Developing Integrative and Interdisciplinary Approaches to Learning: Majors and Minors

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Bio 2010 Report

- ***How best to educate the next generation of research biologists?***
- **General Rule - Students should be conversant not only with the language of their disciple but also with the languages of mathematics, computation, biological and the physical sciences**

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Interdisciplinary Programs

- **Established Sub disciplines** (Biophysics, Biomedical engineering, Biostatistics)
- **Emerging Sub disciplines** (Biomathematics, Mathematical Biology, Quantitative Biology, Systems Biology, Bioinformatics, Computational Biology)
- **Goal of Report**
  - Survey existing majors in emerging sub disciplines
  - Identify integrative structures within majors
  - Compare course structures at various institutions

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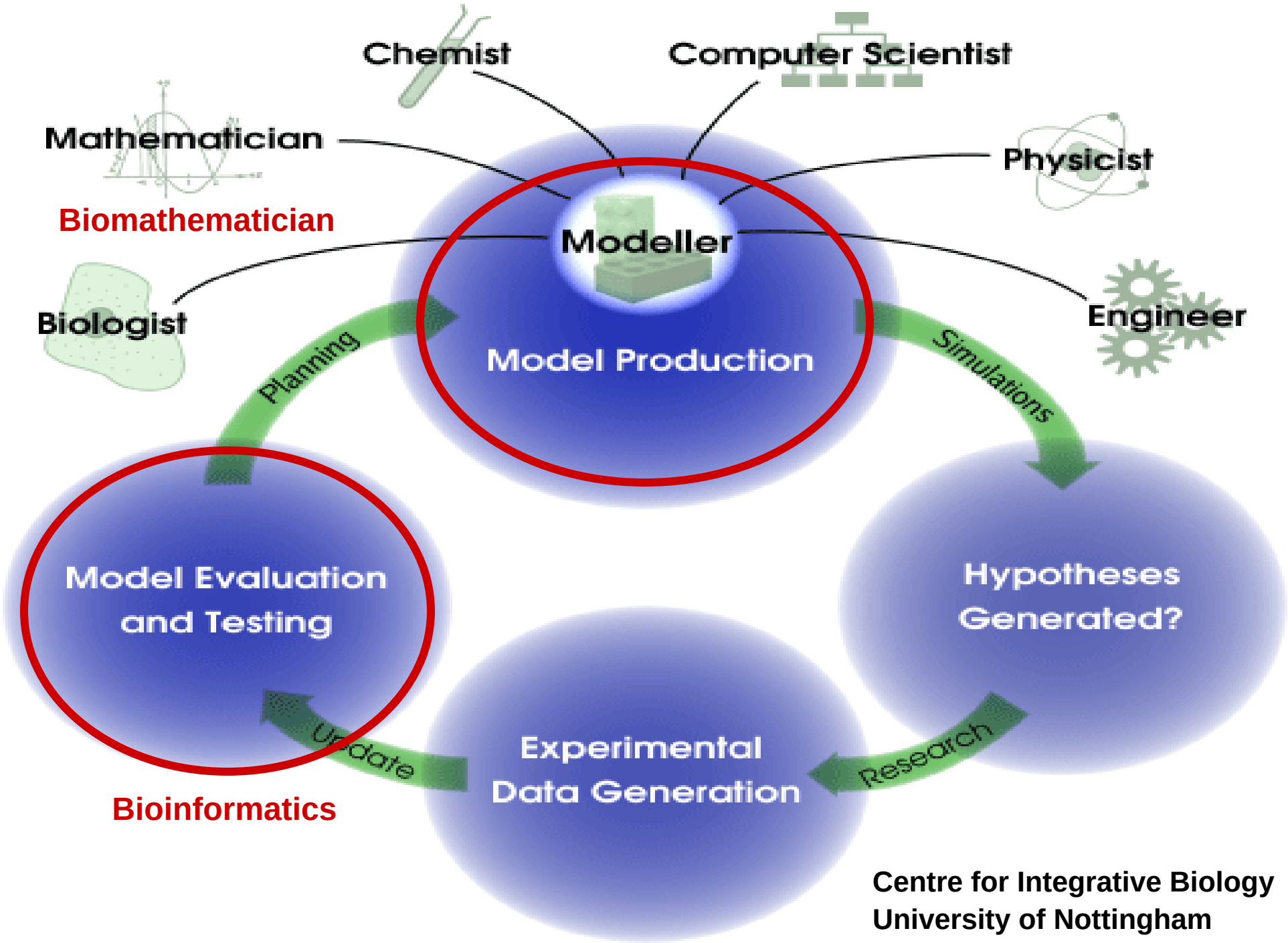
Goals - Integrative and Interdisciplinary Programs

