UNIVERSITY FACULTY SENATE FORMS

Academic Program Approval

This form is a routing document for the approval of new and revised academic programs. Proposing department should complete this form. For more information, call the Faculty Senate Office at 831-2921.

Submitted by: Gilberto Schleiniger phone number: 831-1872

Action: Add major

(Example: add major/minor/concentration, delete major/minor/concentration, revise major/minor/concentration, academic unit name change, request for permanent status, policy change, etc.)

Effective term: 07F
(use format 04F, 05W)

Current degree
(Example: BA, BACH, BACJ, HBA, EDD, MA, MBA, etc.)

Proposed change leads to the degree of: BS
(Example: BA, BACH, BACJ, HBA, EDD, MA, MBA, etc.)

Proposed name: Quantitative Biology

Proposed new name for revised or new major / minor / concentration / academic unit (if applicable)

Revising or Deleting:

Undergraduate major / Concentration:
(Example: Applied Music – Instrumental degree BMAS)

Undergraduate minor:
(Example: African Studies, Business Administration, English, Leadership, etc.)

Graduate Program Policy statement change:
(Attach your Graduate Program Policy Statement)

Graduate Program of Study:
(Example: Animal Science: MS Animal Science: PHD Economics: MA Economics: PHD)

Graduate minor / concentration:

List program changes for curriculum revisions:

List new courses required for the new or revised curriculum:
(Be aware that approval of the curriculum is dependent upon these courses successfully passing through the Course Challenge list. If there are no new courses enter "None")

- MATH 514 – Introduction to Systems Biology – 3 credits
- MATH 260 – Integrative Seminar – 2 one-credit seminars

Other affected units:
(List other departments affected by this new or revised curriculum. Attach permission from the affected units. If no other unit is affected, enter "None")

- Department of Biological Sciences
- Department of Chemistry and Biochemistry

Rationale:
(Explain your reasons for creating, revising, or deleting the curriculum or program.)

This major was designed for mathematically talented students who wish to apply their skills to solving problems in biomedical and life sciences. The demand for such students is well documented, for example in the National Research Council of the National Academies (NRC) Report "Bio 2010 – Transforming Undergraduate Education for Future Research Biologists." The Departments of Biological Sciences and of Mathematical Sciences recognized the national need for such a program, and collaborated in the design of a new major, following NRC recommendations outlined in the Bio 2010 Report.

"Like research in the life sciences, undergraduate education must be transformed to prepare students effectively for the biology that lies ahead. Life sciences majors must acquire a much stronger foundation in the physical sciences (chemistry and physics) and mathematics than they now get. Connections between biology and the other disciplines need to be developed and reinforced so that interdisciplinary thinking and work become second nature."
(Bio 2010, pp. 1-2)

"Increasingly, biomedical researchers must be comfortable applying diverse aspects of mathematics and the physical sciences to their pursuit of biological knowledge.

Undergraduate biology students who become comfortable with the ideas and techniques of mathematics and physical sciences from the start of their education will be better positioned to contribute to future discoveries in biomedical research." (Bio 2010, p. ix)

Students coming to the University of Delaware will have the option of pursuing a bachelor of science degree in an area of great need and tremendous potential impact. Students graduating with a BS in Quantitative Biology from the University of Delaware will be well prepared to join newer graduate programs, such as the Harvard Medical School Graduate Program in Systems Biology, as well as research groups in biomedical and life sciences in other institutes and in industry.

Program Requirements:
(Show the new or revised curriculum as it should appear in the Course Catalog. If this is a revision, be sure to indicate the changes being made to the present curriculum.)

- **University Requirements**

  ENGL 110 Critical Reading and Writing 3
  (minimum grade C-)

  First Year Experience 0-4

  Discovery Learning Experience 3

  Three credits in an approved course or courses stressing multi-cultural, ethnic, and/or gender-related course content 3

- **College Requirements**

  Writing (minimum grade C-) 3
  Second writing course taken after completion of 60 credit hours.

- **Breadth Requirements**

  Eighteen credits from Groups A, B and C with a minimum of six credits from each group. One of the courses should be in the area of Bioethics
  Croup A 6

  Group B 6

  Group C 6

- **Major Requirements**

  A grade of C- or better is required for major courses and related work.

  Biology Section
  BISC 207 Introduction to Biology I 4
  BISC 208 Introduction to Biology II 4
  Three of the following three-credit courses 9
  BISC 302 General Ecology
  BISC 305 Cell Physiology
  BISC 306 General Physiology
  BISC 401 Molecular Biology of the Cell
  BISC 403 Genetic and Evolutionary Biology
  One of the following two-credit laboratory classes 2
  BISC 312 General Ecology Laboratory
  BISC 315 Experimental Cell Biology
  BISC 316 Experimental Physiology
  BISC 411 Experimental Molecular Biology
  BISC 413 Advanced Genetics Laboratory

  Computer and Information Sciences Section
  Either CISC 105 or CISC 106 (for those with no previous equivalent experience), or CISC 181..... 3

  Chemistry Section
  One of the following options (A, B or C, 8 – 12 credits total)

  Option A
  CHEM 103 General Chemistry 4
  CHEM 104 General Chemistry 4

Option B

CHEM 111	General Chemistry	3
CHEM 112	General Chemistry	3
CHEM 119	Quantitative Chemistry I	3
CHEM 120	Quantitative Chemistry II	3

Option C

CHEM 111	General Chemistry	3
CHEM 112	General Chemistry	3
CHEM 220	Quantitative Analysis	3
CHEM 221	Quantitative Laboratory	1

