Strategic Planning for Mathematical and Computational Life Sciences

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Background

Emory University is a nationally recognized teaching and research institution with a total enrollment of 13,000 students. Emory College, the liberal arts division of the University, offers its undergraduates the intellectual resources of a research institution combined with the community of a liberal arts institution that emphasizes integration of scholarly activities with teaching excellence. Emory College offers science majors in biology, chemistry, mathematics, computer science, neuroscience and behavioral biology, and physics. Emory College enrolls about 1300 new students each year for a total of about 5000 undergraduates. About 20% of the 1170 graduates have majors in Biology or Neuroscience and Behavioral Biology. 3-6% of graduates have mathematics or computer science majors. Nearly 50% of all freshman enroll in the Biology introductory series.

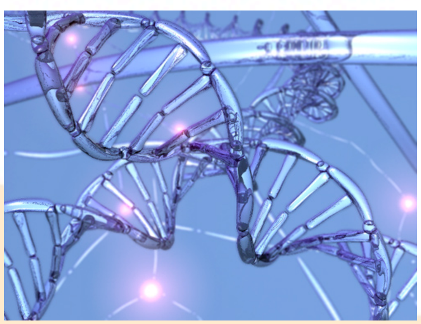
Over the last five years we have **completely redesigned introductory courses by integrating more quantitative skills, interactive pedagogies, and new lab and lecture components that are based in current research problems**. These innovations make the courses more demanding, especially for first year students.

Strategic Plan Goals

- Increase quantitative literacy and integrate research into the curriculum.
- Develop interdisciplinary minors in emerging fields such as bioinformatics, neuroinformatics, computational chemistry, molecular modeling, biostatistics, epidemiology, bioengineering, and biophysics use quantitative and computational concepts as the common, unifying language.

Strategies

- Faculty Seminar on Educational Research and Pedagogy
- Workshops for Faculty and Postdocs
- Teaching Undergraduate Science Program for Graduate Students and Postdocs
- HHMI Fellowships in Teaching and Curriculum Development
- Supplemental Instruction for undergraduate students



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Recently Developed Courses

Introductory Biology Series: Problem-based approach, integrates informatics and genomics.

Our overarching goal is to communicate to students the nature and excitement of scientific discovery by 1) basing the new intro labs on current research, some being conducted by faculty in the department; 2) using modern lab techniques; 3) using computational biology methods and bioinformatics; and 4) using a case study for each topic that connects lab topic to a real-life situation. BIO 141 lab gives in-depth coverage of bacterial resistance and yeast genetics while BIO 142 covers DNA profiling / haplotyping by PCR and zebrafish embryonic development. A postdoctoral fellow or graduate student interested in a teaching career taught each lab, aided by an undergraduate teaching assistant; both had previously completed a workshop on implementing cases studies in the classroom. We tested four new laboratory modules this year in BIO 141 and BIO 142. Both completed an Implementing Case Studies in the Classroom workshop. The 2005-2006 pilot (500 students) identified a need for an increased information technology support to effectively employ informatics resources and to develop instructional materials for techniques for investigation.

- **Freshman Seminar on Bioinformatics:** This freshman seminar covers computational methods in the biological sciences. Dr. Chad Brommer surveyed resources and interviewed researchers on the Emory campus. The course considers technical, scientific, and social perspectives. Students also collaborate on the design of a technical project. No background in either computing or biology is necessary.
- **BIO/CHEM 330:** Melanie Stryer, graduate student in BCB, worked with Dr. Jim Snyder in Chemistry to develop new modules for his molecular modeling course. She added more "in class" problems or exercises and a bioinformatics component. Additional new components: lecture on bioinformatics/the human genome project (adapted from a module Ms. Stryer used previously on graduate students); lecture on obesity that covered topics such as the genetic causes for obesity (leptin, PPARdelta); the metabolic rationale behind the Atkins Diet; and the structure of artificial sweeteners. Among other sources, Ms. Stryer adapted information from a series of lectures given by Howard Hughes investigators that can be found at http://www.hhmi.org/lectures/. Ms. Stryer used Biology Workbench (which offers centralized access to sequence alignment tools and secondary structure prediction tools, among others) to illustrate how bioinformatic tools can be used to understand the molecular basis of disease. Students explored GenBank (to find a DNA sequence), BLAST (to compare similarities in sequences), CLUSTALW (a sequence alignment tool) and Deepview (protein structure analysis tool). Students were then tasked to explore a disease of their own choosing using these tools. Ms. Stryer's problem sets and lectures are available at our website (http://ww.cse.emory.edu/chem330).

Bioinformatics and Biotechnology

Dr. Jaime Rheinecker (chemistry postdoc) developed and co-taught in a Bioinformatics and Biotechnology course with Dr. Chad Brommer (Biology Department). Students picked a disease or drug of personal interest. This would become their semester-long topic for applying what they were learning in class, developing a research proposal, giving research presentations as in a research lab setting, then, at the end of the semester, presenting a poster of their project at a poster session. Jaime coordinated collaborations between students and members of her lab that had knowledge specific to the given project. This allowed the students to meet one-on-one with a research scientist without the pressure of meeting with their teacher, and to see different types of research in the actual lab setting. The graduate student collaborators were invited to a few of the group meetings to contribute to the feedback. The students met with their collaborators on a regular basis to work on the research for their posters, but ultimately designed and prepared the posters by themselves. The lecture portion covered the mechanisms and methodologies used in biotechnology research for research of plants, animals, and microbes. This course involves some advanced genetics, biochemistry, physical chemistry, and computer skills. Students learn and utilize the basic concepts of biotechnology and bioinformatics to solve current issues in biomedicine, food production, and environmental science. Students design and conduct bioinformatics and biotechnology experiments in computer and wet labs. Emphasis will be on industrial and "public research" laboratory and management methodologies. Protocols highlighted include computer technology/software, micro arrays, proteomics, and tissue culture.

