Establish a Post-Baccalaureate Certificate in Computation and Mathematics for Biological Networks (COMBINE) (PCC 18054)

PRESENTED BY	**Janna Bianchini, Chair, Senate Programs, Curricula, and Courses Committee**
REVIEW DATES	**SEC – January 28, 2019 | SENATE – February 5, 2019**
VOTING METHOD	**In a single vote**
RELEVANT POLICY/DOCUMENT	**N/A**
NECESSARY APPROVALS	**Senate, President, University System of Maryland Chancellor, and Maryland Higher Education Commission**

ISSUE

The College of Computer, Mathematics, and Natural Sciences proposes to establish a 12-credit Post-Baccalaureate Certificate in Computation and Mathematics for Biological Networks (COMBINE). Network science has emerged as a new collaborative field including physicists, applied mathematicians, computer scientists, quantitative biologists, and social scientists. The goal of research in this area is to use networks, representing interaction patterns, to understand the behavior of complex systems. While network science has made significant strides in bringing together researchers from different fields based on common questions, huge cultural and communication barriers still exist that inhibit productive interdisciplinary collaboration.

The purpose of this certificate is to immerse graduate students in interdisciplinary education and research that integrates quantitative modeling methods from physics and mathematics with the data processing, analysis, and visualization tools from computer science, in order to gain deeper insights into the structural and dynamical principles governing living systems. Participants will utilize a network-based, data-driven approach, focusing on how interaction patterns can give insights into complex biological phenomena. COMBINE aims to prepare students to become experts in the process of transforming raw biological data into useful information from which new biological insights can be inferred, positioning them to pursue a range of Science, Technology, Engineering, and Mathematics (STEM) careers at the nexus of the computer, physical, and life sciences. The program will be open to students who already been admitted to a UMD doctoral program in one of three areas: life sciences, physical and mathematical sciences, and computational sciences.

The curriculum will consist of 12 credits in the following areas:

- Advanced Interdisciplinary coursework (8 credits):
  - PHYS798N Interdisciplinary Communication for Data-Driven Science (3 credits)
  - PHYS798T Network Science Literature Survey (1 credit)
  - PHYS798U Network Biology Research-in-Progress (1 credit)
  - CMSC828O Advanced Topics in Information Processing: Computational and Mathematical Analysis of Biological Networks across Scales (3 Credits)
- Discipline-Bridging Elective Coursework (4 credits)

- Students choose 2 courses from a list of coursework designed to help bridge the physical/mathematical, computational, and life sciences. The coursework must be chosen outside the student's discipline group and approved by the program director.

This program was developed as a part of a National Science Foundation (NSF)-funded Research Traineeship. Current UMD students are already participating in these courses. The official Post-Baccalaureate Certificate award will allow students to receive recognition on their transcripts that they completed the coursework. The program is designed to continue beyond the period of NSF funding.

This proposal was approved by the Graduate School Programs, Curricula, and Courses committee on November 30, 2018, and was approved by the Senate Programs, Curricula, and Courses committee on December 7, 2018.

RECOMMENDATION(S)

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

COMMITTEE WORK

The committee considered this proposal at its meeting on December 7, 2018. Dr. Daniel Serrano, of the Institute for Research in Electronics and Applied Physics, presented the proposal and answered questions from the committee. The proposal was unanimously approved by the committee.

ALTERNATIVES

The Senate could decline to approve this new certificate program.

RISKS

If the Senate declines to approve this certificate program, the university will lose an opportunity to recognize, with a specific award program, UMD doctoral students who engage in interdisciplinary coursework and research dedicated to network biology.

FINANCIAL IMPLICATIONS

There are no significant financial implications with this proposal as the courses and administrative processes already exist through the College of Computer, Mathematics, and Natural Sciences.

University of Maryland PCC
Program/Curriculum/Unit Proposal

PCC Log No:	18054

Program: COMBINE- Computation and Mathematics for Biological Networks

Department/Unit: Institute for Physical Sciences and Technology (IPST)

College/School: The College of Computer, Mathematical, and Natural Science (CMNS)

Proposal Contact Person (with email): Michelle Girvan (girvan@umd.edu)

Type of Action (check one):

- ☐ Curriculum change (includes modifying minors, concentrations/specializations and creating informal specializations)
  - ☐ Curriculum change is for an LEP Program
- ☐ *Rename a program or formal Area of Concentration*
- ☐ *Establish/Discontinue a formal Area of Concentration*
- ☐ Other:
- ☒ *Establish a new academic degree/certificate program*
- ☐ Create an online version of an existing program
- ☐ Establish a new minor
- ☐ *Suspend/Discontinue a degree/certificate program*
- ☐ Establish a new Master or Certificate of Professional Studies program
  - ☐ New Professional Studies program will be administered by Office of Extended Studies

Italics indicate that the proposal must be presented to the full University Senate for consideration.

Approval Signatures - *Please print name, sign, and date. For proposals requiring multiple unit approvals, please use additional cover sheet(s).*

1. Department Committee Chair _____
2. Department Chair Christopher Jarzynski, 09/14/18 _____
3. College/School PCC Chair _____
4. Dean _____
5. Dean of the Graduate School (if required) _____
6. Chair, Senate PCC Janna Branchini 12-7-18
7. University Senate Chair (if required) _____
8. Senior Vice President and Provost _____

Instructions:
When approved by the dean of the college or school, please send the proposal and signed form to the Office of the Associate Provost for Academic Planning and Programs, 1119 Main Administration Building, Campus-5031, **and** email the proposal document as an MSWord attachment to pcc-submissions@umd.edu.

Summary of Proposed Action (use additional sheet if necessary):

Unit Code(s) (to be entered by the Office of Academic Planning and Programs):

Program: COMBINE- Computation and Mathematics for Biological Networks

Date of Proposal: November 2018

Start Term for New Program: January 2019

Mission and Purpose

1. Describe the program and explain how it fits the institutional mission statement and planning priorities. The University Mission Statement and Strategic Plan can be found on this site: https://www.umd.edu/history-and-mission.

In the continued effort to foster excellence in interdisciplinary research and education at the University of Maryland, and as part of the mission to provide the highest quality graduate and professional education, we propose to create a new Graduate Certificate in Network Biology to be administered by the Institute for Physical Science and Technology (IPST) at UMD. This Graduate Certificate program is designed to accompany the current NSF-funded Research Traineeship (NRT) program, which was award in 2016 and will continue through 2021. The graduate certificate program we propose is designed to continue beyond the period of NSF funding. This unique program is tailored to address important challenges at the forefront of data-enabled science and engineering by training currently enrolled doctoral students to pursue transformative research at the convergence of the physical/mathematical, computer, and life sciences.

In the last decade or so, network science has emerged as a new collaborative field including physicists, applied mathematicians, computer scientists, quantitative biologists, and social scientists. The goal of research in this area is to use networks, representing interaction patterns, to understand the behavior of complex systems. While network science has made significant strides in bringing together researchers from different fields based on common questions, huge cultural and communication barriers still exist that inhibit productive interdisciplinary collaboration. This urgent issue facing today's researchers, coping with the data explosion resulting from the advent of powerful new technologies, demands a transformation. Our proposed Network Biology program, COMBINE, aims to accomplish this mission by using a network science approach, which is inherently cross-disciplinary, to analyze these complex biological data drawn from a variety of different contexts.

