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
6. Wed, 04 Oct 2023 20:48:16 GMT
   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:

Course	Title	Credits
Core Requirements		
BIOI601	Probability and Statistics	3
BIOI602	Principles of Data Science	3
BIOI603	Principles of Machine Learning	3
BIOI604	Course BIOI604 Not Found (Principles of Molecular Biology, Genetics, and Genomics)	3
BIOI605	Course BIOI605 Not Found (Data Sources and Data Management in Bioinformatics)	3
BIOI606	Course BIOI606 Not Found (Sequence and Alignment)	3
BIOI607	Course BIOI607 Not Found (Data Structures and Algorithms for Bioinformatics)	3
BIOI610	Course BIOI610 Not Found (Genome Annotation)	3
BIOI611	Course BIOI611 Not Found (Analysis of Gene Expression Data)	3
Elective Requirement (choose one of the following):		**3**
BIOI621	Course BIOI621 Not Found (Genome Assembly and Annotation)	
BIOI622	Course BIOI622 Not Found (Metagenomics Data Analysis)	
BIOI699	Course BIOI699 Not Found (Capstone Research)	
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

Semester 1 (fall)

- BIOI601 Probability & Statistics (Core)
- BIOI604 Principles of Molecular Biology, Genetics, and Genomics (Core)

Semester 2 (spring)

- BIOI605 Data Sources and Data Management in Bioinformatics (Core)
- BIOI606 Sequence Alignment (Core)

Semester 3 (summer)

- BIOI610 Genome Annotation (Core)

Semester 4(fall)

- BIOI602 Principles of Data Science (Core)
- BIOI611 Analysis of Gene Expression Data (Core)

Semester 5 (spring)

- BIOI603 Principles of Machine Learning (Core)
- BIOI607 Data Structures and Algorithms for Bioinformatics (Core)

Semester 6 (summer)- no classes

Semester 7 (fall)

- BIOI621 Genome Assembly and Annotation (Elective)

Full Time
Semester 1(Fall)

- BIOI601 Probability & Statistics (Core)
- BIOI602 Principles of Data Science (Core)
- BIOI604 Principles of Molecular Biology, Genetics, and Genomics (Core)

Semester 2(Spring)

- BIOI605 Data Sources and Data Management in Bioinformatics (Core)
- BIOI606 Sequence Alignment (Core)
- BIOI607 Data Structures and Algorithms for Bioinformatics(Core)

Semester 3(summer)

- BIOI610 Genome Annotation (Core)

Semester 4(Fall)

- BIOI603 Principles of Machine Learning (Core)
- BIOI611 Analysis of Gene Expression Data (Core)
- BIOI621 Genome Assembly and Annotation (Elective)

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

Learning Outcomes
Explain multiple problem-solving methods in bioinformatics and computational biology.
Apply bioinformatics and computational biology methods to problems in biology and biomedical research.
Interpret and infer results of bioinformatics and computational biology analyses to different audiences.
Communicate results of analyses with considerations of ethical, privacy and legal issues

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 are 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 Academic Calendar 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 addresses 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 o#ered 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

projections, in house marketing research, preparation of PCC document), program management (UMD policies and procedures compliance, program website, data requests), student and program services (admission support, scheduling,
registration, billing and payment, graduation, appeals), and financial management (faculty contracts, payment processing, course charge processor, net revenue distribution).

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 USBLS Occupational Outlook Handbook, or Maryland state Occupational and Industry Projections over the next five years. Also, provide information on the existing supply of graduates in similar programs in the state (use MHEC's Office of Research and Policy Analysis webpage for Annual Reports on Enrollment by Program) and discuss how future demand for graduates will exceed the existing supply. As part of this analysis, indicate the anticipated number of students your program will graduate per year at steady state.

