

## Reacting and Responding to *Bio2010* at Hope College

Hope College is a distinctive and distinguished four-year, liberal arts, undergraduate institution known and respected for excellence in science and mathematics. Hope's current enrollment is 3100 undergraduate students. The Division of Natural Sciences at Hope includes the departments of Biology, Chemistry, Computer Science, Geological & Environmental Sciences, Mathematics, Nursing, and Physics & Engineering, and totals over 60 FTE faculty members. Hope College has a long-standing commitment to provide students opportunities to learn cutting-edge science in coherent and rigorous laboratory courses that stress hands-on, research-based modes of learning, and to work in a collaborative manner with faculty members in research. About 40% of students entering Hope express a strong interest in science and mathematics. Although we do not require research for graduation, about 85% of Hope science, technology, engineering and mathematics (STEM) majors participate in research. We typically have 125 students conducting full-time research each summer in science and mathematics. Many of these students are

funded by 6 separate National Science Foundation (NSF) Research Experiences for Undergraduates (REU) site awards to the college. Hope ranked in the top 6% in the nation in producing future Ph.D. recipients between 1920 and 1985. The Division of Natural Sciences at Hope is recognized by Project Kaleidoscope as a whole "Program that Works" and as a model for other institutions.

The Biology Department at Hope College is comprised of 12 faculty members, two of whom have joint appointments in the Chemistry Department. We offer both the B.A. and the B.S. degrees in Biology, with the majority of our students opting for the B.S. degree. We typically graduate 30-50 students annually with about a third going to professional school, a quarter to a third enrolling in graduate school, and the remainder going to teach at the secondary level, working in industry or gaining employment in a sundry of other options. In 1997 we began teaching a four course core in biology.

The core began with the tier one course, Biological Unity and Diversity. The course attempted to reveal the patterns that have



Undergraduate students participating in a multidisciplinary research project focused on the ecology of plant-fungus-insect interactions. Students are assessing reproduction of aphids that had been feeding on plants infected with or lacking a fungal endophyte. Support from NSF-CRUI.

emerged during the evolution of life and to introduce students to concepts in cell biology, genetics, and evolutionary biology. This course was followed by three tier two courses: Cells and Genetics, Organismal Biology, and Ecology and Evolution which built on the information learned and skills gained in the tier one course. Implementation of the core was a major undertaking as each of the four courses was a new course, built from the "ground up." The core was our attempt to better accomplish our mission of providing students with a broad foundation in biology. The four course core functioned well in many respects. We found that our students were far better prepared for upper level elective courses: their ability to read the primary literature, to write scientifically and to utilize specialized instrumentation all improved with the new core. Nonetheless, our continued assessment of the core courses revealed that some modifications were needed. Concurrently, the National Research Council (NRC) published *BIO2010: Transforming Undergraduate Education for Research Biologists* (NRC, 2003), which came to be known as the *Bio2010* report.

Our initial reaction to the *Bio2010* report was similar to that of many biologists – It was too narrowly focused. It did not give enough consideration to the important disciplines of ecology and evolution. It was written by individuals who probably were not teaching introductory biology. It did not consider real restraints on teaching. There was no advisory committee on biology. Biomedical science cannot be allowed to drive the curriculum. And more. However, as we became more familiar with the content and recommendations of the *Bio2010* report, as we followed the discussions of the report in the literature, and as we talked among ourselves we came to realize that the *Bio2010* report did have a lot to offer, particularly as we continued to rethink our curriculum and approach toward teaching biology. We also had the happy realization that we were already doing much of what was recommended in the report, such as investigative laboratories and undergraduate research and that our core courses in biology reflected the central themes of biology noted in the report.

The content of the *Bio2010* report did help guide much of the more recent changes to our curriculum. We dropped the Biological Unity and Diversity Course, a course more focused on traditional biology, to allow our students to begin taking upper level courses in STEM disciplines sooner. We increased the quantitative emphasis in our courses, having our students utilize a variety of mathematical techniques (matrix algebra, statistics, graphing) in all of our core

courses. With our colleagues in other departments we continued our development of interdisciplinary courses in math and biology (Mathematical Biology), computer science and biology (Bioinformatics), and biology, chemistry and psychology (Introduction to Neuroscience). At this point, our biomedical related courses and our other courses in biology have been equally impacted by the *Bio2010* report recommendations. At the same time, we have tried to resist the skewing of our curriculum in a biomedical direction. Many of our biology majors do go on to careers in the biomedical sciences but many others go on to careers in secondary science education, botany, zoology, ecology, field biology, nature education, and the like so we work to insure that all biology majors have a balanced experience with biology, particularly at the introductory level. In order to take almost any of our upper level courses in biology, students must have taken our sophomore level course in ecology and evolution. We believe strongly that an understanding of these areas of biology is essential for future physicians and biomedical scientists as well as other types of biologists.