CHEM 321	Organic Chemistry	4
CHEM 322	Organic Chemistry	4
CHEM 527	Introductory Biochemistry	3

Mathematics Section

MATH 210	Discrete Mathematics I	3
MATH 241	Analytic Geometry and Calculus A	4
MATH 242	Analytic Geometry and Calculus B	4
MATH 243	Analytic Geometry and Calculus C	4
MATH 302	Ordinary Differential Equations	3
MATH 349	Elementary Linear Algebra	3
MATH 350	Probability Theory and Simulation Methods	3
MATH 426	Introduction to Numerical Analysis and Algorithmic Computation	3
MATH 450	Mathematical Statistics	3
MATH 535	Introduction to Partial Differential Equations	3
MATH 567	Introduction to Systems Biology	3

Physics Section

PHYS 207	Fundamentals of Physics I	4
PHYS 208	Fundamentals of Physics II	4

Other Requirements

Two one-credit integrative seminars	2
Three integrative or technical electives, 6 credits of which should be integrative electives from a list maintained by the Department of Mathematical Sciences	9

Credits to total a minimum of 124

ROUTING AND AUTHORIZATION: (Please do not remove supporting documentation.)

Department Chairperson PETER MONK Peter Monk Date 10/19/06

Dean of College _____ Date _____

Chairperson, College Curriculum Committee _____ Date _____

Chairperson, Senate Com. on UG or GR Studies _____ Date _____

Chairperson, Senate Coordinating Com. _____ Date _____

Secretary, Faculty Senate _____ Date _____

Date of Senate Resolution _____ Date to be Effective _____

Registrar _____ Program Code _____ Date _____

Vice Provost for Academic Programs & Planning _____ Date _____

Provost _____ Date _____

Board of Trustee Notification _____ Date _____

Revised 11/03/04 -Kbs

From: Dave Saunders <saunders@cis.udel.edu>
Subject: **Re: Support letter**
Date: October 26, 2006 2:38:26 PM EDT
To: Gilberto Schleiniger <schleini@math.udel.edu>
Cc: "Keith S. Decker" <decker@cis.udel.edu>, Daniel Chester <chester@cis.udel.edu>, Li Liao <lliao@mail.eecis.udel.edu>

Hi, Gilberto,

CIS has no problem with the anticipated enrollment for CISC 105 or CISC 181 that this major involves. I mention that CISC 106 is now configured as a course introducing Matlab and C programming. It may be desirable to list it as an alternative as well. Right now the engineering majors are taking the 106 and it is possible that 105 will be phased out altogether.

Another remark is that a bioinformatics course has been offered by Li Liao for the last few years. It is being put in with a permanent number this fall. I believe the number is CISC 434. This may be something to consider as an option related to the Quantitative Biology major.

Best, -dave

Gilberto Schleiniger wrote:

> Dear Dave:
> We are proposing a new major, BS in Quantitative Biology, to be offered with the Department of Biological Sciences. Since we are requiring one CISC class for that new major, it would be wise to have a letter of support from your department. We don't expect more than a few students in the major for the first few years, so the impact should really be minimal. In fact, even after the major has achieved "maturity" the number of students is not projected to be very large. But, the various College and University bodies evaluating the proposal will probably question whether Computer and Information Sciences was consulted. I attach a copy of the curriculum for the new major, along with a sample. I can clarify any issues, questions or concerns you may have.
> Thank you very much for your attention to this request.
> Sincerely,
> Gilberto
> ---
> G. Schleiniger
> Director of Undergraduate Studies
> Math Sciences
> University of Delaware
> ---

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David Saunders, Professor and Chair
Dept. of Computer and Information Sciences, Univ. of Delaware
email: saunders@cis.udel.edu Phone: 302-831-6238

Proposal for a BS in Quantitative Biology

G. Schleiniger

October 18, 2006

1 Description

The proposed major is a Bachelor of Science in Quantitative Biology to be offered jointly by the Departments of Mathematical Sciences and Biological Sciences. The program of studies is designed to develop and reinforce the connections between biology, chemistry and mathematics so as to better prepare students to a career that requires interdisciplinary and multidisciplinary work. Graduates will be expected to have acquired a solid foundation in biology, chemistry and mathematics, with an emphasis on preparation for a research career in biomedical and life sciences. The success of this new major will be measured by how well its students perform after graduation, as well as by the career paths they pursue.

The mathematics courses required for this major lie at the core of many applied mathematics areas that have very strong ties to biological and biomedical research, The ties between principles of physics, chemistry, biology and mathematics will be continually developed and reinforced through a sequence of integrative seminars to be taken during the sophomore and junior years, as well as integrative electives to be taken in the junior and senior years. A capstone course, *Introduction to Systems Biology*, will integrate and synthesize the knowledge acquired during the first three years; it will achieve this objective through an emphasis in mathematical modeling in systems biology, including hands-on experience via PBL modules and projects.

2 Rationale and demand

2.1 Institutional factors

The proposed new major is compatible with the academic priorities of the University in that it aims at providing high quality education in an area of national need and

potentially of great impact to the future of research in biomedical and life sciences. The principal outcome of this major should be graduates who will have skills bridging between traditional researchers in biology and those in other fields, notably in physics, chemistry and mathematics — a demand of future life sciences research, if full advantage is to be taken of the latest advances in measurement technologies, and the wealth of experimental *omics* data that is being generated.