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 di#erences 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 di#erences 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

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

OES In-House Market Research: Other Institution Comparison									
Program Name = Bioinformatics, M.S.									
Institution	Website	Delivery Method	Degree Name & Type (MPS, MA, MS, MPH, etc.)	# of Credits	Program Duration	Tuition (course or credit)		Target Population	Prior Education/ Pre-Requisites
						Resident	Non-Resident		
Big Ten Institutions									
University of Illinois Urbana-Champaign	https://ischool.illinois.edu/degrees-programs/ms-bioinformatics	F2F	Bioinformatics, M.S.- Information Sciences Concentration	36	Program can be completed in 1 year	$14,578/year	$26,990/year	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.	Bachelor's degree with at least 3.0 GPA in last two years of coursework. If an applicant's GPA is below a 3.0, then GRE test scores are required. Applicants are required to have strong backgrounds in information science, including undergraduate computing and mathematics- CS Data Structures, CS- Intro Programming, Math-Matrix Theory, and Math-Intro Statistics
Indiana University Bloomington	https://cs.indiana.edu/programs/ms-bioinformatics.html	F2F	Bioinformatics, M.S.	30	Program can be completed in 2 years	$10,630/year	$30,704/year	Designed for students interested in learning how to model, analyze, and manage massive amounts of biological data.	M.S. in Bioinformatics students are expected—but not required—to have at least introductory knowledge of both biology and informatics, including: 1. Approximately 6 credit hours of undergraduate coursework in biology, covering molecular biology, genetics, and evolution, 2. Approximately 6 credit hours of undergraduate coursework in computer science or informatics, covering programming, discrete structures, and data structures If you haven't completed these prerequisites, you will be required to take one or two appropriate 500-level background classes.
University of Iowa	https://informatics.grad.uiowa.edu/programs/bioinformatics-and-computational-biology	F2F	Bioinformatics, MS	31		$605/credit		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.	Applicants are expected to have 6 hours of undergraduate work in computer science and/or informatics and 6 hours in biology (covering genetics, molecular biology and evolution). Work experience may be considered as meeting some of these prerequisite requirements, as determined by the UI Academic Affairs Committee.
University of Michigan Ann Arbor	https://medicine.umich.edu/dept/dcmb/education/degrees/masters-program	F2F	Bioinformatics, M.S.	30	The majority of full-time students can complete the degree in 1 ½ years	$2,033/credit	$3,473/credit	prepares students for a wide range of consulting and applied research positions in industry, government, and academia. The Master's degree also offers outstanding training for students who may be interested in pursuing a Ph.D. but feel that they are not quite prepared (for example, when returning to academics after a period in the work force).	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 are related to biological data analysis is also highly considered.
	https://medicine.umich.edu/dept/dcmb/education/degrees/accelerated-masters-program	F2F	Bioinformatics, Accelerated Master's Program	30	Students complete B.A and M.S in five years	$2,033/credit	$3,473/credit	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 senior year of UM undergraduate study.	Students must submit an online application(link is external) in their junior year of undergraduate study (or approximately 18 months before finishing requirements. Undergraduate majors in Biology, MCDB (formerly CMB), LSI, Math, or CSE are encouraged. Other majors are allowed, if their home department permits and all other criteria can be met.
Michigan State University	https://cmse.msu.edu/academics/bioinformatics-program/	F2F	Bioinformatics Program- Not a degree program	N/A	N/A	$938/credit	$1,758/credit	The bioinformatics modules are a set of introductory courses that help life science students learn basic skills in computation and bioinformatics. These modules are 1 graduate credit, one month long, and flipped classroom (students watch video lectures online for homework and then come to class to solve problems and ask questions).	Postdocs, staff, visiting scholars, faculty, and other MSU-affiliates who are not students can audit these modules for a fee. Undergraduates at the junior/senior level who wish to take the modules should also contact the Coordinator to discuss their eligibility.
University of Minnesota Twin Cities	https://r.umn.edu/academics-research/graduate/bicb/degree-programs/masters	F2F	Bioinformatics and Computational Biology, M.S.	30		$1,539/credit	$2,381/credit	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 workplace.	The program expects incoming graduate students to have a strong background in the quantitative sciences and varied backgrounds in the life/health sciences. Including: Calc1, Intro Programming, Intro Bio, Multivariable calc, algorithms and data structures, statistics, biochemistry, and health sciences.
University of Nebraska Lincoln	https://cse.unl.edu/ms-computer-science-bioinformatics-specialization	F2F	Computer Science M.S.-Bioinformatics Specialization	Thesis- 30 Non-Thesis-36		$472/credit	$1,285/credit	To prepare graduate students for advanced professional practice as bioinformaticians or to prepare graduate students for doctoral studies in bioinformatics. Offers a thesis and non-thesis option.	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.
Northwestern University	https://sps.northwestern.edu/masters/health-informatics/	Online	Health Informatics, M.S.	36	1 Year	$4,883/course		MHI students prepare for emerging opportunities and roles across the healthcare enterprise in classes taught by thought leaders in the informatics field. Graduates leave the program ready to leverage technology tools and data for more efficient, patient-centered healthcare delivery and improved population health, and apply essential skills such as organizational change leadership and project management.	The program expects incoming graduate students to have a strong background in the quantitative sciences
Ohio State University	https://medicine.osu.edu/departments/biomedical-informatics/education/masters-degrees-in-infomatics	F2F	Biomedical Informatics, M.S.	48	2 Years	$ 30,124/year (Within Medical College)	$55,048/year (Within Medical College)	Our degree programs are designed to cultivate biomedical informatics expertise in public health and clinical practitioners and researchers. Intended for students whose interests are academically oriented rather than directed toward professional practice.	Undergraduate GPA of 3.0 or higher on a 4.0 scale.
Purdue University	https://polytechnic.purdue.edu/degrees/ms-computer-and-information-technology	F2F	Computer Science and Information Technology-Bioinformatics and Healthcare computing Specialization	33		$ 4,859/semester	$ 9,401/semester	When you pursue your advanced degree in computer and information technology, your studies and research will represent the intersection of new technologies, 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 infrastructure, computing application, and data management.	A relevant, earned baccalaureate degree in computer science, information technology, computer engineering, information systems, informatics, or other computer-related field of study. Minimally, students should have earned 15-18 credit hours of computational coursework.