- Biomathematics, Quantitative Biology, Systems Biology, Computational Biology:
  - "to develop *analytical* and *predictive* models of biological and medical systems that can serve as important aids to understanding of those systems and as guides for future research and development." (UCLA)
  - "the use of *mathematical models* to help understand phenomena in biology. Modern experimental *biology is very good at taking biological systems apart* (at all levels of organization, from genome to global nutrient cycling), into components simple enough that their structure and function can be studied in isolation. Dynamic *models are a way to put the pieces back together*, with equations that represent the system's components, processes, and the structure of their interactions. (NC)

Goals - Continued

- Bioinformatics, Computational Biology: The development of computer software and algorithms to record and *analyze biology related data* (statistics and computer sciences) [http://www.hupo.org/overview/glossary/]



Centre for Integrative Biology
University of Nottingham

The Undergraduate Major

- Function: to establish an educational foundation in biology, chemistry, math and computer sciences that instills in students a common language
- Path Forward
  - Graduate Schools
  - Medical or other professional schools
  - Industry (Pharmaceutical, Biotech…)

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Working Group #2 - Survey

- Resulted from last year's meeting – Team: John A. Pelesko (Chair), Istvan Karsai, Nancy Horton, Bill Holben, Paul Tian, Robin Snyder, Joydeep Bhattacharjee, Dave Usher (Steering committee liason)
- Charge - Survey programs in "math biology"
- Reduced survey to two broad categories
  - Biomathematics, Quantitative Biology and Systems Biology, Computational Biology
  - Bioinformatics and Computational Biology

The Categories – Program Focus

- Category I - Biomathematics, Quantitative Biology, Systems Biology, Computational Biology
  - "to develop *analytical* and *predictive* models of biological and medical systems that can serve as important aids to understanding of those systems and as guides for future research and development." (UCLA)
- Category II - Bioinformatics, Computational Biology:
  - The development of computer software and algorithms to record and *analyze biology related data*.

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Category I – QB, Systems Biology, Computational Biology

- Identified 11 current undergraduate programs fitting this category
  - UD, Case Western (HHMI Funded)
  - SUNY Buffalo, NJIT, Rutgers, U. of Scranton, Harvey Mudd, U Penn, Florida State, Iowa State, MIT, Harvard
  - 5 housed in mathematics departments
  - 5 housed in biology departments
  - 1 independent degree granting program (SUNY)

Category I – QB, Systems Biology, Computational Biology

- Core independent of the department housing the program
- Menus of core courses did depend on department housing the program
- Math based programs required more math, Bio based required more bio
- Only 5 programs required two or more semesters of physics (Short of Bio 2010 recommendation)
- Only 4 programs required two semesters each of general and organic chemistry (Short of Bio 2010 recommendation)
- Majority required only introductory computer science (Short of Bio 2010 recommendation)
- Majority had a research/capstone requirement

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A Math Based Model at UD

Quantitative Biology

The undergraduate Bachelor of Science in Quantitative Biology major is an interdisciplinary program offered in collaboration between the Departments of Biological Sciences and Mathematical Sciences at the University of Delaware. It was designed for students who like math and biology and want to pursue and integrate both interests in their college career. This program is for students who enjoy the challenge of solving interesting and important biological problems.

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A Math Based Model at UD

- Housed in mathematics department, designed jointly with biology, basic core:
  - Requires 36 units of mathematics
  - Requires 19 units of biology
  - Requires 3 units of computer science
  - Requires 8 units of physics
  - Requires 4 units of integrative seminars

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A Math Based Model at UD

- Integrative aspects
  - Special “bio” section of calculus (early integration)
  - 4 units of integrative seminars (mid-level integration)
  - Capstone course in systems biology (later integration)

During the senior year, students will take a capstone course in which a synthesis of the material in the various science and math courses is the main focus. Students are also very strongly encouraged to work on research during their senior year, in preparation for a senior thesis to be written under the supervision of faculty in two disciplines: Math and biology.