While the Biology Department was considering how it might respond to the recommendations of the *Bio2010* report, the Natural Science Division as a whole was also thinking about the future. This thinking was initiated in part by an invitation from the Howard Hughes Medical Institute (HHMI) to apply for an Undergraduate Science Education Program grant. This grant program is aimed at strengthening science education, particularly in biology and ancillary sciences, at the college level. A second goal is to increase the number of individuals going into teaching and research careers in science. The Science Division had been the recipient of two previous Undergraduate grants from HHMI that had led to significant improvements in our programs. We were thus eager to apply for a third award.

Our discussions related to a grant application were led by Dr. James Gentile, then Dean for the Natural Sciences at Hope and currently the President of Research Corporation. Dr. Gentile organized a committee consisting of faculty members from the various departments in the Natural Science Division and a faculty member from the Psychology Department, which resides in the Division of Social Sciences at Hope. The work of the committee was informed from the beginning by the *Bio2010* report. In this regard, we were very fortunate that Dr. Gentile had been one of the members of the National Research Council's Committee on Undergraduate Biology Education to Prepare Research Scientists for the 21st Century, the committee that authored the *Bio2010* report. Thus the idea of making interdisciplinary teaching and

research the theme of our HHMI grant proposal was put on the table early. However, this was not the only idea we considered. Other themes that we discussed included a more specific focus on biomedical and health related issues and a focus on making the laboratory component of all of our courses project based. But time and time again, Dr. Gentile reminded us of the recommendations of the *Bio2010* report and our own success with an interdisciplinary approach in our non-majors science and math courses at Hope.

Our non-majors science and math courses were changed following a major revision of the general education program at Hope in 1998. During this revision we moved from offering discipline specific non-majors courses in science to interdisciplinary courses in a separate program known as General Education Math and Science (GEMS). There are three types of GEMS courses – four credit hour interdisciplinary science courses, two credit hour laboratory science courses, and two credit hour mathematics courses. The four credit hour courses include both lecture and laboratory components, are designed by faculty in at least two departments in the Division of Natural Sciences, and involve significant consideration of at least two science disciplines and an emphasis on quantitative reasoning. The development of these courses was supported by our second HHMI award and this process helped move the faculty to a greater understanding and appreciation of the value of the interdisciplinary approach in STEM fields. In the end, our decision on a theme for our HHMI grant proposal grew out of a realization that our success in using an interdisciplinary approach for non-science majors could be replicated for our STEM major programs and that this approach would move us toward meeting the recommendations of the *Bio2010* report.

We considered three approaches to this theme. One was to develop an interdisciplinary science major. This idea was quickly rejected when we learned that such majors had difficulty finding employment. The second idea was to develop interdisciplinary introductory courses, which would replace courses such as introductory chemistry and introductory biology. Although this approach has worked well at some institutions, we decided the strengths of the disciplinary approach might be too diluted and that there were too many other issues, such as medical school requirements, to allow us to offer such courses at this time. The third approach and the one we adopted was to incorporate interdisciplinary modules into all of our introductory level STEM courses and to develop two new interdisciplinary science minors, neuroscience and computational science and modeling. As we



Students Cheryl Jacobs and Xiao Bai with faculty mentor Dr. Virginia McDonough and research associate Dr. Joseph Stuke. Aims of the laboratory are to determine how cells incorporate fatty acids from their environment and subsequently localize and metabolize them.

continued our discussion of the modules for the introductory level courses, we decided to utilize a case study approach or, more accurately, an investigative interdisciplinary case study approach. Our committee was guided in this by committee member, Dr. Joanne Stewart, Professor of Chemistry at Hope. In addition to the use of case studies in our introductory courses and the new minors, our proposal included the development of interdisciplinary courses at the advanced level, support for initiating or sustaining interdisciplinary research teams, as well as support for student research, training of pre-service K-12 teachers, and a postdoctoral fellow program.