This proposal is the result of discussions among UD faculty in Biological Sciences, Chemistry and Biochemistry, Chemical Engineering, and Mathematical Sciences. These discussions were motivated by a report of the National Research Council (NRC) of the National Academies: *BIO2010 — Transforming Undergraduate Education for Future Research Biologists*. The proposed curriculum follows recommendations contained in the BIO2010 Report. It was approved by the faculty in Mathematical Sciences, and endorsed by the Department of Biological Sciences. It also received enthusiastic support from other researchers (see support letters in the Appendices).

The new major can be started with minimal additional resources; it will utilize existent UD resources, thus maximizing the return of University investments in facilities and personnel, while providing current and future students an additional alternative to pursue first-class educational opportunities at the University of Delaware. As new faculty arrive on campus, and new courses are developed that may serve this new major, we will be looking to use those resources for further improvement of the program.

2.2 Student demand

It is anticipated that the initial number of new majors will be small, consisting mostly of current UD students who will change into the new major from biology, chemical engineering and mathematics. The number of majors should steadily increase as we proceed with efforts to inform our Admissions Office, high school counselors, and prospective students visiting our campus about the new BS in Quantitative Biology (BSQB). It is expected that mathematically talented students who might otherwise lose interest in studying the life sciences will be attracted to this new major. Conversely, students in life sciences who find they have mathematical ability beyond what is demanded by the traditional curriculum may also find the BSQB attractive.

After five years of existence, it is expected that the BSQB major will have about 10 to 15 freshmen, and about 5 graduating students. The goal is not necessarily to have a very large number of students in the major, but rather to have a good

number of talented students who are able to follow a very demanding curriculum, and who will be well prepared to pursue a research career. If we succeed with this goal, we will already be making a very important contribution to the education of a new breed of biomedical and life sciences researchers.

The following citations are indicative of a recognized demand for a program of studies of the type represented by the proposed BSQB. Note also Vol. 303 of *Science* (February 2004), a special issue on Mathematics and Biology.

How biologists design, perform and analyze experiments is changing swiftly. Biological concepts and models are becoming more quantitative, and biological research has become critically dependent on concepts and methods drawn from other scientific disciplines. The connections between the biological sciences and the physical sciences, mathematics, and computer science are rapidly becoming deeper and more extensive. (BIO2010, p. 1)

In contrast to biological research, undergraduate biology education has changed relatively little during the past two decades. The ways in which most future research biologists are educated are geared to the biology of the past, rather than to the biology of the present or future. Like research in the life sciences, undergraduate education must be transformed to prepare students effectively for the biology that lies ahead. Life sciences majors must acquire a much stronger foundation in the physical sciences (chemistry and physics) and mathematics than they now get. Connections between biology and the other disciplines need to be developed and reinforced so that interdisciplinary thinking and work become second nature. (BIO2010, pp. 1–2)

In the postgenomic era of research, multidisciplinary and interdisciplinary research will command center stage, requiring team approaches and the collaboration of many individuals from vastly different fields, ranging from computational mathematics to clinical science. (The Role of the Private Sector in Training the Next Generation of Biomedical Scientists, American Cancer Society et al., 2000).

2.3 Transferability

As indicated in Section 2.2, we expect an initial small number of students to transfer to the new major. Accommodations on a case-by-case basis will be made, whenever possible, so as to minimize the amount of extra course work needed by transferring students, without compromising the principal goals of the major.

2.4 Regional, state, and national factors

There are no comparable courses of study at the undergraduate level in the region. The University of Delaware will be one of the first schools in the US to address the need for this kind of undergraduate program. Many experts believe that this type of program will eventually be developed by other universities. On the other hand, several interdisciplinary graduate programs have been created in recent years: The Harvard Medical School, Department of Systems Biology (Ph.D. Program in Systems Biology), the University of Washington and the Fred Hutchinson Cancer Research Center, in collaboration with the Institute for Systems Biology (Molecular and Cellular Biology Graduate Program, and Biomolecular Structure and Design Graduate Program), the University of California, San Diego (Graduate Program in Systems Biology), the Department of Systems Biology and Translational Medicine, Texas A&M University (Interdisciplinary Graduate Program), the Center for the Study of Biological Complexity, Virginia Commonwealth University (Ph.D. Program in Integrative Life Sciences), the University of Texas Southwestern Medical Center (Integrative Biology Graduate Program), the The Lewis-Sigler Institute for Integrative Genomics, Princeton University (Graduate Program in Quantitative and Computational Biology), and Cornell, Rockefeller, Sloan-Kettering Cancer Center (Tri-Institutional Program in Computational Biology and Medicine).

2.5 Other strengths

The proposed course of study for the BSQB is unique, in that it will continually develop and reinforce the connections between the various disciplines that play a central role in modern biomedical and life science research. The presence on campus of faculty in several departments and institutes who conduct research in diverse areas of biological sciences is of particular value to the program, as the opportunities for undergraduate research across campus will be very attractive.

The willingness of researchers in industry to collaborate in making the new major a success (see letters of support) will be very helpful as we try to arrange internship opportunities for the students in the major. Researchers from industry, as well as from other departments on campus, will be invited as guest lecturers, and to help with the integrative seminars and student projects for the capstone course.

3 Enrollment, Admissions and Financial Aid

3.1 Enrollment

There is no enrollment limit for the BS in Quantitative Biology. The clientele for this program, at least for the first five years, is not expected to be much larger than for a typical BS in Mathematics.

3.2 Admission requirements

The admission criteria are the same as for the BS in Mathematics.