Rutgers University New Brunswick	https://shp.rutgers.edu/health-informatics/master-of-science-health-informatics/	Online	Health Informatics, M.S.	36		$950/credit		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	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
University of Wisconsin–Madison	https://guide.wisc.edu/graduate/biostatistics-medical-informatics/biomedical-data-science-ms/	F2F	Biomedical Data Science, MS	31		$811/credit	$1,644/credit	The current explosion of biomedical data provides an awesome opportunity to improve understanding of the mechanisms of disease and ultimately to improve human health care. However, fully harnessing the power of high-dimensional, heterogeneous data requires a new blend of skills including programming, data management, data analysis, and machine learning.	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.'s, Pharm.D.'s, R.N.'s). 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

State of Maryland System Institutions: Overseen by MHEC									
Hood College	https://www.hood.edu/graduate/academics/programs/bioinformatics-ms	F2F	Bioinformatics, M.S.	33	Program can be completed in 2 years	$610/credit		The program meets the growing demand for desk- and bench-based science professionals to demonstrate expertise in the experimental design, data handling and data analysis of biology studies that examine genes—genomics, proteins—proteomics, and metabolites—metabolomics.	B.A. or B.S. in a life science or computer science field with a GPA of 2.75 or higher OR Bioinformatics certificate from Hood OR M.A. or M.S in a biology-related or computer science-related field with a 3.0 or better.
Johns Hopkins University	https://advanced.jhu.edu/academics/graduate/ms-bioinformatics/	F2F or Online	Bioinformatics, M.S.	33	Program can be completed in 16-24 months	Location: Baltimore, MD Requirements: 11 courses Time to Complete		Designed for students interested in combining studies in data and computer sciences with biological science areas, including molecular biology, biochemistry, personalized medicine, and genomic sequencing. The MS in Bioinformatics degree also serves as a foundation for medical school, law school, or advanced study in public health.	Bachelor's degree from an accredited college or university in the biological sciences or in engineering. Programs require a minimum GPA of 3.0 on a 4.0 scale. Two semesters of Organic Chemistry, one semester of biochemistry, Intro to Programming, Data Structures, one course in Statistics, Calculus.
Morgan State University	https://catalog.morgan.edu/preview_program.php?catoid=25&poid=5677	F2F	Bioinformatics, M.S.	30 (recently reduced from 36)		$464/credit	$912/credit	Designed to train such professionals with an educational background that blends biology with computer science. This program provides students with a strong foundation in computer programming, biostatistics, computer visualization, biostatistics, computational biology, computational mathematics, and database management.	a bachelor's degree from a regionally accredited college or university, preferably in bioinformatics, computer science, mathematics, statistics, or science (biology, chemistry, physics).
Mount Saint Mary's University	https://msmary.edu/academics/graduate-school/master-science-biotechnology-management.html	Blended	Biotechnology and Management, M.S.	36	Program can be completed in 1-2 years (8-week sessions)	$694/credit		The MSB program is designed for working adults in biotechnology or related industries.	
UMB **UMD, Baltimore**	https://graduate.umaryland.edu/clinicalinformatics/	F2F	Clinical Informatics, MS	34	2 Years	$746/credit	$972	Our curriculum focuses on biomedical data, clinical processes, and computational systems, which students will apply to the practice of medicine, in order to enhance health outcomes, improve patient care and strengthen the clinician-patient relationship. Coursework will also address leadership, professionalism, ethics, governance, bias, equity, and social determinants of health	Physicians, nurses, pharmacists, scientists, and researchers trained in informatics will be uniquely equipped to direct optimal implementation of health information technology for clinical care delivery and continuous quality improvement. The MS in Clinical Informatics is designed for professionals who are committed to improving our national health agenda.
UMGC UMD University Global Campus	https://www.umgc.edu/academic-programs/masters-degrees/biotechnology/bioinformatics.cfm	Online	Biotechnology, M.S.- Bioinformatics Specialization	36		$514/credit	$659 /credit	Prepares students to become qualified bioinformatics professional for public- or private-sector organizations.	Undergraduate coursework in molecular biology, programming, and statistics is required for admission.