We were very grateful to receive an award in 2004 from HHMI for our proposed projects. To date, we have been able to utilize this award to begin to meet some of the recommendations of the *Bio2010* report. Our Neuroscience Minor was approved by the Hope Curriculum Committee in 2005. We have established a high end computing facility that will serve to support the Computational Science and Modeling program as well as other computation needs of research and courses in STEM fields. We have developed interdisciplinary case studies for several introductory courses, such as a case study on vision for physics and biology, a case study on enzymes for biology and organic chemistry, a case study on alcohol dependency for biology and psychology and a case study on the global carbon cycle for general chemistry and biology. The development of these case studies was facilitated through workshops organized and run by Dr. Stewart, who was named the Director of Integrative Studies in the Sciences. It is important to note that such workshops are vital for the successful development and use of interdisciplinary case studies as faculty members need time to reflect on their own and other STEM

disciplines and on what interdisciplinarity means. In addition, faculty members must come to value an interdisciplinary approach before they can be asked to devote time in their disciplinary courses to approaches/topics of other STEM disciplines.

In addition to the case studies, our *Bio2010*-informed HHMI grant has supported the development of several interdisciplinary courses including Advanced Neuroscience Research and Marine Biology and Biophysics. Interdisciplinary research programs in biology and computer science; biology, chemistry and mathematics; and chemistry and geological and environmental science have also been initiated with support from the HHMI grant. These research programs bring together both faculty and students from different STEM departments at Hope to study important topics at the interface of disciplines. The methods and results of these research projects are also being incorporated into upper level courses at Hope, further integrating research and teaching.

As we carry out the initiatives supported by our HHMI grant, we are working to develop and utilize assessment methods to provide us with information about the impact of these programs and ways in which they are or are not meeting our goals. This assessment information will help drive our efforts to further soften, if not break down, barriers between disciplines so that we can better prepare our students, both those with biomedical interests and those with other interests, for the future of science and to more fully meet the recommendations of the *Bio2010* report.

The Biology Department at Hope College, as well as the Division of Natural Sciences at Hope as a whole, at first reacted to the *Bio2010* report in a neutral, if not negative way. Eventually we came to understand how a consideration of the recommendations of the *Bio2010* report could have a positive impact on our STEM programs at Hope. Having a strong proponent of *Bio2010* on campus in the person

of Dr. Gentile did impact how quickly we moved from reaction to response. A key feature of this transition was the time and space for faculty members with an interest in science education to come together for discussion. In responding to the invitation from the Howard Hughes Medical Institute to apply for an award, we had the extra impetus to make that discussion occur. Our programs in STEM fields at Hope have been altered by that discussion and new initiatives and we trust that our students are benefiting from those changes. Making time for STEM faculty at institutions to have meaningful conversations about the *Bio2010* report can be an important step in moving institutions from reaction to response.

#### References

National Research Council, Committee on Undergraduate Biology Education to Prepare Research Scientists for the 21st Century. *BIO2010: Transforming Undergraduate Education for Future Research Biologists*. Washington, DC: The National Academies Press; 2003.

#### Thomas L. Bultman

Department of Biology  
 Hope College  
 Holland, MI 49423  
 EM: bultmant@hope.edu

*Christopher C. Barney, Ph.D., is the T. Elliot Weier Professor of Biology at Hope College. He served as the Chairperson of Biology for 5 years and the Director or Co-director of the Biology Department REU program for 12 years. He currently serves as the Director of the Hope College HHMI Program. He and the undergraduate students in his lab do research in the areas of thirst and water balance, the control of metabolic rate and body temperature, and blood pressure regulation in collaboration with Dr. Maria Burnatowska-Hledin and Dr. Greg Fraley.*

*Thomas L. Bultman, Ph.D., is Chairperson and Professor of Biology at Hope College. He is a biology councilor in CUR and the PI of NSF-CRUI and NSF-MRI awards, and co-PI of an NSF-REU award. His research deals with the multidisciplinary study of the ecology of plant-fungal-insect interactions in which he collaborates with a plant physiologist, a population geneticist, an analytical chemist, and a mathematician.*