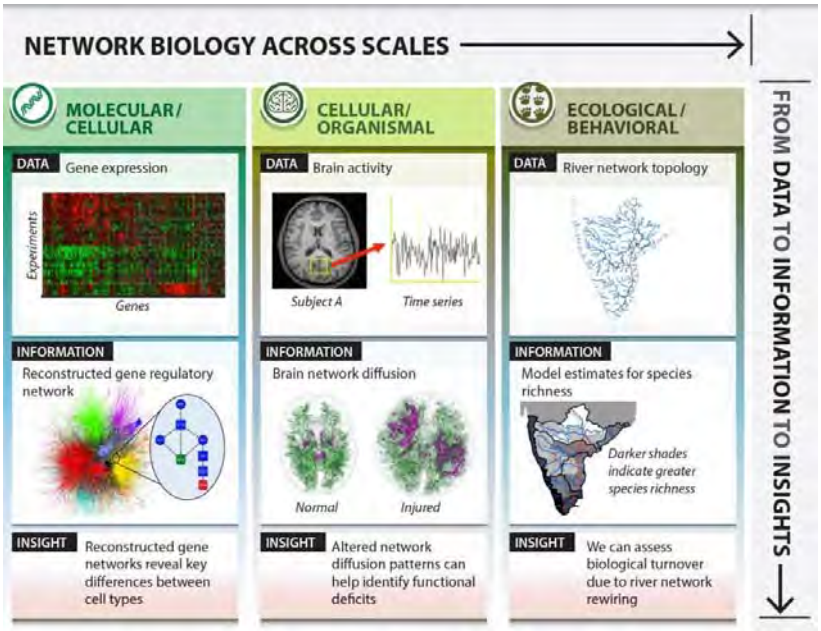
COMBINE immerses graduate students in interdisciplinary research and training that integrates: quantitative modeling methods from physics and mathematics with data processing, analysis, and visualization tools from computer science to gain deeper insights into the structural and dynamical principles governing living systems. Participants will utilize a network-based, data-driven approach, focusing on how interaction patterns can give insights into complex biological phenomena. COMBINE aims to prepare students to become experts in the process of transforming raw biological data into useful information from which new biological insights can be inferred, positioning them to pursue a range of Science, Technology, Engineering, and Mathematics (STEM) careers at the nexus of the computer, physical, and life sciences.

The Network Biology program strives to dissolve disciplinary barriers by offering innovations in graduate education. The program is designed to train students from different fields side-by-side so that, in helping to educate each other, they may discover the convergence of their differing perspectives and pave the way for ground-breaking new research.

Program Characteristics

2. 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.

COMBINE: Computation and Mathematics for Biological Networks, is a new University of Maryland graduate program in Network Biology. COMBINE immerses graduate students in interdisciplinary education, research and training that integrates quantitative modeling methods from physics and mathematics with data processing, analysis, and visualization tools from computer science to gain deeper insights into the structural and dynamical principles governing living systems. Participants will utilize a network-based, data-driven approach, focusing on how interaction patterns can give insights into complex biological phenomena. COMBINE prepares students to become experts in the process of transforming raw biological data into useful information from which new biological insights can be inferred, positioning them to pursue a range of Science, Technology, Engineering, and Mathematics (STEM) careers at the nexus of the computer, physical, and life sciences.



COMBINE applies the methods of network science (developed largely within the physics, applied mathematics, and computer science communities) to the study of biological systems from microscopic to macroscopic scales.

Participants will receive training in four areas of network analysis: quantitative metrics for biological networks; mechanistic models of biological networks; network statistics and machine learning for biological applications; and visualization techniques for large, complex biological data sets. This training will provide the foundation for research in one or more of the following areas: bio-molecular, neuronal and/or ecological/behavioral networks. This training is covered within CMSC828O (described in item 1.4 below).

3. What are the educational objectives of the program?

The program's overarching goal is to build a new model for graduate education that intentionally and thoughtfully prepares students for scientific research at the interface of the physical/ mathematical, computer, and life sciences, while simultaneously providing the necessary training so that they may readily translate research experiences to a diverse set of potential careers. The program's training elements focus on:

1. *Integrated, interdisciplinary problem solving*: through coursework from multiple disciplines and weekly interdisciplinary seminar, we will prepare students to tackle complex cross-disciplinary problems by carefully integrating approaches from different fields. Our goal is to move beyond the ad-hoc combination of skills that characterizes many interdisciplinary interactions and to cultivate specific skills that are readily transferable and highly applicable to multiple disciplines.
2. *Communication to diverse audiences:* a major focus of our program will be to train students to effectively communicate complex scientific ideas to diverse audiences, including both scientists from disparate fields and non-scientists from industry and the general population. Students will develop their communication skills in our Intensive Data Project course and Career Development Workshop.

4. Describe any selective admissions policy or special criteria for students selecting this program.

The COMBINE certificate will be open to students who have already been admitted to a doctoral program on campus. Students who express an interest in the certificate program would be reviewed to ensure they have the necessary background to successfully complete the required coursework.

Students for the Network Biology program will be drawn from one of three different disciplines:

1. Life Sciences: Behavior, Ecology, Evolution, and Systematics; Molecular and Cellular Biology; Computational Biology, Bioinformatics and Genomics; and Neuroscience and Cognitive Sciences
2. Physical and mathematical sciences: from Physics, Biophysics, and Applied Mathematics.
3. Computational sciences: Computer Science, Electrical and Computer Engineering

5. Indicate the course requirements with course numbers, titles and credits. If applicable, indicate if any course will also count for a general education requirement. In an appendix, provide the course catalog information (credits, description, prerequisites, etc.) for all of the courses. Note that suffixed "selected" or "special" topics courses should be avoided. If suffixed-selected or special topics courses are offered regularly in the new program, you should make the courses permanent. Also, please review the basic requirements of degree programs or certificate programs to ensure that they meet the minimum policy requirements.

Please note: new courses or modifications to courses need to be submitted through the Testudo Curriculum Management system and will need to follow the normal VPAC course proposal review process. You may submit individual course changes to VPAC concurrently with the PCC proposal;

however, the course changes may be held depending on the outcome of the PCC proposal.

Note about course numbers: PHYS798N, PHYS798T, PHYS798U, and CMSC828O are are all temporary course numbers. We are working with Physics, AMSC (Applied Mathematics and Scientific Computing), and Computer Science to get permanent course numbers. PHYS798N, PHYS798T, and PHYS798U will receive new course numbers cross-listed between Physics and AMSC. CMSC828O will receive a new permanent CS course number.