3.3 Student expenses

Student expenses should be commensurate with those incurred by a typical biology major.

4 Curriculum Specifics

The degree to be awarded is a bachelor of science. The curriculum requirements are consistent with University requirements for a baccalaureate degree, more specifically for a bachelor of science.

- **University Requirements**

  ENGL 110 Critical Reading and Writing (minimum grade C-) 3

  First Year Experience 0-4

  Discovery Learning Experience 3

  Three credits in an approved course or courses stressing multi-cultural, ethnic, and/or gender-related course content 3

- **College Requirements**

  Writing (minimum grade C-) 3
  Second writing course taken after completion of 60 credit hours.

- **Breadth Requirements**
  Eighteen credits from Groups A, B and C with a minimum of six credits from each group. One of the courses should be in the area of Bioethics

Croup A 6

Group B 6

Group C 6

- **Major Requirements**
  A grade of C- or better is required for major courses and related work.

  Biology Section

  BISC 207 Introduction to Biology I 4

  BISC 208 Introduction to Biology II 4

  Three of the following three-credit (CORE BIO) courses 9

  BISC 302 General Ecology

  BISC 305 Cell Physiology

  BISC 306 General Physiology

  BISC 401 Molecular Biology of the Cell

  BISC 403 Genetic and Evolutionary Biology

  One of the following two-credit (CORE BIO LAB) laboratory classes ...2

  BISC 312 General Ecology Laboratory

  BISC 315 Experimental Cell Biology

  BISC 316 Experimental Physiology

  BISC 411 Experimental Molecular Biology

  BISC 413 Advanced Genetics Laboratory

  Computer and Information Sciences Section

  Either CISC 105 or CISC 106 (for those with no previous equivalent experience), or CISC 181 Introduction to Computer Science 3

  Chemistry Section

  One of the following options (A, B or C, 8 – 12 credits total)

  Option A

  CHEM 103 General Chemistry 4

  CHEM 104 General Chemistry 4

  Option B

  CHEM 111 General Chemistry 3

  CHEM 112 General Chemistry 3

CHEM 119 Quantitative Chemistry I 3
CHEM 120 Quantitative Chemistry II 3

Option C

CHEM 111 General Chemistry 3
CHEM 112 General Chemistry 3
CHEM 220 Quantitative Analysis 3
CHEM 221 Quantitative Laboratory 1

CHEM 321 Organic Chemistry 4
CHEM 322 Organic Chemistry 4
CHEM 527 Introductory Biochemistry 3

Mathematics Section

MATH 210 Discrete Mathematics I 3
MATH 241 Analytic Geometry and Calculus A 4
MATH 242 Analytic Geometry and Calculus B 4
MATH 243 Analytic Geometry and Calculus C 4
MATH 302 Ordinary Differential Equations 3
MATH 349 Elementary Linear Algebra 3
MATH 350 Probability Theory and Simulation Methods 3
MATH 426 Introduction to Numerical Analysis and Algorithmic Computation 3
MATH 450 Mathematical Statistics 3
MATH 535 Introduction to Partial Differential Equations 3
MATH 514 Introduction to Systems Biology 3

Physics Section

PHYS 207 Fundamentals of Physics I 4
PHYS 208 Fundamentals of Physics II 4

Other Requirements

Two one-credit integrative seminars 2
MATH 260 Integrative Seminar

Three integrative or technical electives, 6 credits of which should be integrative electives from a list maintained by the Department of Mathematical Sciences 9

Credits to total a minimum of 124

Sample Curriculum — BSQB

Freshman Year

BISC 207	Intro to Biology I	(4)	BISC 208	Intro to Biology II	(4)
CHEM 103	General Chemistry	(4)	CHEM 104	General Chemistry	(4)
ENGL 110	Crit Read/Write	(3)	MATH 210	Discrete Math I	(3)
MATH 241	Calculus A	(4)	MATH 242	Calculus B	(4)
First Year Experience		(1)			
Total		**16**	**Total**		**15**

Sophomore Year

CHEM 321	Organic Chemistry	(4)	CHEM 322	Organic Chemistry	(4)
CORE BIO		(3)	CORE BIO		(3)
MATH 243	Calculus C	(4)	CISC 181	Intro Comp Sci	(3)
MATH 349	Linear Algebra	(3)	MATH 302	Diff Equations	(3)
Breadth	Group C	(3)	MATH 260	Integrative Sem	(1)
Total		**17**	**Total**		**14**

Junior Year

CORE BIO		(3)	CHEM 527	Intro to Biochem	(3)
MATH 350	Probab & Simul	(3)	MATH 450	Math Stat	(3)
MATH 426	Num Computing	(3)	MATH 535	Intro to PDEs	(3)
PHYS 207	Physics I	(4)	PHYS 208	Physics II	(4)
Integrative Elective		(3)	MATH 260	Integrative Sem	(1)
			Breadth	Group A	(3)
Total		**16**	**Total**		**17**

Senior Year

CORE BIO LAB		(2)	Bioethics	Group A	(3)
MATH 514	Intro Sys Biology	(3)	Integrative Elective		(3)
Breadth	Group B	(3)	Breadth	Group B	(3)
Integrative Elective		(3)	Breadth	Group C	(3)
Research I		(3)	Research II		(3)
Total		**14**	**Total**		**15**

Total number of credits: 124

5 Resources Available

5.1 Learning resources

The resources needed by the proposed BSQB are the same as those needed by current majors in biological sciences, chemistry, chemical engineering and mathematics. Wet labs, computer labs, library resources, etc., all exist within the University, and there would be no adverse impact on those resources by the relatively small number of majors in the new program.