Colleges & Universities in the Washington DC - Baltimore MD area									
American University	https://www.american.edu/cas/biology/biotechnology/	F2F or Online	Biotechnology, M.S.- Bioinformatics Track	30	Program can be completed in 16 months	$1,866/credit		Designed to transform your understanding of science and prepare you to be a leader in the biotechnology industry.	Appropriate undergraduate science courses or significant practical background
Catholic University of America	https://biology.catholic.edu/academics/graduate/ms-biotechnology/why-cua/index.html	F2F	Biotechnology, M.S.	30	18 month accelerated option or 24 months regular option	$2,075/credit		Designed for students interested in scientific research at biotechnology companies, federal agencies, and research institutions	Applicants must have completed a bachelor's degree in biology or a related field.
George Mason	https://masononline.gmu.edu/programs/bioinformatics-and-computational-biology-ms/	Online	Bioinformatics and Computational Biology, M.S.	31		$793/credit	1,681/credit	This program addresses growing national and regional demand for trained computational biologists. Graduates are qualified to pursue careers that require knowledge and applications of current bioinformatics methods and the ability to develop and use new bioinformatics software.	Ideal candidates for this program have a background or interest in biological or computer sciences.
Georgetown University	https://bioinformatics.georgetown.edu/	F2F	Bioinformatics, M.S.	30	Program can be completed in 2-3 semesters	$2,360/credit		Graduates from the program will have gained knowledge and experience in both Biochemistry, Molecular Biology, and Bioinformatics, making them great candidates for job positions in the D.C. biotechnology hub. Graduates often pursue a career in industry, government, and academia, or pursue another advanced degree (MS, PhD, MD).	A regionally or nationally accredited bachelor's degree.
George Washington University	https://smhs.gwu.edu/biochemistry-molecular-medicine/educational-programs	F2F	Bioinformatics and Molecular Biochemistry, M.S.	30	Accelerated 1 year program or regular 2 year program	$1,315/credit		Designed for students interested in medical genomics, proteomics, analytical bioinformatics, Big Data statistics, system biology, pharmaceutical oncology, algorithm development, Next-Generation sequencing, data analysis and annotation. After graduating, students work as bioinformatitians in academia or industry, or pursue PhD programs at GW or at other leading institutions.	Applicants should have a bachelor's degree with a strong background in biology, chemistry and mathematics. Required courses for admission include General Biology (year), General Chemistry (1 year), Organic Chemistry (1 year) and College Physics (1 year).
Liberty University	https://www.liberty.edu/online/business/masters/health-informatics/	Online	Health Informatics, M.S.	42	Program can be completed in 2 years	$565/credit		Online health informatics programs train people to combine the two fields of healthcare and information technology to organize, manage and secure health information. People in this field use various classification systems to code and categorize patient information for insurance reimbursement purposes and to maintain patients' medical and treatment histories.	A regionally or nationally accredited bachelor's degree with a 3.0 or above GPA is required for admission in good standing
Other Major Institutions Offering Similar Programs									
Arizona State University	https://chs.asu.edu/programs/biomedical-informatics-ms	F2F	Bioinformatics, M.S.	32	Program can be completed in 2 years	$1,144/credit	$1,563/credit	Students looking to advance their knowledge in order to become professionals in the field.	Applicants are eligible to apply to the program if they have earned a bachelor's or master's degree in biology, computer science, engineering, nursing or statistics from a regionally accredited institution. Applicants who have earned degrees in other unrelated fields must have basic competencies in college-level calculus (similar to MAT 270), general biology (similar to BIO 188) or physiology, statistics (similar to STP 226) and basic computer programming (similar to CSE 100 or CSE 110).