In addition to completing their PhD degree requirements in one of three disciplinary areas, COMBINE program participants are required to complete the following courses. This means at least 12 credits total with 8 credits from the new required COMBINE courses (CMSC828O-3 credits, PHYS798N- 3 credits, PHYS798T – 1 credit, PHYS798U -1 credit) and 4 credits from elective discipline-bridging coursework: (A) one regular (3 or 4 credit) course at the graduate or advanced undergraduate level from one of the other two disciplines (chosen from a list of appropriate courses) and (B) one out-of-field graduate seminar course (1 credit or more) from the third discipline.

COMBINE students are required to fulfill at least 12 credits, as following: (Appendix A)

1. **Advanced Interdisciplinary coursework:**

1.1 PHYS 798N: Interdisciplinary Communication for Data-Driven Science (3 credits)
Students will work on a semester-long individual research project under the direction of a faculty mentor, and they will concurrently use this project to develop and refine their science communication skills. Class sessions will address interdisciplinary science communication with some discussion of data exploration, analysis, and visualization. The motivating idea behind this course is to fill a major gap in graduate science education by helping students develop and hone the skills necessary for communicating data-driven, interdisciplinary research. The course has a significant focus on developing skills for communication to diverse audiences. Students will learn to communicate with individuals in the same field, with individuals in another specified field to which their research is applicable, and with a general science audience. As such, this course might be more aptly called “Interdisciplinary Communication for Data Driven Research”.

1.2 PHYS798T: Network Science Literature Survey (1 credit)
For this course, students will work in pairs to present and lead discussion of data-driven interdisciplinary research articles dealing with network science. Some sessions will feature invited faculty or postdocs that will give research talks and career perspectives/advice. Students will practice communication of scientific results and concepts to individuals in their own field and with individuals in other field to which the students’ research is applicable.

1.3 PHYS798U: Network Biology Research-in-Progress (1 credit)
For this course, students will each deliver an oral research-in-progress presentation. Students will practice communication of scientific results and concepts to a general scientific audience (as opposed to an audience of their own immediate field). Presentations will be followed by instructor and peer feedback. Peer reviewing will also be implemented online. Some sessions will feature invited faculty or postdocs that will give research talks and career perspectives/advice.

1.4 CMSC828O: Advanced Topics in Information Processing; Computational and Mathematical Analysis of Biological Networks across Scales (3 credits)

At the end of this course, students will be able to describe, implement and analyze algorithms that solve fundamental problems in biological network analysis: descriptive summaries of network structure and properties, probabilistic and dynamical network models, statistical models for networked data and network visualization. They will also be able to apply these methods to data in networks from biological applications: molecular, neuronal and ecological networks by completing a semester-long project.

2. Discipline-bridging elective coursework (2 courses – at least 4 credits):

This introductory coursework is designed to help bridge the physical/ mathematical, computational, and life sciences. The students' discipline-bridging coursework, must be chosen outside their discipline group, and approved by the program director during the annual progress/study plan meeting.

- *BIOL704:* Cell Biology from a Biophysical Perspective (3 credits) L
- *BSCI404:* Cell Biology from a Biophysical Perspective (3 credits) L
- *BSCI453*: Cellular Neurophysiology (3 credits) L
- *BIPH704:* Cell Biology from a Biophysical Perspective (3 credits) L
- *CBMG 688Y:* Special Topics in Cell Biology and Molecular Genetics; Bioinformatics and Genomics (2 Credits)L
- *CBMG 688P:* Special Topics in Cell Biology and Molecular Genetics; Programming for Biology (2 Credits) C , L
- *BIOM601:* Biostatistics I (4 credits) M/P
- *NACS643*: Computational Neuroscience (4 credits) C , L
- *NACS641*: Introduction to Neurosciences (4 credits) C , L
- *PHYS615*: Nonlinear Dynamics of Extended Systems (3 credits) M/P
- *MATH420*: Mathematical Modeling (3 credits) M/P
- *AMSC660:* Scientific Computing (3 credits) M/P
- *BSCI474:* Mathematical Biology C
- *CMCS882T:* Advanced Topics in Information Processing; Vision, Planning and Control in Aerial Robotics (3 credits)
- BSCI 441: Plant Physiology (4 credits) L
- *PLSC 411*: Plant Sciences((4 credits) L

(Requirements: L life sciences, C computational, M/P Math/ Physics)

6. 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.).

An urgent issue facing today's researchers is coping with the data explosion resulting from the advent of powerful new technologies. More data is not the same as better information without the interdisciplinary techniques required for such a transformation.

The components of our curriculum exist to prepare graduate students to address these needs and tackle these issues. We expect that successful program participants will graduate as professionals ready to take on current challenges at the forefront of data-enabled science and engineering and pursue transformative research at the convergence of the physical/mathematical, computer, and life sciences.

The development of our curriculum was also shaped thanks to the input of the following parties:

1. The COMBINE faculty, which includes biologists, computer scientists, engineers, physicists, and mathematicians. (See Appendix B)
2. The Internal UMD Review Committee for the NSF Research Traineeship program call for proposals.
3. UMD Linguistics Prof. Colin Phillips, who has extensive experience in graduate interdisciplinary curriculum as Principal Investigator of an IGERT (Integrative Graduate Education and Research Traineeship) and an NRT program in language science.
4. The COMBINE NRT Evaluation and Assessment team and Advisory Board.

7. 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*.

	Term in program			
	Fall I	Spring I	Fall II	Spring II
Interdisciplinary Coursework I (CMSC8280)	X			
Interdisciplinary Coursework II (PHYS798N)			X	
Discipline-bridging course		X		
Discipline-bridging seminar			X	
COMBINE seminar I (PHYS798T)	X			
COMBINE seminar II (PHYS798N)				X

8. Indicate whether the program will be offered in a non-standard delivery format, such as online delivery, off-campus, or through non-standard terms. Please note that MHEC requires a separate proposal for online or off-campus delivery. If the program will be offered in non-standard terms, describe the term structure and whether the Office of the Registrar and the Office of International Scholar and Student Services have been notified and support the proposal.

N/A

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

N/A

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

Outcomes:

- Survey important research results in network science. This will be achieved primarily through PHYS798T and assessed through class presentations and participation.
- Learn methods of network analysis. This will be achieved primarily through CMSC828O and will be assessed through student performance on problem sets.
- Develop an appreciation and understanding of the questions and methods of other fields. This will be achieved primarily through discipline-bridging coursework and assessed through performance therein.
- Apply methods of network analysis to biological data. This will be assessed through the evaluation of the final projects in CMSC828O and the final paper in PHYS798N.
- Develop interdisciplinary communication skills for:
    - Oral presentations. Included as parts of CMSC828O, PHYS798N, PHYS798U. Assessed through instructor created rubrics.
    - Poster presentations. Included as part of PHYS798N. Assessed through instructor created rubrics.
    - Developing manuscripts. Included as part of PHYS798N. Assessed through instructor created rubrics.

See Appendix C

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

We aim to support the University of Maryland's continuous efforts and strong record of educating minorities at all levels, therefore the recruitment process will focus on diversity in addition to engaging and retaining a group of outstanding students. Expanding the pool of talented students interested in pursuing research in the areas related to our program will be achieved by leveraging the University's participation-broadening initiatives. By working closely and replicating successful models at UMD such as the Applied Mathematics program, which is dedicated to recruiting and retaining both women and minority students, the program will be well-positioned to recruit students from underrepresented groups. An example of an effective practice for recruitment will be having faculty individually reach out to prospective applicants from underrepresented groups.