Current faculty, in addition to those who will be hired under ongoing searches, will properly teach and advise students in this major. The administration of this interdisciplinary major will be done primarily in the Department of Mathematical Sciences, with help from the Department of Biological Sciences in student advisement.

A Howard Hughes Medical Institute (HHMI) grant awarded to the University will fund collaboration among biology, chemistry, chemical engineering and mathematics faculty in the development of instructional modules to be used in the BSQB, as well as for teaching biological sciences majors.

6 Resources Required

The capstone course proposed with the BSQB should be team-taught by a mathematician and a researcher in systems biology, at least the first few times it is offered. This will require some workload adjustments within the departments involved, and this has been agreed on by those departments. Support to start this program will also come from a Howard Hughes Medical Institute grant.

7 Implementation and Evaluation

Some sections of MATH 241 will give preference to students in Biological Sciences and in the BSQB. The calculus material to be covered will be the same as for the other sections of 241, but with a strong emphasis on examples of applications to the life sciences. Those students who do not get AP credit for MATH 241, will be directed to take the special "bio" section of calculus.

Collaboration among some key faculty in Mathematical Sciences and in Biological Sciences will help include more quantitative analysis in introductory biology courses; this has already started in Fall 06, and will continue. By Fall 07, some changes

implemented in those classes will make them even more attractive to the incoming students to the BSQB major. Starting in Spring 08, material for the one-credit integrative seminars will have been developed, funded by the HHMI grant, and we will start offering those seminars. The capstone course is to be offered in the Fall of the senior year, thus preparing students for meaningful internships and undergraduate research during the following Winter Session.

The new major will be part of the assessment plan of the Department of Mathematical Sciences. We also plan to keep track of the movements into and out of the major, as well as of graduating seniors, in order to evaluate the effectiveness of the program in meeting its goals.

8 Appendices

Attached are a detailed description of the capstone course, letters of support from the Department of Biological Sciences, from the Department of Mathematical Sciences, from the Department of Chemistry and Biochemistry, from Dr. Prasad Dhurjati of Chemical Engineering, and from Dr. Anastasia M. Khoury Christianson of Astra Zeneca. Also included is a testimonial by Dr. Lauren A. O'Donnell, UD alumna, and other supporting documentation.

Proposal for MATH 514 — Introduction to Systems Biology

Course goals and description

This course is to be a capstone course for the proposed BS in Quantitative Biology (BSQB). The main goals of MATH 514 are to integrate and synthesize knowledge the students acquired in biology, biochemistry and mathematics. The BSQB Program aims at training students to apply mathematical tools to solve problems in the life sciences, and to be able to communicate seamlessly between the disciplines of life sciences and mathematics. Thus, they should be trained to understand the goals of biologists and to capture the essential features of biological systems in a mathematical language.

The ability to translate biology into mathematics without losing a lot in the translation process is important, and the ability to interpret the mathematical models in a way to generate biological insights is also critical. Students in the BSQB Program will learn important mathematical tools, biology, and biochemistry — it is crucial to bring these together. The reconnection of the mathematics back to the underlying biological processes is an essential part of systems biology. The systems biology modeling process is successful when the iterative process between biology and mathematics leads to a continuous improvement in the level of understanding of the biologist. Thus, a systems biology course is an excellent choice as a capstone course for the BSQB Program.

Instructional methodology

The course structure will be as follows.

1. Approximately one third of the class time will be devoted to lectures and discussions conducted by the instructors and by guest lecturers from industry and academia; approximately two thirds of the time will be devoted to problem-based learning (PBL) modules of varying duration.

2. Students will work in groups on each PBL module. Some modules will include a computer lab and/or a wet lab, and all will include a project report.

3. There will be a final project: The students will select a biological system to study, to model mathematically, and to analyze; they will also write a report.

Prerequisites

A **core biology** course (see the curriculum for BSQB), CHEM 527 and MATH 535.

Course syllabus

The models considered throughout the course will range from algebraic models of steady-state systems (e.g. metabolic fluxes, stoichiometry), to ODE models of time-dependent, spatially homogeneous systems (e.g. microbial growth, compartment models), to PDE models of spatial-temporal varying systems (e.g. diffusion, reaction-diffusion), to stochastic models (e.g. cell variability in gene expression); they may include feedback and control. The course material can be divided into 3 parts.

Part I: Introduction

1. What is the systems biology approach: Examples chosen from different application areas — medical research, agricultural research, biotechnology industrial processes, etc.

2. From biological data and biological problems to modeling, validation, refinement and new insights. Examples from various application areas as in item 1 above.

Part II: Mathematical modeling of biological systems

Through examples in lectures, and through PBL modules, a systematic approach to mathematical modeling, analysis and interpretation will be developed with the following main components.

1. Defining goals and expectations.

2. Making assumptions.

3. Identifying key variables and phenomena.

4. Identifying system connectivity and functional relationships among components.

5. Model building.

6. Model validation and refinement.

7. Using the model to generate hypothesis and to design experiments.

Part III: Topics in systems biology modeling

1. Quantitative approaches: Topics from network models, spatial-temporal models, stochastic models, feedback and control systems, discrete models.

2. Systems levels: Topics from regulation of genetic networks, metabolic pathways, cellular level organizations, organisms (plants and animals), etc.

3. Applications: Topics from pharmacokinetics and pharmacodynamics, agricultural research, industrial processes, environmental biotechnology, medical research, etc.

