbody>
</table>

**Total Annual Tuition Revenue**: $288,000, $403,760, $424,360, $472,058, $531,240

**Total Annual Direct Expenses**: $134,927, $173,936, $179,154, $184,529, $190,065

**Total Annual OES Administrative Fee**: $28,800, $40,376, $42,436, $47,206, $53,124

**Annual Distributable Revenue**: $124,273, $189,448, $202,770, $240,323, $288,051

## Indirect Expenses

<table>
<thead>
<tr>
<th></th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administrative Salaries and Fringe</td>
<td>$53,692</td>
<td>$55,303</td>
<td>$56,962</td>
<td>$58,671</td>
<td>$60,431</td>
</tr>
<tr>
<td>1. Administrative Salaries</td>
<td>$39,596</td>
<td>$40,784</td>
<td>$42,007</td>
<td>$43,268</td>
<td>$44,566</td>
</tr>
<tr>
<td>Director (20% FTE)</td>
<td>$25,846</td>
<td>$26,621</td>
<td>$27,420</td>
<td>$28,243</td>
<td>$29,090</td>
</tr>
<tr>
<td>Faculty Director Stipend</td>
<td>$15,000</td>
<td>$15,450</td>
<td>$15,914</td>
<td>$16,391</td>
<td>$16,883</td>
</tr>
<tr>
<td>Program Manager (33% FTE)</td>
<td>$13,750</td>
<td>$14,163</td>
<td>$14,587</td>
<td>$15,025</td>
<td>$15,476</td>
</tr>
<tr>
<td>2. Fringe Benefits: 35.6%</td>
<td>$14,096</td>
<td>$14,519</td>
<td>$14,955</td>
<td>$15,403</td>
<td>$15,865</td>
</tr>
<tr>
<td><strong>Total Indirect Expenses</strong></td>
<td>$97,928</td>
<td>$112,616</td>
<td>$115,349</td>
<td>$118,155</td>
<td>$121,035</td>
</tr>
</tbody>
</table>

**Net Revenue**

<table>
<thead>
<tr>
<th></th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>OES Distribution to CMNS</td>
<td>$124,273</td>
<td>$189,448</td>
<td>$202,770</td>
<td>$240,323</td>
<td>$288,051</td>
</tr>
<tr>
<td>Indirect Expenses</td>
<td>$97,928</td>
<td>$112,616</td>
<td>$115,349</td>
<td>$118,155</td>
<td>$121,035</td>
</tr>
<tr>
<td><strong>Balance</strong></td>
<td>$26,345</td>
<td>$76,832</td>
<td>$87,421</td>
<td>$122,169</td>
<td>$167,016</td>
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</tbody>
</table>
DATE: 08/11/2021

TO: Michael P. Cummings, PhD
Professor, Department of Biology, and Institute for Advanced Computer Studies
Director, Center for Bioinformatics and Computational Biology
Director, Master of Professional Studies Program in Data Science and Analytics

FROM: On behalf of the University of Maryland Libraries:
Jodi Coalter, Life Sciences & Outreach Librarian
Maggie Saponaro, Director of Collection Development Strategies
Daniel Mack, Associate Dean, Collection Strategies & Services

RE: Library Collection Assessment

We are providing this assessment in response to a proposal by the College of Computer, Mathematical, and Natural Sciences to create Master’s in Bioinformatics and Computational Biology program. The Bioinformatics and Computational Biology program asked that we at the University of Maryland Libraries assess our collection resources to determine how well the Libraries support the curriculum of this proposed program.

Serial Publications

University of Maryland Libraries currently subscribe to a large number of scholarly journals—almost all in online format—that focus on bioinformatics, computational biology, and biology.