We will also engage with the two established, NSF-funded UMD programs for broadening participation: the Louis Stokes Alliances for Minority Participation (LSAMP), Bridge to the Doctorate (BD) Fellowship, and the ADVANCE program for increasing participation and advancement of women in academia. By connecting with the BD Fellowship program, which partially supports minority students during their PhD tenure, our Network Biology program will be well-positioned to recruit and support talented minority students. Interactions with UMD's ADVANCE program, e.g. a featured presentation by the ADVANCE program, a tour Career Development Workshop, will help our community better understand and overcome the challenges that

women face in the university setting. In addition, we will recruit through events like the Conference for Undergraduate Women in Physics, sponsored by the American Physical Society, and the Annual Biomedical Research Conference for Minority Students, the largest meeting in the U.S. for African-American and Hispanic students interested in graduate school in STEM disciplines.

12. 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 add supporting correspondence as an appendix.

Attached IPST letter of intention to continue support the program, past- NSF period, as well as AMSC and CS commitment to support the courses.

13. Accreditation and Licensure. Will 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.

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

No cooperative agreements are crucial for the success of the program, but the program will benefit from UMD/NCI partnership, the UM Medical School/UMD collaboration (CHIB), the Brain Initiative efforts at UMD, CBCB, AMSC, Biophysics

Faculty and Organization

15. Faculty and organization. Who will provide academic direction and oversight for the program? As an appendix, please indicate the faculty involved in the program. Include their titles, credentials, and courses they may teach for the program.

Professor Michelle Girvan serves as the program Director, overseeing the students, faculty, and staff activities as chair of the Executive Committee. She will be assisted by the Deputy Director, which will be a rotating position filled by another COMBINE faculty member.

The PI/ Director and Deputy Director will receive input from the independent advisory board, from Dr. Gili Marbach-Ad, the program internal evaluator to ensure the program runs efficiently and effectively.

Resource Needs and Sources

16. Each new program is required to have a library assessment in order to determine any new library resources that may be required. Please contact your departmental/programmatic library liaison or Daniel Mack at dmack@umd.edu, Associate Dean of Collections, to request a library assessment that will be added as an appendix.

N/A

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

Each student will be placed in the laboratory or office space provided by the respective research advisor (their PhD advisor).

18. 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.

One instructor with knowledge of the broad network science and network biology landscape and with expertise in network research for the spring Network Analysis course (currently CMSC828O). One instructor with expertise in interdisciplinary science communication at the intersection of the physical, computer, and life sciences for the spring Data Practicum course (currently PHYS798N) for Spring Data Practicum course. And an instructor for the spring and fall semesters.

See attached AMSC, PHYS, and CS letters of commitment to support the courses.

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

The main program costs, as its currently operating, past NSF-grant would be:

1. Administrative support / managing
2. Other expenses, such as recruitment events and Symposiums

Attached IPST letter of intention to continue support the program.

20. Use the Maryland Higher Education Commission (MHEC) commission financial tables to describe the program's financial plan for the next five years: https://docs.google.com/spreadsheets/d/1V6iSZG05edMitWP6CAOXjCoGO58Gf6VXxPaacKfrhZ4/edit#gid=0. Add these tables as attachments.

TABLE 1: RESOURCES	2018	2019	2020	2021	2022
Resources Categories	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
1.Reallocated Funds		$ -	$ -	$ -	$ 82,840
2. Tuition/Fee Revenue (c+g below)	$ -	$ -	$ -	$ -	$ -
a. #FT Students	14	14	14	14	14
b. Annual Tuition/Fee Rate	$ 20,189	$ 20,794	$ 21,418	$ 22,061	$ 22,723
c. Annual FT Revenue (a x b)	-	-	-	-	-
d. # PT Students	0	0	0	0	0
e. Credit Hour Rate	$ 449.80	$ 463.29	$ 477.19	$ 491.51	$ 506.25
f. Annual Credit Hours	12	12	12	12	12
g. Total Part Time Revenue (d x e x f)	$ -	$ -	$ -	$ -	$ -
3. Grants, Contracts, & Other External Sources	$ 139,050	$ 142,442	$ 145,935	$ 149,533	$ -
4. Other Sources	$ -	$ -	$ -	$ -	$ -
TOTAL (Add 1 - 4)	**$139,050**	**$142,442**	**$145,935**	**$149,533**	**$82,840**

TABLE 2: EXPENDITURES					
Expenditure Categories	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
1. Faculty (b+c below)	$53,200	$54,796	$56,440	$58,133	$59,877
a. #FTE	0.4	0.4	0.4	0.4	0.4
b. Total Salary	$40,000	$41,200	$42,436	$43,709	$45,020
c. Total Benefits	$13,200	$13,596	$14,004	$14,424	$14,857
2. Admin. Staff (b+c below)	$46,550	$47,947	$49,385	$50,866	$10,478
a. #FTE	0.5	0.5	0.5	0.5	0.1
b. Total Salary	$35,000	$36,050	$37,132	$38,245	$7,879
c. Total Benefits	$11,550	$11,897	$12,253	$12,621	$2,600
3. Total Support Staff (b+c below)	$13,300	$13,699	$14,110	$14,533	$7,485
a. #FTE	0.2	0.2	0.2	0.2	0.1
b. Total Salary	$10,000	$10,300	$10,609	$10,927	$5,628
c. Total Benefits	$3,300	$3,399	$3,501	$3,606	$1,857
4. Equipment	$0	$0	$0	$0	$0
5. Library	$5,000	$5,000	$5,000	$5,000	$5,000
6. New or Renovated Space	$0	$0	$0	$0	$0
7. Other Expenses: Operational Expenses	$21,000	$21,000	$21,000	$21,000	$0
TOTAL (Add 1 - 7)	**$139,050**	**$142,442**	**$145,935**	**$149,533**	**$82,840**

21. 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.

Our program is designed to support the careers of STEM scientists who will be able to tackle complex problems in academic, industry, and government settings. This is in line with the state's priorities to increase the number of STEM degrees awarded to students in order to satisfy growing demand in STEM-related fields. Specifically in the context of our program, the demand for jobs that require (big) data analysis is expected to increase. This includes several industries, including biotechnology/biomedicine, which our biology-focused program can enable. The use of connectivity and artificial intelligence by various industries is also expected to grow and our network-focused curriculum prepares students to tackle problems in these areas.

22. 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.