References

At this time there is no plan to adopt a textbook for the course. Several books and journal articles will be used as references. PBL modules will be developed by the instructors. After a few offerings of the course, sufficient material will exist to write a book or notes for the course. Some typical references are listed below.

1. **Books**

   - *An Introduction to Systems Biology: Design Principles of Biological Circuits*, by Uri Alon. Chapman & Hall/CRC, 2007. (A very good text emphasizing a network approach to systems biology.)
   - *Foundations of Systems Biology*, H. Kitano (editor). MIT Press, 2001. (Provides an overview of some aspects of systems biology.)
   - *Systems Biology in Practice*, E. Klipp, R. Herwig, A. Kowald, C. Wierling and H. Lehrach. Wiley, 2005. (A somewhat shallow overview of system biology practice, but useful to select topics for more in-depth study.)

- *Systems Biology — Properties of Reconstructed Networks*, B. O. Palsson. Cambridge University Press, 2006. (A nice book on the topic of reconstructed networks and their mathematical representation.)

2. **Articles**

- H. De Jong, *Modeling and simulation of genetic regulatory systems: A literature review*, J. of Comp. Biology 9(1), 2002, pp. 67–103.
- *Science — Special Issue on Systems Biology*, March 2002.

UNIVERSITY OF DELAWARE

DEPARTMENT OF BIOLOGY
OFFICE OF THE CHAIR

University of Delaware
Newark, Delaware 19716-2590
Ph. 302/831-6977
Fax: 302/831-2281

Daniel D. Carson, Ph.D.
Trustees Distinguished Professor
and Chairman
Department of Biological Sciences
118C Wolf Hall
Telephone (302) 831-6977
Fax No. (302) 831-1033
E-mail: dcarson@udel.edu

September 26, 2006

Professor Peter Monk
Interim Chair
Department of Mathematical Sciences
University of Delaware
Newark, DE 19716

Dear Professor Monk:

The Department of Biological Sciences is pleased to support the creation of a new interdisciplinary major in Quantitative Biology (Bachelor of Science). Students in this degree program will enroll in existing Biological Sciences courses. As we understand this, no new resources are required for the biology component of this degree program.

I believe that this degree offers an attractive new program of study for students interested in future employment or research in biological or biomedical sciences. In addition, this program is in line with the recent National Academy of Sciences' Research Council report, "Bio 2010", stating that current and anticipated future directions in biomedical research require students to be more educated in physical and quantitative science. This new degree program helps fill this vital niche.

Sincerely,

Daniel Carson

Daniel Carson
Trustees Distinguished Professor
and Chairman

UNIVERSITY OF DELAWARE

DEPARTMENT OF MATHEMATICAL SCIENCES

501 Ewing Hall
University of Delaware
Newark, Delaware 19716-2553
Ph: 302/831-2653
Fax: 302/831-6333/4486

Wednesday, October 11, 2006

To: Gilberto Schleiniger
Mathematical Sciences

From: Peter Monk
Interim Chair, Mathematical Sciences P.M.

Re: BS degree in Quantitative Biology

By a strong majority, at our meeting on 10/10/06, the faculty of the Department of Mathematical Sciences has voted to approve your proposal for a Bachelor of Science degree in Quantitative Biology.

The proposal includes only one new course, a capstone course at the 500 level. This course can be covered without a further hire at this time due to the expected hire of a Mathematical Biologist this year. For the first two years it is offered the Department is willing to support team teaching this course with a faculty member from another department to ensure that the capstone course properly represents the multidisciplinary nature of this degree. No new resources will be requested at this time.

From: John Burmeister <jlburm@mail.chem.udel.edu>
Subject: **Re: Letter of support**
Date: October 23, 2006 3:02:17 PM EDT
To: Gilberto Schleiniger <schleini@math.udel.edu>
Cc: John L Burmeister <jlburm@chem.udel.edu>, White Hal <halwhite@UDel.Edu>, riordan@UDel.Edu
Reply-To: jlburm@UDel.Edu

Gilberto:

We would welcome your new BS/Quantitative Biology majors in the CHEM courses specified in the proposed curriculum, with the following provisos:

1. Our experience with other majors being required to take the BS/CHEM, BS/BIOC, BS/CHEG - required CHEM-111/112/119/120 sequence has not been positive. Most recently, the Environmental Engineering curriculum has substituted CHEM-103/104 for what had been a CHEM-111/112/119 requirement when the major was first created. The ENEG majors had an extremely difficult time, almost to a person, coping with the rigors of CHEM-111/112/119.

2. The natural GenChem/QuantChem sequences are either CHEM-103/104/220/221 (taken by our BA/CHEM and BA/XCE majors) or CHEM-111/112/119/120 (taken, as I've noted earlier, by BS/CHEM, BS/BIOC, and BS/CHEG majors). I would therefore not recommend the "mix and match" Option C.

3. We are at the physical limit imposed by having one laboratory room available for CHEM-321/322. With a CHEM-321 enrollment of 390 in 06F, we are running TWENTY lab sections of ca. 20 students each per week in Drake 320. We even have lab sections scheduled (and populated!) on Friday night and Saturday morning. Even a modest additional enrollment would cause enrollment problems for us in this course.

Cordially, JB

P.S. Please let me know if this E-mail will suffice. If not, I'll be happy to send you a hard copy.