The Libraries subscribe to most of the top ranked journals that are listed in the computational biology category in the Science Edition of Journal Citation Reports.* These journals include the following, all of which are available online:

- *PLoS Computational Biology*
- *Journal of Computational Biology*
- *Computational Biology and Chemistry*
- *Biomedical Engineering and Computational Biology*
- *IEEE/ACM Transactions on Computational Biology and Bioinformatics*

One highly-ranked core journal to which the Libraries does not currently subscribe is *Journal of Bioinformatics and Computational Biology*, published by World Scientific Publishing Co. PTE LTD. However, articles in journals that we do not own will likely be available through Interlibrary Loan/Document Delivery.

*Note: Journal Citation Reports is a tool for evaluating scholarly journals. It computes these evaluations from the relative number of citations compiled in the Science Citation Index and Social Sciences Citation Index database tools.
Databases

The Libraries’ Database Finder (http://www.lib.umd.edu/dbfinder) resource offers online access to databases that provide indexing and access to scholarly journal articles and other information sources. Many of these databases cover subject areas that would be relevant to this proposed program. Databases that would be useful in the field of bioinformatics and computational biology are Web of Science, PLoS Biology, SciFinder, PubMed, IEEE Xplore, BioOne, Biosis Previews, and ACM Digital Library. Some of the other subject databases that would be relevant to this curriculum include SpringerLink, Springer eBooks in Computer Science, Lecture Notes in Computer Science, and Science Direct.

In many—and likely in most—cases, these indexes offer full text copies of the relevant journal articles. In those instances in which the journal articles are available only in print format, the Libraries can make copies available to students through the Libraries’ Interlibrary Loan service (https://www.lib.umd.edu/access/ill-article-request). (Note: see below.)

Monographs

The Libraries regularly acquire scholarly monographs in computational biology and allied subject disciplines. Monographs not already part of the collection can usually be added upon request.

Even though most library research for this course/program likely will rely upon online journal articles, students may wish to supplement this research with monographs. Fortunately, more and more monographs are available as e-books. Even in instances when the books are only available in print, students will be able to request specific chapters for online delivery through the Interlibrary Loan program (https://www.lib.umd.edu/access/ill-article-request). (Note: see below).

A search of the University of Maryland Libraries’ WorldCat UMD catalog was conducted, using a variety of relevant subject terms. This investigation yielded sizable lists of citations of books that we own. Terms searched included “computational biology” (949 results), “bioinformatics” (2,389 results), and “metagenomics” (132 results). A further search revealed that the Libraries’ membership in the Big Ten Academic Alliance (BTAA) dramatically increases these holdings and citations (1,996 results for “computational biology”, 5,553 results for “bioinformatics”, and 442 results for “metagenomics”). As with our own materials, students can request that chapters be copied from these BTAA books if the books are not available electronically.

Interlibrary Loan Services

Interlibrary Loan services (https://www.lib.umd.edu/access/ill) provide online delivery of bibliographic materials that otherwise would not be available online. As a result, remote users who take online courses may find these services to be helpful. Interlibrary Loan services are available free of charge.

The article/chapter request service scans and delivers journal articles and book chapters within three business days of the request—provided that the items are available in print on the UM Libraries’ shelves or in microform. In the event that the requested article or chapter is not available on campus, the request will be automatically forwarded to the Interlibrary Loan service (ILL). Interlibrary Loan is a service
that enables borrowers to obtain online articles and book chapters from materials not held in the University System of Maryland.

**Additional Materials and Resources**

In addition to serials, monographs and databases available through the University Libraries, students in the proposed program will have access to a wide range of media, datasets, software, and technology. Media in a variety of formats that can be utilized both on-site and via ELMS course media is available at McKeldin Library. GIS Datasets are available through the GIS Data Repository ([https://www.lib.umd.edu/gis/data-and-resources](https://www.lib.umd.edu/gis/data-and-resources)) while statistical consulting and additional research support is available through the Research Commons ([http://www.lib.umd.edu/rc](http://www.lib.umd.edu/rc)) and technology support and services are available through the Terrapin Learning Commons ([http://www.lib.umd.edu/tlc](http://www.lib.umd.edu/tlc)).