The following tables summarize our most relevant findings on market demand and job openings for careers that our program enables:

From USBLS (https://www.bls.gov/ooh/):

Area	Jobs in 2016	Employment change 2016 to 2026
Biochemists and Biophysicists	31,500	3,600
Computer and Information Scientists	27,900	5,400
Computer programmers	294,900	-22,600
Mathematicians and Statisticians	40,300	12,300
Physicists	19,900	2,800

From MD Occupational and Industry Projections for PhD-holders (http://www.dllr.state.md.us/lmi/iandoproj/):

Area	Openings in 2014	Openings in 2024
Biochemists and Biophysicists	1,620	2,049
Computer and Information Research Scientists	2,544	3,221
Computer and Mathematical Occupations	129,260	165,444
Life Scientists	15,221	17,726
Mathematical Science Occupations	7,309	9,628
Mathematicians	336	452
Physical Scientists	10,188	11,576
Physicists	1,199	1,322
Software Developers, Applications	13,549	18,272
Statisticians	3,133	4,010

The following table summarizes our most relevant findings regarding the existing supply of graduates in similar programs in the state:

From MHEC (PhD degrees granted http://mhec.maryland.gov/publications/Documents/Research/AnnualReports/Degrees2016ByProgram.pdf.pdf):

Institution	Degree	Graduates between 2003 and 2016
University of Maryland College Park	Biophysics	5
Johns Hopkins	Applied and Computational Math	57
Johns Hopkins	Biostatistics	66
Johns Hopkins	Biophysics	133
University of Maryland Baltimore	Human Genetics	12

23. 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.

To our knowledge there is no dedicated PhD program in Network Science or Network Biology in Maryland. Bowie State, Johns Hopkins, UMBC and UMCP offer Computer Science PhD degrees, while Johns Hopkins and UMCP offer Biophysics PhD degrees. However, none of these programs offers a formal curriculum-based focus on Network Biology.
The most similar program available is the Johns Hopkins Jenkins Biophysics Program, but this program (i) has a large focus on molecular sciences (while our program covers a broader range of research scales) and (ii) is ideal for students with strong math and computer science backgrounds, while our program is designed to cross-train students from diverse backgrounds (including those with strong math and computer science backgrounds but also those who come from biology and do not have extensive math/CS skills).

24. 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?

No significant impact expected beyond our intended outreach efforts to recruit students from minority-serving institutions, including HBIs.

25. For new Post-Baccalaureate Certificates derived from existing master's programs only, include the complete curriculum of the existing master's program.

Not applicable.

Appendix A: Course Descriptions

COMBINE- Core Courses:

PHYS 798N: **Interdisciplinary Communication for Data-Driven Science (3 credits)**

Students will work on a semester-long individual research project under the direction of a faculty mentor, and they will concurrently use this project to develop and refine their science communication skills. Class sessions will address interdisciplinary science communication with some discussion of data exploration, analysis, and visualization. The motivating idea behind this course is to fill a major gap in graduate science education by helping students develop and hone the skills necessary for communicating data-driven, interdisciplinary research. The course has a significant focus on developing skills for communication to diverse audiences. Students will learn to communicate with individuals in the same field, with individuals in another specified field to which their research is applicable, and with a general science audience. As such, this course might be more aptly called “Interdisciplinary Communication for Data Driven Research”.

PHYS798T: **Network Biology Literature Survey(1 credit)**

For this course, students will work in pairs to present and lead discussion of data-driven interdisciplinary research articles dealing with biological networks. Some sessions will feature invited faculty or postdocs that will give research talks and career perspectives/advice. Students will practice communication of scientific results and concepts to individuals in their own field and with individuals in other field to which the students’ research is applicable.

PHYS798U**:Network Biology Research-in-Progress (1 credit)**

For this course, students will each deliver an oral research-in-progress presentation. Students will practice communication of scientific results and concepts to a general scientific audience (as opposed to an audience of their own immediate field). Presentations will be followed by instructor and peer feedback. Peer reviewing will also be implemented online. Some sessions will feature invited faculty or postdocs that will give research talks and career perspectives/advice.

CMSC828O**: Advanced Topics in Information Processing; Computational and Mathematical Analysis of Biological Networks across Scales (3 credits)**

At the end of this course, students will be able to describe, implement and analyze algorithms that solve fundamental problems in biological network analysis: descriptive summaries of network structure and properties, probabilistic and dynamical network models, statistical models for networked data and network visualization. They will also be able to apply these methods to data in networks from biological applications: molecular, neuronal and ecological networks by completing a semester-long project.

Discipline- Bridging Courses:

(Requirements: [L] life sciences, [C] computational, [M/P] Math/ Physics)

BIOL704: **Cell Biology from a Biophysical Perspective (3 credits)** [L]

Also offered as: BSCI404.
Formerly: BIOL708O
An approach to cell biology by focusing on mechanisms and unifying paradigms. It will not assume a great deal of factual biological knowledge, but will expect a background that prepares students to think quantitatively and mechanistically.

BSCI404: **Cell Biology from a Biophysical Perspective (3 credits)** [L]

Formerly: BSCI338O
An approach to cell biology by focusing on mechanisms and unifying physical paradigms. It will not assume a great deal of factual biological knowledge, but will expect a background that prepares students to think mechanistically and quantitatively.

BSCI453**: Cellular Neurophysiology (3 credits)** [L]

The cellular and molecular basis of nervous system function.

BIPH704: **Cell Biology from a Biophysical Perspective (3 credits)** [L]

An approach to cell biology by focusing on mechanisms and unifying paradigms. It will not assume a great deal of factual biological knowledge, but will expect a background that prepares students to think quantitatively and mechanistically.

CBMG 688Y: **Special Topics in Cell Biology and Molecular Genetics; Bioinformatics and Genomics (2 Credits)** [L]

provides an overview of some major topics and research areas bioinformatics and genomics, and includes material from basic foundations through advanced concepts. The course consists of readings, lectures, discussions, collaborative learning activities, writing assignments, and exams.

CBMG 688P: **Special Topics in Cell Biology and Molecular Genetics; Programming for Biology (2 Credits)** [C, L]

Students should gain an ability to implement standard bioinformatics tools and manipulate large data files in a unix environment. Although true programming is beyond the scope of this course, students should achieve an ability to understand, use and edit programs in awk, Python and R.

BIOM601: **Biostatistics I (4 credits)** [M/P]

Prerequisite: BIOM301 or STAT464; or students who have taken courses with comparable content may contact the department.
Estimation and hypothesis testing, t tests, one and two way analysis of variance, regression, analysis of frequency data. Lecture will emphasize uses and limitations of these methods in biology, while the laboratory will emphasize the use of statistical analysis software for the analysis of biological data.

NACS643**: Computational Neuroscience (4 credits)** [C, L]

Prerequisite: NACS641; and must have completed a course in calculus; and permission of instructor.

Provides a mathematical foundation in computational neuroscience.

NACS641**: Introduction to Neurosciences (4 credits)** [C, L]

Detailed examination of neurophysiology and sensorimotor systems.

***PHYS615*: Nonlinear Dynamics of Extended Systems (3 credits)** [M/P]

Prerequisite: PHYS601.

Theory and applications of nonlinear dynamics of extended systems including nonlinear waves, pattern formation, turbulence, self-organized criticality and networks. Additional topics to be selected by instructor from areas of current research.