Computational Neuroscience

Graduate student Terrence Michael Wright, Jr. worked with Dr. Ronald Calabrese and Dr. Astrid Prinz to develop a simulations-based lab course in electrophysiology, BIO 470. This course consisted of lectures given by Drs. Calabrese and Prinz, and provided the students with a comprehensive survey of fundamental topics in cellular neuroscience. They used a program called Neurons in Action (Sinauer, 2007) for the majority of the course. We also wanted to provide students with an introduction to more advanced topics that are relevant to contemporary cellular neuroscience; namely mechanisms of central pattern generation, second messenger cascades and homeostatic regulation of ongoing neuronal activity. Since these types of simulations are not readily available in commercially available simulation environments, Michael developed new modules for the students. Using a freely available modeling package, WinPP (http://www.math.pitt.edu/~bard/xpp/xpponw95.html), Michael created models for these topics based on published models in the field that could be used as laboratory exercises for the students, as follows: a pair of reciprocally inhibitory oscillator neurons that underlie the timing of the leech heartbeat central pattern generator (Cymbalyuk *et al.*, 2001); a refined model on second messenger cascades in the R15 neuron of *Aplysia* (Yu *et al.*, 2004); and a model of homeostatic plasticity in the stomatogastric nervous system of decapod crustaceans (Liu *et al.*, 1998). Each of these models is flexible enough to allow the students to explore the models without a need for programing skills.

Life Science Calculus Series

Dr. Dwight Duffus developed the MATH 115-116 series over the past five years in consultation with biology faculty. The Biology Department will require students considering a major in biology to enroll in the MATH 115-116 sequence, designed specifically for life science majors, beginning Fall 2007. The calculus topics, examples, material on modeling and the probability & statistics component (in MATH 116) are particularly appropriate for the life sciences.

- **Math 215**: Aron Barbey (graduate student in Psychology) worked with Mike Ferrara (graduate student in Mathematics) to develop probability and statistics materials for a new MATH 215 course first offered in the spring of 2005. This new course provides a more extensive treatment of the statistical methods and analyses that support experimental research than provided by the earlier MATH 115 course. The course covers the probability theory needed to underpin inferential statistics, an introduction to experimental design, and thorough presentation of the Z-test, t-test, analysis of variance, and correlation and regression. The course provides an extensive treatment of the statistical analyses and methods commonly employed in experiment research, and presents these materials in a way that facilitates student learning (e.g., using PowerPoint presentations, graphical and diagrammatic representations, and hands-on student learning assignments). Mr. Barbey and Dr. Duffus taught the course in spring 2006.
- **CS 153**: This Computing for Bioinformatics course introduces tools of computer science that are relevant to bioinformatics, with a focus on fundamental problems with sequence data. Practical topics will include Perl programming, data management, and web services. The course emphasizes computational concepts.

Future Plans

Interdisciplinary Minors: Each minor will include cross-departmental mentoring and research experiences.

- **Computational Techniques in Biomedical Imaging:** Dr. James G. Nagy, Mathematics and Computer Science, will lead the development of a biomedical imaging concentration to complement existing courses in neuroscience and psychology. Beginning with a freshman seminar, students will use the MatLab computing environment to manipulate images. Dr. Nagy will adapt an existing course to use advanced topics in biomedical imaging and will develop an advanced course where students will work on interdisciplinary software projects.
- **Experimental and Computational Neuroscience:** A group of Biology and NBB professors, led by Drs. Dieter Jaeger, Astrid Prinz and Ron Calabrese, propose to develop an investigative experience for the introduction to neuroscience course, a junior seminar covering current research issues and intellectual challenges in neuroscience.
- **Informatics**: Biology, Chemistry and Mathematics faculty also plan an interdepartmental concentration in informatics. Math/CS will develop Introduction to Computing for Bioinformatics to introduce the tools and concepts relevant to biological sequence data. Advanced courses on new bioinformatics tools and paradigms would be appropriate for Math/CS majors, while biology majors might emphasize applying bioinformatics tools in genomics and proteomics.

Science Teaching Seminars and Practicums for Graduate Students and Postdocs in Biology and Mathematics

On-line Collaboratory for Undergraduate Education

National Symposium in Best Practices in Teaching Undergraduate Quantitative Methods (2009)

Computational and Life Sciences Strategic Initiative

Strategic Planning theme for the whole University
http://www.cls.emory.edu/

The convergence of Genomics, Synthetic Sciences, Systems Biology, and Informatics/Computational Science is rapidly transforming our ability to understand and positively influence our lives and where we live. The Computational and Life Sciences (CLS) Initiative at Emory establish a community of scholars that integrates the science disciplines and spearheads innovative methodologies that combine computational and synthetic approaches to science through the convergence of genomics, synthetic sciences, systems biology, and informatics.

This initiative will promote three breakthrough concentrations where Emory can achieve scholarly excellence and competitive distinction in the next few years: Computational Science and Informatics, Synthetic Sciences, and Systems Biology. Synergies will be leveraged among these three focus areas to excel in terms of scientific discovery, faculty programs, and facilities, and to become a driving force in education, basic and applied research, and knowledge transfer. As the result of this initiative, Emory will pioneer new modes of discovery and emerge as a leader in frontier science.

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