The subject specialist librarian/s for the discipline/s, including **Jodi Coalter** (Life Sciences & Outreach Librarian, jcoalter@umd.edu), **Svetla Baykoucheva** (Chemistry and Life Sciences Librarian, and liaison to Cell Biology and Molecular Genetics, sbaykouc@umd.edu), and **Nevenka Zdravkovska** (Head of the STEM Library and liaison to computer science and mathematics, nevenka@umd.edu) also serve as an important resource to programs such as the one proposed. Through departmental partnerships, subject specialists actively develop innovative services and materials that support the University's evolving academic programs and changing research interests. Subject specialists provide one-on-one research assistance online, in-person, or via the phone. They also provide information literacy instruction and can provide answers to questions regarding publishing, copyright and preserving digital works.

**Other Research Collections**

Because of the University’s unique physical location near Washington D.C., Baltimore and Annapolis, University of Maryland students and faculty have access to some of the finest libraries, archives and research centers in the country vitally important for researchers in bioinformatics and computational biology. These include the Library of Congress, the National Archives, National Library of Medicine, National Agricultural Library, and the Smithsonian, to name a few.

**Conclusion**

With our substantial journals holdings and index databases, as well as additional support services and resources, the University of Maryland Libraries have resources to support teaching and learning in bioinformatics and computational biology. These materials are supplemented by a strong monograph collection. Additionally, the Libraries Scan & Deliver and Interlibrary Loan services make materials that otherwise would not be available online, accessible to remote users in online courses. As a result, our assessment is that the University of Maryland Libraries are able to meet the curricular and research needs of the proposed Master’s in Bioinformatics and Computational Biology program.
The following faculty members are projected to teach in the program. All faculty are full-time unless otherwise indicated.

<table>
<thead>
<tr>
<th>Name</th>
<th>Highest Degree Earned, Program, and Institution</th>
<th>UMD Title (indicate if part-time)</th>
<th>Courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stephen Altschul</td>
<td>Ph.D., Mathematics, MIT</td>
<td>Adjunct Professor</td>
<td>BIOI606 Sequence Alignment</td>
</tr>
<tr>
<td>Babak Azimi-Sadjadi</td>
<td>Ph.D., ECE, UMD</td>
<td>Visiting Lecturer</td>
<td>DATA/MSML/BIOI 603: Principles of Machine Learning</td>
</tr>
<tr>
<td>Sandra Cerrai</td>
<td>Ph.D., Mathematics, Scuola Normale Superiore of Pisa</td>
<td>Prof &amp; Assoc Chair</td>
<td>DATA/MSML/BIOI 601: Probability and Statistics</td>
</tr>
<tr>
<td>Michael Cummings</td>
<td>Ph.D., Organismic and Evolutionary Biology, Harvard University</td>
<td>Professor</td>
<td>BIOI605: Data Sources and Data Management in Bioinformatics</td>
</tr>
<tr>
<td>Najib M. El-Sayed</td>
<td>Ph.D., Molecular Parasitology, Yale</td>
<td>Professor</td>
<td>BIOI604: Principles of Molecular Biology, Genetics, and Genomics BIOI610: Genome Annotation</td>
</tr>
<tr>
<td>Mohammad Taghi Hajiaghayi</td>
<td>Ph.D., Computer Science, MIT</td>
<td>Professor</td>
<td>DATA/MSML/BIOI 602: Principles of Data Science</td>
</tr>
<tr>
<td>Brantley Hall</td>
<td>Ph.D. Genomics, Bioinformatics, and Computational Biology, Virginia Tech</td>
<td>Assistant Professor</td>
<td>BIOI622 Metagenomics Data Analysis</td>
</tr>
<tr>
<td>Leonid Koralov</td>
<td>Ph.D., Mathematics, SUNY at Stony Brook</td>
<td>Prof &amp; Assoc Chair</td>
<td>DATA/MSML/BIOI 601: Probability and Statistics</td>
</tr>
<tr>
<td>Alejandra Mercado</td>
<td>Ph.D., ECE, UMD</td>
<td>Associate Director</td>
<td>DATA/MSML/BIOI 603: Principles of Machine Learning</td>
</tr>
<tr>
<td>Arefeh A Nasri</td>
<td>Ph.D., Transportation Engineering, UMD</td>
<td>Visiting Lecturer</td>
<td>DATA/MSML/BIOI 602: Principles of Data Science</td>
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<tr>
<td>Name</td>
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<td>Title</td>
<td>Course Title</td>
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<tr>
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<tr>
<td>Rob Patro</td>
<td>Ph.D., Computer Science, UMD</td>
<td>Associate Professor</td>
<td>BIOI607 Data Structures and Algorithms for Bioinformatics</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>BIOI611 Analysis of Gene Expression Data</td>
</tr>
<tr>
<td>Mihai Pop</td>
<td>Ph.D., Computer Science, Johns Hopkins University</td>
<td>Professor</td>
<td>BIOI621 Genome Assembly and Annotation</td>
</tr>
</tbody>
</table>
Course Descriptions