***MATH420*: Mathematical Modeling (3 credits)** [M/P]

Prerequisite: MATH240 or MATH461 or MATH341 and MATH241 or MATH340 and MATH246, or MATH341 and STAT400 And CMSC106 or CMSC131 or students who have taken courses with comparable content may contact the department.

Also offered as: AMSC420.

The course will develop skills in data-driven mathematical modeling through individual and group projects. Emphasis will be placed on both analytical and computational methods, and on effective oral and written presentation of results.

***AMSC660:* Scientific Computing (3 credits)** [M/P]

Prerequisite: Must have knowledge of C or Fortran. And AMSC460 or CMSC460; or (CMSC466 or AMSC466); or (must have knowledge of basic numerical analysis (linear equations, nonlinear integration, interpolation); and permission of instructor).

Monte Carlo simulation, numerical linear algebra, nonlinear systems and continuation method, optimization, ordinary differential equations. Fundamental techniques in scientific computation with an introduction to the theory and software of each topic.

***BSCI474:* Mathematical Biology** [C]

Prerequisite: MATH 130/MATH 131
Students develop quantitative reasoning skills through the understanding of mathematically based biological models. Models are chosen from a variety of biological disciplines, including biological population dynamics, infectious disease propagation, molecular evolution, and phylogenetic trees. Mathematical skills developed include: solving non-linear difference equations, eigenvector analysis, multi-dimensional stability analysis, and the use of Excel and Matlab to implement these algorithms as computer models.

***CMCS882T:* Advanced Topics in Information Processing; Vision, Planning and Control in Aerial Robotics (3 credits)** [C]

This is a comprehensive course on aerial robotics, with a focus on quadcopters and their related hardware and software implementations. The course will cover both the theoretical and practical aspects of quadcopters, with special focus on perception, planning and control algorithms involved in the same.

BSCI 441: Plant Physiology (4 credits) [L]

This course will provide an introduction to the basic physical and physiological principles necessary for understanding the interactions between plants and their environment. The overall objective is to understand plant responses and adaptations to the environment and the ecological relevance of these responses.

***PLSC 411*: Plant Sciences((4 credits)** L

Prerequisite: BSCI170; and BSCI171. Or PLSC201; or permission of AGNR-Plant Science & Landscape Architecture department.

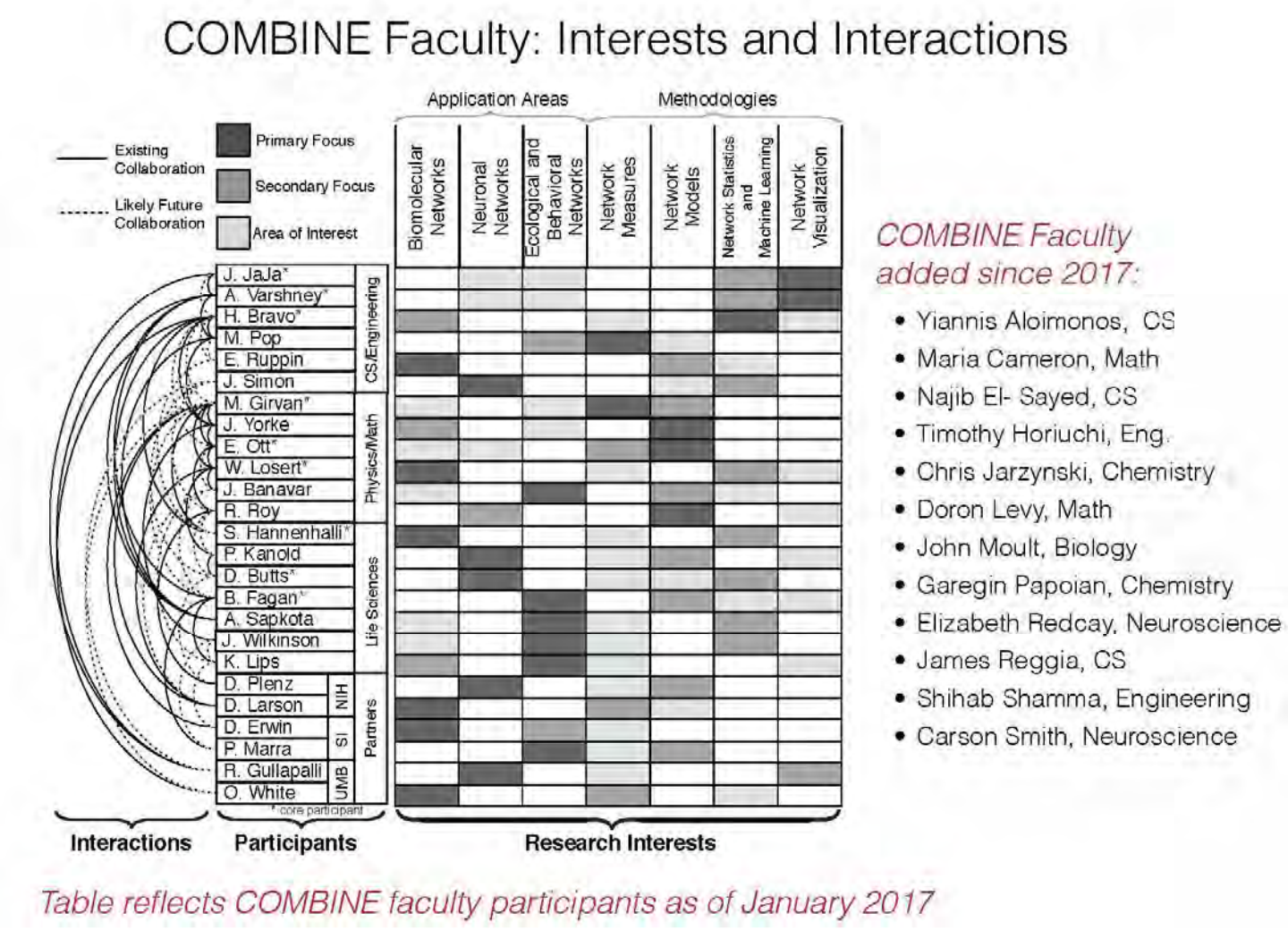
An introduction to genetic principles and technologies in plants, centered on linking phenotype to genotype. Topics include Mendelian inheritance of single and complex traits, epigenetics, population genetics and plant breeding. Examples on creating and mapping genetic mutations in both model plants and non-model crops are discussed. Current genetic and genomic approaches are highlighted, such as genome engineering and reprogramming, TILLING, and genome-wide association mapping.

***ENEE 620*: Random Processes in Communications and Control (3 credits)** M/P

Prerequisite: ENEE 324 or equivalent.

Introduction to random processes: characterization, classification, representation; Gaussian and other examples. Linear operations on random processes, stationary processes: covariance function and spectral density. Linear least square waveform estimating Wiener-Kolmogroff filtering, Kalman-Bucy recursive filtering: function space characterization, non-linear operations on random processes.

Appendix B: COMBINE Faculty



Appendix C - Plan for assessing student learning outcomes:

During the NSF-funded NRT program (i.e, through 2021), a multi-level strategy for producing and implementing constructive assessment on the program goals will be used, which encompasses the five levels of program evaluation: participation, satisfaction, education, application, and impact.