Columbia University	cs.columbia.edu/education/ms/computationalbiology/	F2F	Computer Science, M.S.-Computational Biology Track	30		$2,196/credit		The Computational Biology Track is intended for students who wish to develop working knowledge of computational techniques and their applications to biomedical research.	Applicants should have a bachelor's degree with a strong background in biology, chemistry and mathematics.
Harvard University	https://www.hsph.harvard.edu/sm-computational-biology/	F2F	Computational Biology and Quantitative Genetics, M.S.	80	Program can be completed in 18 to 24 months	$65,460/year		The SM in Computational Biology and Quantitative Genetics is intended as a terminal professional degree which will enable you to launch your career in bioinformatics.	An undergraduate degree in mathematical sciences or allied fields (e.g. biology, psychology, economics). Calculus through partial differentiation and multivariable integration, One semester of linear algebra or matrix methods, Either a two-semester sequence in probability and statistics or a two-semester sequence in applied statistics, At least one semester of training in biology, with some familiarity with molecular biology and genetics.
Stanford University	https://online.stanford.edu/programs/biomedical-informatics-ms-degree?certificateId=1240186&method=load	Blended	Biomedical Informatics, M.S.	45	Program can be completed in 2-5 years	$1,400/credit		Our mission is to train future research leaders to design and implement novel quantitative and computational methods that solve challenging problems across the entire spectrum of biology and medicine. The program is flexible, and attracts applicants with training in biology, research and clinical medicine, computer science, data science and analytics, statistics, and engineering.	Applicants should have a bachelor's degree with a strong background in biology, chemistry and mathematics.
University of Delaware	https://bioinformatics.udel.edu/Education/bicb-ms/	F2F	Bioinformatics and Computational Biology, M.S.	31		$979/credit		The thesis-based MS degree prepares students for advanced research.	A regionally or nationally accredited bachelor's degree.
Virginia Commonwealth University	https://bulletin.vcu.edu/graduate/vcu-life-sciences/center-study-biological-complexity/bioinformatics-ms/	F2F	Bioinformatics, M.S. (Or Bioinformatics, MPS [Non-thesis])	34		$524/credit	$1,132/credit	Students enter the program from a variety of academic backgrounds (biology, chemistry, computer science, mathematics/statistics, etc.) assisted by flexible "bridge curricula" designed to help them meet program prerequisites. Students will have an effective exposure to the biotech industry and other career options and to real-life applications of their learning.	A graduate student admitted to a program or concentration requiring a final research project, work of art, thesis or dissertation, must qualify for continuing master's or doctoral status according to the degree candidacy requirements of the student's graduate program. Admission to degree candidacy, if applicable, is a formal statement by the graduate student's faculty regarding the student's academic achievements and the student's readiness to proceed to the final research phase of the degree program.
Boston University	https://www.bu.edu/bioinformat	F2F	Bioinformatics, M.S.	32	Program can be	$61,050/year		Our MS program, the first of its kind, was founded in 1999 and	Application Requirements: Transcripts; Three recommendations; Personal statement;
Northeastern University	https://www.northeastern.edu/graduate/program/master-of-science-in-bioinformatics-online-14245/	Online	Bioinformatics, M.S.	32	Program can be completed in 2 to 3 years	$55,400/year		Combining challenging academics in biology, computer science, and information technology with real-world experience, the program helps students integrate the knowledge, skills, experience, and confidence they need to achieve their goals and make a difference in our world. The Master of Science in Bioinformatics is structured to provide students with the skills and knowledge to develop, evaluate, and deploy bioinformatics and computational biology applications. The program is designed to prepare students for employment in the	Requirements Online application; Application fee; Transcripts from all institutions attended; Personal statement; Resumé; 2 letters of recommendation; GPA 3.0 + GRE not required; English language proficiency:

