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Biomedical informatics training at Stanford in the 21st century

Russ B. Altman *, Teri E. Klein

Department of Genetics, Stanford University Medical Center, L-301 Stanford, CA 94305-5120, USA

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Abstract

The Stanford Biomedical Informatics training program began with a focus on clinical informatics, and has now evolved into a general program of biomedical informatics training, including clinical informatics, bioinformatics and imaging informatics. The program offers PhD, MS, distance MS, certificate programs, and is now affiliated with an undergraduate major in biomedical computation. Current dynamics include (1) increased activity in informatics within other training programs in biology and the information sciences (2) increased desire among informatics students to gain laboratory experience, (3) increased demand for computational collaboration among biomedical researchers, and (4) interaction with the newly formed Department of Bioengineering at Stanford University. The core focus on research training—the development and application of novel informatics methods for biomedical research—keeps the program centered in the midst of this period of growth and diversification.

Keywords: Biomedical informatics training; Stanford University; Biomedical computation; Ontologies; Simulation; Bioinformatics; Clinical informatics; Public health informatics; History

1. Introduction

Stanford's Biomedical Informatics (BMI, http://bmi.stanford.edu/)[1] training program evolved from the Medical Information Sciences (MIS) program started in the early 1980s. At the time of its founding, this program was focused on clinical informatics, and more specifically, on decision support and artificial intelligence applications in medicine. It was started in response to a need for training at the intersection of computer science and biomedicine. Even before the program started, Stanford had developed a milieu in which computer applications in the natural sciences already existed: the DENDRAL project focusing on the interpretation of mass spectroscopy data preceded the founding of the program [1], and concurrently with the program there exited computational biology projects aimed at planning molecular biological experiments (MOLGEN [2]) and interpreting X-ray crystallographic data (CRYSALIS [3]), among others. These projects were conducted with graduate students from computer science and biosciences, and the formation of the MIS program promised to create a cadre of students particularly well suited to these projects. Shortly after the program was started, new research efforts focusing on molecular biology emerged including a second generation of MOLGEN (MOLGEN II [4]), and the PROTEAN project [5], which aimed to interpret NMR data for the determination of protein three-dimensional structure. During this time, projects related to clinical medicine also thrived, including the MYCIN projects to diagnose and treat clinical infections [6], the ONCOCIN projects to manage cancer therapy [7], the RX project in data mining of rheumatological disease databases [8] and others.

In the early 1990s, the core faculty within the MIS program was expanded to work in basic molecular biology. The increased breadth of application areas stemmed from the explosion of molecular biological information and increased NIH interest in training for genomics and molecular medicine. The core faculty reasoned that the curriculum (which had successfully trained students for ten

* Corresponding author. Fax: +1 650 725 3863.
E-mail address: russ.altman@stanford.edu (R.B. Altman).
[1] http://www.smi.stanford.edu/academics/.

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years) could evolve to accommodate increased diversity in biomedical application domains. Thus, for example, the requirement for human physiology was generalized to include any appropriate coursework within biology. The focus on decision science was generalized to include more offerings in statistics and probability. The computer science curriculum was liberalized to require only the most basic courses (data structures and algorithms, and machine learning) and to allow students to craft the rest of their program to match their interests. These changes allowed the program to train students in very diverse application areas ranging from 3D molecular structure determination to electronic medical records to automated analysis of radiological images. Students took two years of 50% coursework and 50% research. The faculty believed that the joint training was a strength because (1) it prepared students for a wide range of application opportunities after graduation, and (2) it allowed students to see the underlying methodological similarities across biomedical informatics (particularly in schema design, knowledge representation, machine learning, and data mining). The faculty acknowledged that certain algorithmic methods play important roles in certain application domains such as the importance of dynamic programming methods in sequence analysis, the role of computational geometric methods in 3D structure and radiology, and the complexities of representing processes in clinical guidelines.

By the mid-1990s, the "traditional" core MIS classes introducing clinical decision systems, clinical record systems and clinical databases were supplemented with courses introducing computational molecular biology and computational analysis of imaging data. The ability quickly to re-engineer the original curriculum for bioinformatics and the relatively early recruitment of bioinformatics oriented faculty gave Stanford an initial advantage for attracting students in bioinformatics. Before other institutions could create new programs, Stanford had 10 years of informatics-applied-to-biomedical domain experience, and for a number of years achieved nearly 100% recruitment of accepted students.

Around 1998, the program noted for the first time that students with a stated interest in biological applications outnumbered students with an interest in clinical applications. This reflected the excitement in the scientific community surrounding the genome sequence projects, the emergence of high-throughput genomic data sources (such as microarray expression chips), and the early-adoption of the world wide web by biological databases. In 2000, the MIS program was renamed to "Biomedical Informatics" (BMI) to recognize the broader mission of the program. The curriculum was again examined and relaxed further, in order to accommodate a broad range of interests. Nevertheless, the five core pillars of the curriculum (core biomedical informatics, computer science, probability and statistics, domain biology, and ethical/legal/social implications) and the amount of time spent on each has remained virtually constant since 1982.

2. Biomedical informatics at Stanford today

Biomedical Informatics at Stanford is an interdepartmental degree-granting program (IDP, reviewed by a University-appointed quality control committee every five to eight years since its inception). BMI graduates from Stanford recently have been successful in the academic job market. The focus on academic training, and the depth of learning in the contributing related academic fields has created a cadre of graduates who feel comfortable working in departments with both biologists and computer scientists. They thus straddle the field, can communicate with those trained in traditional disciplines, and are often in an excellent position to lead collaborative efforts. In the last five years, our PhD graduates have been offered faculty positions immediately upon graduation, by departments at Harvard, Duke, UC Santa Cruz, U. Michigan, Princeton, U. Pittsburgh, Penn State, Stanford, UC Irvine, U. Beijing and others, who recognized that these scientists would immediately strengthen the local biomedical training and research milieu. Some graduates have pursued post-doctoral training in biological labs. There have also been students electing to pursue industrial consulting, law school, and biotech-oriented startups.

The great interest at the undergraduate, graduate and post-graduate level in biomedical informatics has led our program to offer a wider set of study options, to meet different needs. The core of our training program is research training in biomedical informatics at the graduate level for PhD students, and MS students who engage in significant research projects. We have added five additional options within the last few years. First, we have established an online professional MS degree that has the same course requirements as our "academic" research MS, but removes the requirement for research. This program is meant for students who are employed full time, have support of their supervisors, and wish to add an MS credential through part-time study over three to five years. We are in our third year of this program, with approximately eight students. These students must enter with significant biological or medical backgrounds, because our online offerings concentrate mostly on the technical content in computer science and statistics/probability. Second, Stanford has a mechanism for undergraduates to add MS training to their experience as part of a "coterminal" MS degree, awarded at graduation along with their undergraduate degree. This degree has the same requirements as the distance learning MS. While research is not required, most students do engage in research. We have had four to six students per year for the last three years. Coterminal MS degree recipients have gone to industry as well as to further PhD or MD training. Third, we have created a series of certificate programs where students can take coherent subsets of our course offerings online (or in person if they are local) and receive certificates in bioinformatics, clinical informatics, and genomics. Fourth, we have worked with faculty in the School of Engineering to create a pre-approved