The evaluation strategy integrates both internal and external expertise, lead by:

1. Gili Marbach-Ad, Research Associate Professor in the College of Computer, Mathematical, and Natural Science (CMNS) at UMD and director of the CMNS Teaching and Learning Center.
2. Mark Connolly, Associate Research Scientist and Principal Investigator at the Wisconsin Center for Education Research, University of Wisconsin-Madison.

Together, the evaluation team, developed clear annual assessment goals, reflected on progress, successes, and challenges. Accordingly, assessment instruments that enable measurable and publishable outcomes will be developed, refined, validated, and implemented.

The Evaluation team's efforts are guided by an independent advisory committee comprising experts in interdisciplinary science research and professional development:

1. Luis Amaral
2. Steven Schiff
3. Neo Martinez
4. Jeffrey Chen
5. Robert Gentlemen

COMBINE has several overarching goals for individual trainees. First and foremost, we seek to prepare students for interdisciplinary research and diverse careers at the interface of the physical, mathematical, computer, and life sciences. Furthermore, we aim for our trainees to develop a suite of transferable skills, including the ability to communicate science to diverse audiences, to collaborate productively as leaders and team members, and to serve as mentors to their peers and more junior science students.

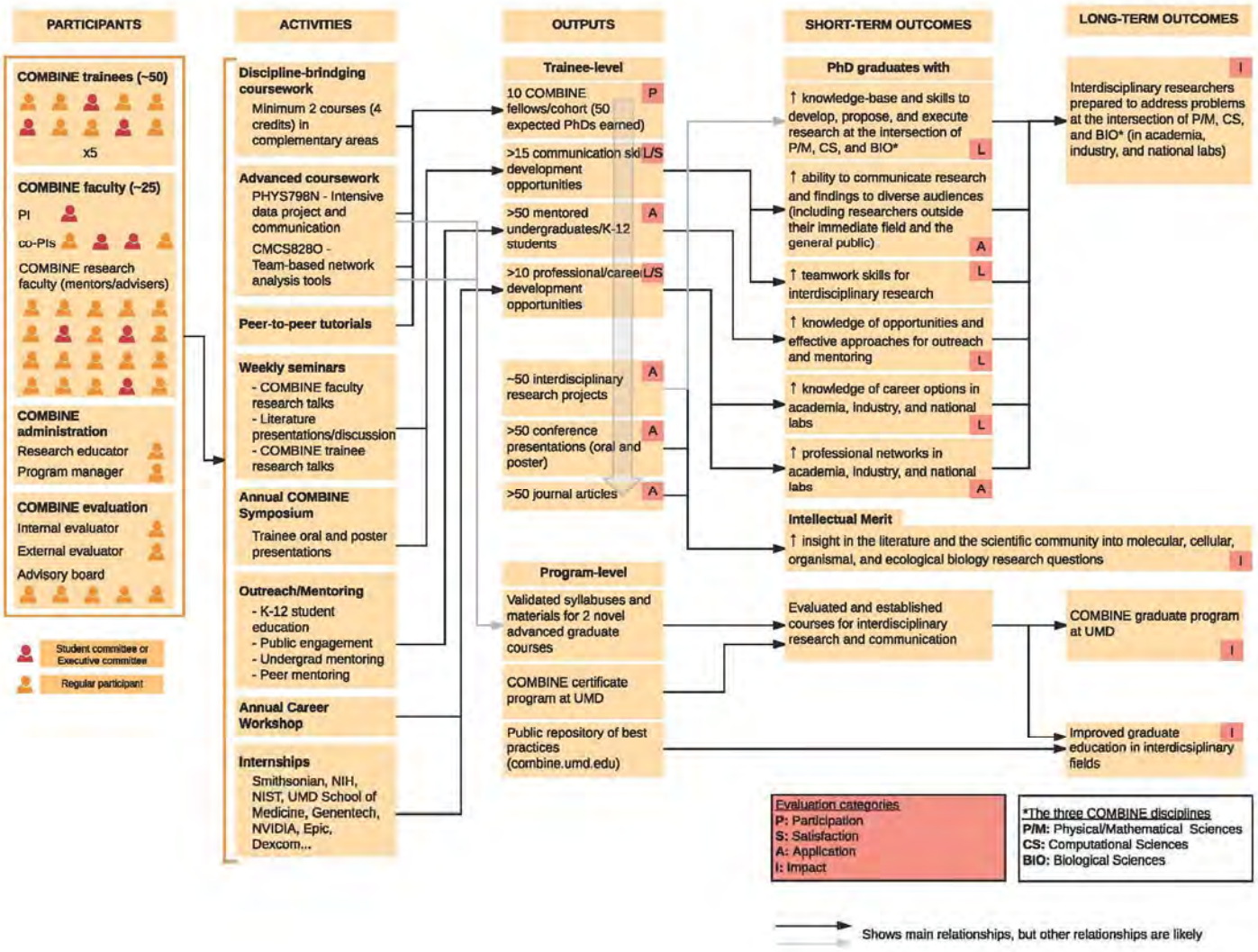
The main training goals of the project are to expose graduate students to interdisciplinary career opportunities in academia, industry, and national labs and prepare them to successfully pursue any of these pathways.

We probe the students' skills and knowledge gained by participating in the training program activities, by using surveys of all program participants and case studies of the subset of participants. Collecting data in the form of publications, conference abstracts, course specific writing assignments, and more, the level of application of those new gained skills will be determined.

After the period of NSF funding has been completed in 2021. Our plan is to incorporate the results of the extensive assessment activities conducted during the period of NSF funding (2016-2021) in order to make improvements to the program so that after the NSF funding, a simpler assessment can be effectively used to evaluate the student learning outcomes. The list below gives the student learning outcomes and the plan for achieving and assessing them. These assessment methods will continue after NSF funding is complete.

- Survey important research results in network science. This will be achieved primarily through PHYS798T and assessed through class presentations and participation.
- Learn methods of network analysis. This will be achieved primarily through CMSC828O and will be assessed through student performance on problem sets.
- Develop an appreciation and understanding of the questions and methods of other fields. This will be achieved primarily through discipline-bridging coursework and assessed through performance therein.
- Apply methods of network analysis to biological data. This will be assessed through the evaluation of the final projects in CMSC828O and the final paper in PHYS798N.
- Develop interdisciplinary communication skills for:
    - Oral presentations. Included as parts of CMSC828O, PHYS798N, PHYS798U. Assessed through instructor created rubrics.
    - Poster presentations. Included as part of PHYS798N. Assessed through instructor created rubrics.
    - Developing manuscripts. Included as part of PHYS798N. Assessed through instructor created rubrics.
- Surveys of students and faculty will also continue

Program outcome assessment plan during the NSF-funded period (i.e. until 2021) of the Certificate Program



UNIVERSITY OF MARYLAND
DEPARTMENT OF PHYSICS

Peter S. Shawhan
Physical Sciences Complex, Room 2120
College Park, Maryland 20742-2440
Tel: (301) 405-1580 Fax: (301) 314-9525
pshawhan@umd.edu

October 12, 2018

To the review committee:

I am writing this letter in my capacity as Associate Chair for Graduate Education for the University of Maryland Department of Physics to affirm that I will be working with the COMBINE (Computation and Mathematics for Biological Networks) program team to obtain permanent course numbers for the following courses that have been offered with temporary course numbers in 2018:

- PHYS798N: Interdisciplinary Communication for Data-Driven Science
- PHYS798T: Network Science Literature Survey
- PHYS798U: Network Science Research-in-Progress

We will obtain permanent PHYS course numbers and intend to have them cross-listed with the Applied Math and Scientific Computing (AMSC) Program here at the university. See also the letter of support from the Chair of the Physics Department, Steve Rolston.