BIOI601 Probability and Statistics (core), co-listed with DATA601 and MSML601
An introduction to the fundamental concepts of probability theory and statistics. The course covers the basic probabilistic concepts such as probability space, random variables and vectors, expectation, covariance, correlation, probability distribution functions, etc. Important classes of discrete and continuous random variables, their inter-relation, and relevance to applications are discussed. Conditional probabilities, the Bayes formula, and properties of jointly distributed random variables are covered. Limit theorems, which investigate the behavior of a sum of random variables, are discussed. The main concepts of random processes are then introduced. The latter part of the course concerns the basic problems of mathematical statistics of point and interval estimation and hypothesis testing.

BIOI602 Principles of Data Science (core), co-listed with DATA602 and MSML602
An introduction to the data science pipeline, i.e., the end-to-end process of going from unstructured, messy data to knowledge and actionable insights. Provides a broad overview of what data science means and systems and tools commonly used for data science and illustrates the principles of data science through several case studies.

BIOI603 Principles of Machine Learning (core), co-listed with DATA603 and MSML603
A broad introduction to machine learning and statistical pattern recognition. Topics include the following. Supervised learning: Bayes decision theory; discriminant functions; maximum likelihood estimation; nearest neighbor rule; linear discriminant analysis; support vector machines; neural networks; deep learning networks. Unsupervised learning: clustering; dimensionality reduction; principal component analysis; auto-encoders. The course will also discuss recent applications of machine learning, such as computer vision, data mining, autonomous navigation, and speech recognition.

BIO604 Principles of Molecular Biology, Genetics and Genomics (core)
Provides a review of basic concepts in molecular biology, genetics, and genomics. Topics include the following: prokaryotic and eukaryotic genome structure and organization (including 3D architecture); Mendelian genetics, recombination, linkage and linkage disequilibrium, genome-wide association studies; review of genome projects, comparative genomics, genome variation, single nucleotide polymorphisms and genotyping; gene expression and the transcriptome, transcriptional regulation, gene regulatory networks; translation and translational regulation; proteomics approaches; integrative genomics.

BIOI605 Data Sources and Data Management in Bioinformatics (core)
An introduction to the different types of data generated for bioinformatics analyses and data management principles required for scientific rigor and reproducibility. Data sources include, but are not limited to, sequencing data, 'omics data (e.g., proteomics, metabolomics, lipidomics), imaging data, and clinical data. Data organization will cover topics such as management and curation of metadata, downloading data from and submitting data to public repositories, and using databases versus spreadsheets and tables.