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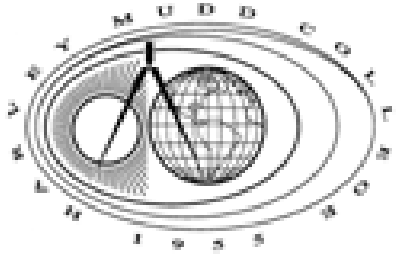
A Bio Based Model at Harvey Mudd



It has been predicted that the 21st century will be "the century of biology." And as biology and biotechnology become more important in the coming decades, so will the application of quantitative methods to biological science. Mathematical and computational components are vital to many areas of contemporary biological research, such as genomics, molecular modeling, structural biology, ecology, evolutionary biology, and systems analysis of neurobiology, physiology and metabolism. HMC students interested in the interface between biology and mathematics may pursue the Mathematical Biology Major, which is jointly administered by the Biology and Mathematics Departments.

A Bio Based Model at Harvey Mudd

- Housed in the biology department but jointly administered with mathematics
- Requires 10 units of math
- Requires 15 units of biology
- Requires 3 units of computer science
- Requires 4 units of integrative courses in mathematical biology

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A Bio Based Model at Harvey Mudd

- Integrative aspects
  - Requires 4 units of integrative courses in mathematical biology (mid-level integration)
  - Requires a senior thesis research experience (later integration)

Students who choose this major become immersed in the scientific and intellectual cultures of both biology and mathematics, and the major is sufficiently flexible to allow students to concentrate in a particular area of mathematical biology. Students in this major have both a Biology advisor and a Mathematics advisor, who will help them plan a program tailored to the their interests and goals.

An Different Approach at Harvard

- **Introductory course** integrates chemistry with biology (LS 1a & 1b)
- **Chemical and Physical Biology** aims to provide the next generation of life scientists with the background needed to make new advances in the quantitative understanding of living systems.
  - Chemistry through physical chemistry
  - Mathematics: menu of courses including ODE, PDE, linear algebra, combinatorics, mathematical modeling
  - Physics: 1 year
  - Undergraduate Research (Capstone experience)

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Category II – Bioinformatics and Computational Biology

- Identified 10 current undergraduate programs fitting this category
  - –Iowa State, UC Santa Cruz, BYU, RPI, USP, NJIT, UCSD, Ramapo, Canisius, Rochester
  - –4 are independent programs
  - –1 housed in biology department
  - –2 housed in computer science departments
  - –1 housed in department of education
  - –1 housed in biomolecular engineering
  - –1 joint program (CS, Bio, Math)

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Category II – Bioinformatics and Computational Biology

- Focus of these programs is weighted towards Bio, CS, and Mathematics
- Core is common, Bio, CS, Math
- Little or no physics requirements (1 program required 3 semesters, most required none)
- Majority required 4 or more courses in CS
- Majority required 4 or more courses in Math (includes Stats)
- Majority had a research/capstone requirement

Bioinformatics at Iowa State

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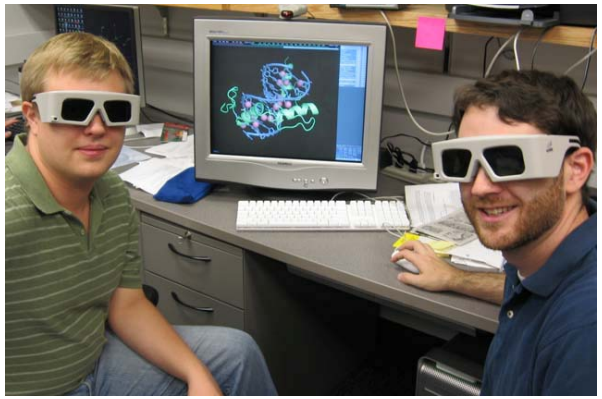

Bioinformatics and Computational Biology Undergraduate Major (BCBio)
Bioinformatics and Computational Biology is an interdisciplinary science at the interfaces of the biological, informational and computational sciences. The science focuses on a variety of topics. These include gene identification, expression, and evolution; RNA, protein, and genome structure; and molecular and cellular systems and networks. The large group of participating faculty provides students with a multidimensional perspective on bioinformatics and computational biology and presents them with broad range of possibilities to get involved in research.