OES In-House Market Research: Projected Enrollment Information				
Program Name = Bioinformatics, M.S.				
Occupation	**# of Jobs in the Field**	**Where Professionals are Employed**	**Professional Salary Information**	**Projected Job Growth**
Information from U.S. Bureau of Labor Statistics' Occupational Outlook Handbook				
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)
Information from State of Maryland's Occupational and Industry Projections				
Bioinformatics Scientists (Biological Scientists, All Other)	4,620	Federal Executive Branch Scientific Research and Development Services Colleges, Univerisities, and Professional Schools Management, Scientific, and Technical Consulting Services Pharmaceutical and Medicine Manufacturing	Mean Annual Wage: $107,849 **Maryland is the second highest top paying state for this occupation.	**Maryland has the second highest employment level in this occupation in the United States. (Only CA is higher). **Maryland has the highest concentration of jobs in this occupation in the United States.
Bioinformatics Technicians (Statistical Assistants)	3,520	Scientific Research and Development Services Colleges, Univerisities, and Professional Schools Federal Executive Branch Pharmaceutical and Medicine Manufacturing General Medical and Surgical Hospitals	Mean Annual Wage: $50,570 **Maryland is the second highest top paying state for this occupation.	**Maryland has the fifth 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.

Five-Year Enrollment Trends						
Year	**Hood College**	**Johns Hopkins University**	**Morgan State University**	**Mount Saint Mary's University**	**UMB**	**UMGC**
	Bioinformatics, M.S.	**Bioinformatics, M.S.**	**Bioinformatics, M.S.**	**Biotechnology and Management**	**Clinical Informatics, MS**	**Biotechnology, M.S.- Bioinformatics Specialization**
	Approved in 2016	*Approved in 2003*	*Approved in 2002*	*Approved in 2012*	*Approved 2021*	*Approved in 2007*
2016	5	141	5	23	Approved 2021	395
2017	15	169	3	10		446
2018	24	174	3	14		498
2019	32	173	6	13		543
2020	28	183	9	17		597
2021	25	207	11	29		598

Five-Year Degree Recaps						
Year	**Hood College**	**Johns Hopkins University**	**Morgan State University**	**Mount Saint Mary's University**	**UMGC**	**UMGC**
	Bioinformatics, M.S.	**Bioinformatics, M.S.**	**Bioinformatics, M.S.**	**Biotechnology and Management**	**Clinical Informatics, MS**	**Biotechnology, M.S.- Bioinformatics Specialization**
	Approved in 2016	*Approved in 2003*	*Approved in 2002*	*Approved in 2012*	*Approved 2021*	*Approved in 2007*
2017		36	1	9	Approved 2021	92
2018	1	32	3	15		91
2019	3	39	1	5		113
2020	10	51	0	6		137
2021	5	43	5	8		130
2022	7	59	3	6		154

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.