Gilberto Schleiniger wrote:

> Dear John:
>
> We are proposing a new major, BS in Quantitative Biology, to be offered with the Department of Biological Sciences. Since we are requiring several CHEM classes for that major, it would be wise to have a letter of support from your department. We don't expect more than a few students in the major for the first few years, so the impact should really be minimal. But, the various College and University bodies evaluating the proposal will probably question whether Chemistry and Biochemistry was consulted. Hal White was in the design team of the new major and knows all about it.
>
> I don't know whether you are the right person to ask for a letter of support; if not, can you please direct me to the right contact in your department?
>
> I attach a copy of the curriculum for the new major, along with a sample. Hal can also clarify any issues, or you can contact me directly for any questions or concerns.
>
> Thank you very much for your attention to this request.
>
> Sincerely,

Gilberto

G. Schleiniger
Director of Undergraduate Studies
Math Sciences
University of Delaware

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John L. Burmeister
Alumni Distinguished Professor and Associate Chairman
Department of Chemistry and Biochemistry
University of Delaware
Newark, DE 19716
(302)831-1130
FAX (302)831-6335
http://www.udel.edu/chem/burmeister/jlb.htm

Professor Gilberto Schleiniger
Department of Mathematics
University of Delaware
Newark DE 19716

Dear Professor Schlieniger:

I am writing this letter in strong support of the proposed Bachelor of Science Major in Quantitative Biology. Such a program is timely and is ideally suited for the demands of forefront academic and industrial research in biotechnology.

Traditionally, students trained in biology have been weak in mathematics. It is also rare for a mathematics student to have a deep understanding of life sciences. A student with training in biology and mathematics has the potential to make major contributions in modern biotechnology.

The recent revolution in biotechnology has been brought about by new measurement technologies that have led to an explosion in the amount of experimental data that is being generated. Such data broadly goes under the umbrella of "omics" and includes genome sequences, transcriptomic information, proteomics, metabolomics, etc. The expectation is that this data explosion will lead to important discoveries in industrial and agricultural biotechnology, medicine, discovery of new pharmaceutical drugs, etc. However, such expectations on significant breakthroughs will only be met if there is a generation of scientists who are trained in both biology and mathematics.

The analysis of biological data requires strong quantitative skills and domain knowledge of the biological system. Biological systems are dynamic, complex and highly interconnected. Making sense of such systems require knowledge of system level mathematical tools to model and analyze the system, design new experiments and come up with hypothesis on how the system components work together. At the very least, one needs to train students who understand the biological significance of the data, who are equipped with quantitative tools to analyze the data, who are capable of building mathematical models to put the pieces together and who can exploit quantitative tools to exploit the biological data to the fullest. It is such students who are trained in both biology and mathematics who will come up with the significant breakthroughs of the future. These students will be in very high demand in graduate schools and in the biotechnology and pharmaceutical industry.

Harvard University was the first to set up a Department of Systems Biology as a serious recognition of the need to bring quantitative disciplines and the life sciences together. It is much easier to do this interdisciplinary training when the students are young and well before they have been separated into the mutually exclusive pools of biologists and mathematicians. A B.S. in quantitative biology at Delaware is a recognition of an important and present need in training future leaders in biotechnology.

Based on my quarter century of research experience in biotechnology and chemical engineering, I enthusiastically support this program and would be very happy to participate in making it a success.

Prasad Dhurjati
Professor of Chemical Engineering
University of Delaware
http://www.che.udel.edu/dhurjati

AstraZeneca

Thomas M. Apple, Ph.D.
Dean, College of Arts and Sciences
University of Delaware
Newark, DE 19711

October 7, 2006

Dear Dean Apple,

I am writing with my most enthusiastic support for establishing a Quantitative Biology degree program at the University of Delaware. As I am sure you are well aware, the recent advances in biological research and trends towards disease modeling and systems approaches to biology certainly require future biologists to have a strong foundation in computational skills, especially in advanced mathematics and statistical sciences, to sustain the whole system approach to understanding biological processes and disease.

Application of system biology is certainly on the incline and requires strong connection between quantitative and phenotypic aspects of biology. Miniaturization and high throughput capabilities for generation and interpretation of data such as genetic, genomic, metabonomic, proteomic, etc. require more complex data manipulation and analysis skills than what is now covered in a standard Biology degree curriculum. Moreover, there is increased demand for analysis of complex biological data such as biomedical image data, acoustic data, and whole cell/organ measurements, to name a few, and all of these measurements require more sophisticated algorithms and analysis skills than are currently available. The current practice of collaborations between experts in different fields needs to be improved by ensuring better understanding of each other's fields through additional training (namely computational training for biologists).

Whole system evaluation requires multidimensional analysis of often very disparate data yet very few scientists have the necessary in depth training in both Biology and Mathematics today to effectively perform such cross-functional analyses. Part of the challenge is the lack of strong experience and skills in both biology and mathematics within one person to ensure an appreciation of the biological challenge(s) while applying the most appropriate computational analyses. The second part of the challenge is in having enough understanding of what can and cannot be achieved with computational tools to trust results from such complex analyses. Thus the need for training stems not only from the need for skilled scientists to perform complex analyses, but also from the need for

skilled biologists to accept the output of such analyses and predictions, interpret them appropriately and know how to progress with them.

System biology and the trend towards understanding the complex network of biological interactions and processes is also growing in popularity within the Pharmaceutical industry where the need to translate clinical findings to pre-clinical and animal data is essential for the understanding of disease and for the development of therapeutic agents. This need transcends the Pharma industry to the regulatory agencies where there are initiatives like the FDA's "Critical Path" Initiative that anticipates accelerated product development based on new Biomedical Discoveries that are only possible with the appropriate systems approaches and predictive tools. Thus again, demonstrating the growing need for mathematically savvy bioscientists.