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Bioinformatics at Iowa State

- Housed in bioinformatics and computational biology
- Requires 12 units of math
- Requires 9 units of statistics
- Requires 3 units of physics
- Requires 11 units of biology
- Requires 12 units of computer science
- Requires 15 units of specially designed courses in bioinformatics

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Bioinformatics at Iowa State

- Integrative aspects
  - Requires 15 units of specially designed courses in bioinformatics (early and mid-level integration)
  - Requires independent study or team research project (later integration)

BCBIO 211. Introduction to Bioinformatics and Computational Biology.
(3-0) Cr. 3. S. Overview of bioinformatics and computational biology. Database searching, sequence alignment, gene prediction, RNA and protein structure prediction, construction of phylogenetic trees, comparative and functional genomics.

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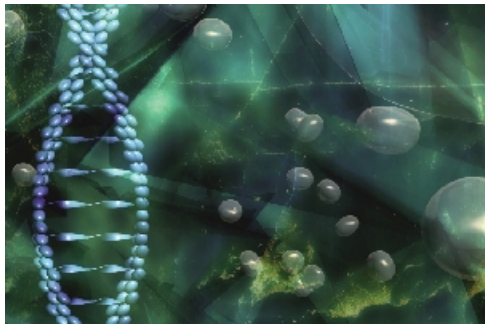
Bioinformatics at NJIT

NJIT New Jersey's Science & Technology University



Computation is doing for biology today what the microscope did four centuries ago - allowing scientists to peer deeper into the fundamental processes of life and to extract, record, retrieve, analyze, visualize and ultimately to utilize for medical and other practical purposes tremendous quantities of information. The human genome, for example, has three billion "letters" in it, organized into some 30,000 genes.

The Bachelor of Science in Bioinformatics degree provides the student with an understanding of bioinformatics, computer science and biology fundamentals, along with supporting science and mathematics. This degree is ideal for students interested in pursuing a career in the biotechnology, pharmaceutical, biomedical or related industries, or for those interested in pursuing advanced degrees in bioinformatics or medicine.

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Bioinformatics at NJIT

- Housed in computer science
- Requires 15 units of biology
- Requires 14 units of mathematics
- Requires 4 units of physics
- Requires 18 units of computer science
- Requires bioinformatics seminar courses

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Bioinformatics at NJIT

- Integrative aspects
- Requires bioinformatics seminar courses (early and mid-level integration)
- Requires a capstone course (later integration)

Senior Capstone Program

Put your learning to the test, gain valuable experience and make a difference for a business or organization through the senior capstone program required of all CCS students. This semester-long class is a chance to draw on your years of learning at NJIT and apply it to an authentic need presented by one of NJIT's many industry partners. Through the capstone's entrepreneurship track, you can even start your won business. The more than 200 industry sponsors have included Microsoft, Johnson & Johnson, PSE&G Inc., NASA and the National Science Foundation. Then it's up to the teams--four to six students not only from CCS, but also from other majors throughout NJIT--to design and implement a solution. At the same time, you'll learn skills in problem solving, project management, leadership, team dynamics, presentation and communication.

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Another Approach – Integrative Sciences at Princeton

- **Introductory course** integrates biology, chemistry, physics, & computer sciences
  - Counts as two courses each semester (2 chemistry, 2 physics, 1 computer science) [done within biology and math framework]
  - Course meets 5 days a week for 50 minutes and has two three hour labs
  - Team taught by a group of 10 faculty
  - Five text books required
  - "This course provides an *integrated, mathematically sophisticated introduction to the natural sciences*."
- Integration continues in sophomore and junior years
  - An Integrated, Quantitative Introduction to the Natural Sciences
  - Experimental Project Laboratory in Quantitative and Computational Biology

General Observations

- No “universal model” – programs depend on local conditions, but evolving common “core”
- Integrative approaches vary, but appear at all levels
- Integrative approaches include
  - Revision of standard courses
  - Integrative seminar style courses
  - New courses
  - Capstone courses
  - Undergraduate research experiences

Some Recommendations

- In-depth survey of integrative approaches identified to more fully understand best practices regarding integration and aims of various programs
- Compare and iterate on Bio 2010….Bio 2020?
- Study difference between “interdisciplinary” and “integrative” – better understand barriers to “integrative”
- Assess success/failure of new programs

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