MS in Bioinformatics and Computational Biology					
Five-Year Program Budget					
Tuition Revenue	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
A. Total enrolled students	9	19	20	21	23
First year enrollment	9	10	10	11	12
Second year enrollment		9	10	10	11
B. Total # of 3-credit Courses (by enrollment year)	8	10	10	10	10
# of courses offered for students in year one of the program	8	8	8	8	8
# of courses offered for students in year two of the program		2	2	2	2
C. Per Course Rate	$4,000	$4,120	$4,244	$4,371	$4,502
Total Tuition Revenue	$288,000	$403,760	$424,360	$472,058	$531,240
Direct Expenses	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
A. Instructor Salaries and Fringe	$134,927	$173,936	$179,154	$184,529	$190,065
1. Subtotal: Instructor salaries	$103,870	$133,900	$137,917	$142,055	$146,316
Average 3-credit course salary	$13,000	$13,390	$13,792	$14,205	$14,632
Program specific courses (100% FTE)	7	7	7	7	7
Shared courses (33% FTE)	3	3	3	3	3
2. Fringe Benefits: 29.9%	$31,057	$40,036	$41,237	$42,474	$43,749
Total Direct Expenses	$134,927	$173,936	$179,154	$184,529	$190,065
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					
	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Administrative Salaries and Fringe	$53,692	$55,303	$56,962	$58,671	$60,431
1. Administrative Salaries	$39,596	$40,784	$42,007	$43,268	$44,566
Director (20% FTE)	$25,846	$26,621	$27,420	$28,243	$29,090
Faculty Director Stipend	$15,000	$15,450	$15,914	$16,391	$16,883
Program Manager (33% FTE)	$13,750	$14,163	$14,587	$15,025	$15,476
2. Fringe Benefits: 35.6%	$14,096	$14,519	$14,955	$15,403	15,865
Hourly Wages	$38,736	$51,648	$52,552	$53,474	$54,414
1. Hourly Wages	$36,000	$48,000	$48,840	$49,697	$50,571
Graders for program specific courses ($6K per course)	30,000	42,000	42,840	43,697	44,571
Graders for shared courses ($2K per course)	6,000	6,000	6,000	6,000	6,000
2. Hourly Wages Benefits: 7.6%	$2,736	$3,648	$3,712	$3,777	$3,843
Marketing	$2,500	$2,575	$2,652	$2,732	$2,814
1. Marketing	2,500	2,575	2,652	2,732	2,814
Equipment	$1,500	$1,545	$1,591	$1,639	$1,688
1. Equipment	1,500	1,545	1,591	1,639	1,688
Travel & Recruitment	$1,500	$1,545	$1,591	$1,639	$1,688
1. Travel & Recruitment	$1,500	$1,545	$1,591	$1,639	$1,688
Total Indirect Expenses	$97,928	$112,616	$115,349	$118,155	$121,035

Net Revenue	Year 1	Year 2	Year 3	Year 4	Year 5
OES Distribution to CMNS	$124,273	$189,448	$202,770	$240,323	$288,051
Indirect Expenses	$97,928	$112,616	$115,349	$118,155	$121,035
Balance	**$26,345**	**$76,832**	**$87,421**	**$122,169**	**$167,016**

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) while statistical consulting and additional research support is available through the Research Commons (http://www.lib.umd.edu/rc) and technology support and services are available through the Terrapin Learning Commons (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.

Faculty Information- Bioinformatics and Computational Biology

The following faculty members are projected to teach in the program. All faculty are full-time unless otherwise indicated.

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

Rob Patro	Ph.D., Computer Science, UMD	Associate Professor	BIOI607 Data Structures and Algorithms for Bioinformatics BIOI611 Analysis of Gene Expression Data
Mihai Pop	Ph.D., Computer Science, Johns Hopkins University	Professor	BIOI621 Genome Assembly and Annotation

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 will 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.