BIOI606 Sequence Alignment (core)
In-depth coverage of biological sequence alignment including the following: definitions, algorithms, and statistics for local, global, pairwise, and multiple alignments; scoring schemes; BLAST, BLAST variants, and similar programs; motif finding; and related topics.

BIOI607 Data Structures and Algorithms for Bioinformatics (core)
An introduction to the fundamental data structures and algorithms underlying many parts of Bioinformatics. Standard data structures for efficient indexing and sequence search will be covered, including the suffix array and the FM-index, as well as alignment-free methods for sequence comparison. This course will also introduce the fundamental algorithms in computational phylogenomics and biological network analysis. Finally, bioinformatics
oriented applications of classic unsupervised learning algorithms (e.g., clustering and dimensionality reduction) and database techniques (e.g., sorting, selection, joining) will be examined. The focus will be both on formal understanding of computational efficiency as well as the practical applications of these concepts.

**BIOI610 Genome Annotation (core)**
An introduction to approaches for the structural and functional annotation of genome content. Topics covered include the following: ab initio gene/coding sequence discovery; signals and signal sensors (including regulatory sequences); non-protein coding genes and other structural features of genome sequences; similarity searches (orthologs, paralogs, xenologs); clustering of genes by sequence similarity; clusters of orthologous genes; phylogenetic classification of genes; gene ontologies, gene set enrichment analyses; next generation sequencing functional assays; integrated genomics circuits; and annotation databases.

**BIOI611 Analysis of Gene Expression Data (core); prerequisite: BIOI604**
This course focuses on the analysis of transcriptomics data, and specifically on the analysis of gene and transcript level expression. Material covered includes transcript and gene expression estimation from RNA-seq data (short and long-read), basic experimental design and statistical methods for differential expression analysis, discovery of novel transcripts via reference-guided and de novo assembly, and the analysis of single-cell gene expression data (e.g., single-cell expression quantification, dimensionality reduction, clustering, pseudotime analysis).

**BIOI621 Genome Assembly and Annotation (elective); prerequisite: BIOI604**
An introduction to the algorithms and tools used to reconstruct genome sequences from shotgun sequencing data and to annotate the resulting sequence. The first part of the course will cover the theoretical underpinnings of core assembly paradigms and discuss the practical use of these paradigms in the context of current sequencing technologies. Also discussed will be approaches for scaffolding the reconstructed sequences along chromosomes using mate-pair and other types of information such as mapping data. An important focus of the course will be on approaches for validating the output of sequence assemblers, also discussing the impact assembly errors can have on downstream analyses such as genome annotation and comparative analyses. The second part of the course will discuss approaches for interpreting sequence annotations in the context of a reconstructed genome, focusing on genome browsers and other visualization and analytical tools and approaches for analyzing and interpreting gene synteny information. A particular focus will be on the impact of repetitive sequences on the quality of genome assemblies and ability to effectively analyze gene synteny and to conduct comparative genomic analyses.

**BIOI622 Metagenomics Data Analysis (elective); prerequisite: BIOI604**
An introduction to metagenomics, the study of sequence data derived from environmental samples without the cultivation of individual organisms. The course will provide an overview of the entire process of obtaining and analyzing metagenomic data including sample collection, DNA isolation strategies, sequencing strategies, and initial data processing. Additionally, taxonomic analysis, the determination of the identity of organisms within a metagenomic sample and the analysis of whole metagenome shotgun sequencing with metagenomic assembly and functional annotation will be discussed. Diversity metrics used to summarize the ecological structure of microbial communities in terms of richness or distance as well as the visualization of these metrics will be discussed. Finally, methods to identify features that differ between microbial communities will be reviewed.

**BIO699 Capstone Research (elective)**
The course provides an opportunity for a more in-depth research experience focusing on an original research project. Expected learning outcomes include that the student should be able to: design and conduct a bioinformatics or computational biology project; place the research in the context of biological problems; develop a written report and other deliverables if applicable.