Regards,

Peter Shawhan

Dr. Peter S. Shawhan
Professor & Assoc. Chair for Graduate Education
Department of Physics
The University of Maryland

UNIVERSITY OF MARYLAND

William E. Kirwan Hall, 3103
College Park, Maryland 20742
301.405.0924 TEL

APPLIED MATHEMATICS & STATISTICS, AND SCIENTIFIC COMPUTING PROGRAM

October 25, 2018

To: PCC Review Committee, University of Maryland
Re: UMD Network Biology Program

To whom it my concern:

Following the commitment of the Institute for Physical Science and Technology (IPST) to administer UMD's NSF-funded Network Biology program for graduate students, COMBINE (Computation and Mathematics for Biological Networks), the Applied Mathematics & Statistics, and Scientific Computation (AMSC) program commits to continue the following course and seminars and apply for regular course numbers to be cross-listed between AMSC and Physics:

- Interdisciplinary Communication for Data-Driven Research, 3 credits (currently offered as "Data practicum at the intersection of the physical, computer, and life sciences," PHYS798N)
- Network Science Literature Survey, 1 credit (currently offered as PHYS798T)
- Network Science Research in Progress Seminar, 1 credit (currently offered as PHYS798U)

The certificate program's goal is to offer these courses once per year, cross-listed between Physics and AMSC, as long as there is sufficient enrollment (~10 students per course per semester). If the enrollment falls well below this level (which is not expected), the courses may be offered less frequently, but often enough to meet the needs of students enrolled in the certificate program. The AMSC program will work with the Physics Department to provide the teaching resources for these courses. Joint Physics/IPST faculty who are part of AMSC are suitable and likely candidates to serve as instructors of these courses.

The AMSC program has a long tradition of encouraging and supporting interdisciplinary programs of this type and we are pleased to offer this support.

Sincerely,

Howard Elman

Howard Elman
Professor and Director of AMSC

Prof. Ramani Duraiswami
Department of Computer Science
Institute for Advanced Computer Studies
3361 A.V. Williams Building; #115
College Park, MD 20742, USA

October 15, 2018

To Whom it May Concern:

The letter is to confirm the support of the Department of Computer Science for UMD's Network Biology program for graduate students, COMBINE (Computation and Mathematics for Biological Networks), for the remaining period of NSF funding (approximately 4 years, including the no-cost extension period), and also beyond that timeframe. The Computer Science Department is committed to continuing to allocate teaching resources for the following new course:

Advanced Topics in Information Processing; Computational and Mathematical Analysis of Biological Networks across Scales (CMSC828O)

This course promotes training in interdisciplinary research, and the CS department will continue to offer it once per year with sufficient enrollment. If the enrollment falls below 15 students, the course may be offered less frequently. The department will also apply for a permanent course number for this new interdisciplinary course, through its normal education committee review process.

Sincerely,

Ramani Duraiswami, Ph.D.
Professor and Associate Chair for Graduate Education
Department of Computer Science
Director, Perceptual Interfaces and Reality Lab.
University of Maryland at College Park, MD 20742
Phone: (301) 405 6710
ramani@umiacs.umd.edu
www.umiacs.umd.edu/~ramani

UNIVERSITY OF MARYLAND
INSTITUTE FOR PHYSICAL SCIENCE AND TECHNOLOGY
Office of the Director

College Park, Maryland 20742-2431
Tel: (301) 405-4878 Fax: (301) 314-9363
http://www.ipst.umd.edu

September 28, 2018

Professor Michelle Girvan
Department of Physics
3341 A.V. Williams Building
Campus

Dear Professor Girvan:

This letter is to express support for the COMBINE (Computation and Mathematics for Biological Networks) graduate certificate program in Network Biology. Currently, COMBINE is an NSF-funded NRT (NSF Research Traineeship Program) that has recently completed its second of five years of funding, with an expected one year no-cost extension. The COMBINE program is applying for a graduate certificate program in Network Biology that will begin during the period of NSF funding and continue after NSF funding is complete.

The Institute for Physical Science and Technology (IPST) is committed to administering and supporting this graduate certificate program, both for the remainder of the NSF funding period and after NSF funding is complete. IPST will work with CMNS and the Provost's office to ensure the success of this new graduate certificate program.

Three of the four new COMBINE courses (currently listed as PHYS798N, PHYS798T, and PHYS798U), will be cross-listed with the Physics Department and Applied Mathematics & Statistics, and Scientific Computation (AMSC) program, which is run jointly by IPST, the Department of Mathematics and the Center for Scientific Computation and Mathematical Modeling. IPST will work with the AMSC program as necessary to help procure permanent course numbers for these courses.

Sincerely,

Christopher Jarzynski, Distinguished University Professor
Director, Institute for Physical Science and Technology
Professor, Department of Chemistry and Biochemistry
Professor, Department of Physics

UNIVERSITY OF MARYLAND
DEPARTMENT OF PHYSICS
Office of the Chair

0208 Physical Sciences Complex
College Park, Maryland 20742-411
Tel: (301) 405-5946 Fax: (301) 405-0327
http://www.umdphysics.umd.edu

March 12, 2018

To whom it may concern:

The Department of Physics at the University of Maryland intends to continue its support of the COMBINE (Computation and Mathematics for Biological Networks) Program for the 5-year duration of NSF funding (expected end date of August 2022), and also beyond that timeframe. The department will continue to provide teaching resources for the following COMBINE advanced interdisciplinary course and seminar:

- Interdisciplinary Research Communication (Currently offered as "Data practicum at the intersection of the physical, computer, and life sciences", PHYS798N - 3 credits)
- Interdisciplinary Network Science Seminar (PHYS798T- 1 credit)

These two courses will be offered once per year by the Physics Department (and cross-listed with the Applied Mathematics & Statistics, and Scientific Computation (AMSC) program, as long as there is sufficient enrollment (~10 students per course per semester). If the enrollment falls well below this level (which is not expected), the courses may be offered less frequently. The Physics Department will work together with the AMSC program and its parent institute, the Institute for Physical Science and Technology (IPST), to provide the teaching resources for these courses. Joint Physics/IPST faculty are likely candidates to serve as instructors of these courses.

Sincerely,

Steven L. Rolston
Professor and Chair
Department of Physics