Today, it is not uncommon to find seasoned Bioscientists seeking additional training in computational tools in order to perform their day-to-day activities or as a professional development opportunity. Although such training addresses the acute needs of the industry short term, it is not nearly as rigorous as a proper four-year undergraduate foundation in quantitative biology would provide to enable long term application of quantitative biological training in graduate and professional degrees and especially in medical training. The University of Delaware is clearly aware of the trends in the biological sciences and is well poised to provide excellent training to its students from within existing infrastructure of faculty and expertise as well as connections to surrounding medical and pharmaceutical communities. They are also well placed to draw from their surrounding industry to provide students hand-on experience through collaborations, guest lectures and internship opportunities.

In summary, I am most enthusiastic in my support of the Quantitative Biology Degree at the University of Delaware and look forward to its establishment. I am enthusiastic enough about the value and long term benefits of establishing such a program that I would be happy to participate in any program related activities that the University might seek input from area scientists advising students or providing industrial perspective to the program through guest lectures or training opportunities.

Sincerely yours,

Anastasia K. Christianson, Ph.D.
Director, Discovery Medicine Informatics
AstraZeneca Pharmaceuticals

October 8, 2006

Gilberto Schleiniger, Director of Undergraduate Studies
Department of Mathematical Sciences
University of Delaware

Dear Dr. Schleiniger,

I am writing to you to express my enthusiasm and support for the proposed Bachelor of Science in Quantitative Biology at the University of Delaware. As an undergraduate in the Animal Science department (BS, 2000), I received a dynamic education in the life sciences with thorough training in biology, chemistry and biochemistry. In addition, I did two years of undergraduate research with Dr. Carl Schmidt on a molecular virology project on herpesviruses, which led to the completion of an Undergraduate Research Thesis. These positive experiences at the University of Delaware inspired me to pursue a career in biomedical research. I recently completed my doctorate in Cell and Molecular Biology at the University of Pennsylvania Medical School, where my thesis work examined how Human Immunodeficiency Virus (HIV) induces injury and death of particular types of neurons during HIV infection of the brain, and on pharmacological methods to block that neuronal loss. Currently, I am an adjunct professor of chemistry at Philadelphia University, and I will be starting my postdoctoral research at Fox Chase Cancer Center in November, where I will have a dual focus on neurotropic viruses and the immune response of the brain to viral infections and cancer. None of this would have been possible without the outstanding education I received at the University of Delaware.

Although I feel well-prepared to be an independent scientist, I have recently realized in retrospect that one area of my educational background is underdeveloped. In order to fully appreciate and analyze the implications of one's data, scientists need to be fluent in mathematics as it applies to modeling biological systems, in addition to perhaps the more obvious, in-depth understanding of biology and chemistry. Specifically, molecular biologists need to know how to best apply mathematical modeling to the massive quantities of data that can now be produced so readily (such as gene expression profiles of virally-infected versus non-infected cells, predicting sequence evolution in viral swarms and the outcomes thereof, or the mapping of signal transduction pathways and feedback loops activated in an infected cell, as just a few examples in virology.) As the field of molecular biology (and virology) has exploded over the past few years, students with an interest in research need refocused and advanced training to better analyze their data and to develop models and experiments that make the best use of the information available to them. This cannot be done without an aggressive emphasis on the intimate link between mathematics and the life sciences. The program in Quantitative Biology answers this critical need directly.

Based on the proposed goals and curriculum for the Quantitative Biology program, I believe this course of study will not only adequately train and enlighten students about

the tightly integrated relationships between biology, chemistry, and mathematics, but also will build a dynamic, competitive, and thoughtful foundation for the upcoming generation of research scientists. I am excited for students at the University of Delaware to have such a progressive and competitive addition to both their math and science education, as it will allow them to enter the field of biomedical research with the power and knowledge to make a significant, useful impact.

Sincerely,

Lauren A. O'Donnell
University of Delaware, BS 2000
University of Pennsylvania, PhD 2006

From: Norbert Mulders <mulders@UDel.Edu>
Subject: **Quantitative biology major**
Date: October 25, 2006 11:28:13 AM EDT
To: schleini@math.udel.edu, dusher@UDel.Edu
Cc: hadji@UDel.Edu

Gilberto, David,

I just talked with George Hadjipanayis about the physics component in the proposed quantitative biology major. Since you are projecting small numbers, we should be able to accommodate students in PHYS 207/208 (Although for PHYS207 it would be much easier to do this in Fall then in Spring).

However, we were wondering if you all the implications of moving from PHYS201/202 to PHYS207/208. The difference between those two sets of courses is substantial. PHYS201/202 cover a much wider range of physics, including for example some optics an fluid mechanics. PHYS207/208 are calculus based courses, and can go deeper, but sacrifice breadth. PHYS207 is strictly mechanics, PHYS208 only electricity and magnetism. For the current audience for PHYS207/208 this works well since they normally broaden their scope by taking additional courses such as "Optics' for the physics majors and "Fluids" for some of the engineers. It looks to me as if the program that you are proposing does not have this type of courses?

Unrelated, but maybe something to consider, we find that most of our students are more comfortable with the MATH341/MATH342 sequence than with the MATH302/349 one.

Norbert Mulders
Director, Physics and Astronomy Undergraduate Programs
Department of Physics and Astronomy
University of Delaware