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Research and Education

Medical Informatics Training and Research at Columbia University

Introduction

The medical informatics training and research environment at Columbia University has evolved considerably since we last wrote about our program for the Yearbook of Medical Informatics in 1995 [1]. In this article we provide a summary of the current state of the research and educational programs, beginning with their historical base, proceeding to the philosophical perspective on which the department is built, and closing with a discussion of the degree programs and curriculum.

Departmental Roots and Growth

Columbia's Department of Medical Informatics was formed in 1994, emerging from the previous Center for Medical Information Science that had been created in the late 1980s when Dr. Paul Clayton had been recruited to Columbia from LDS Hospital and the University of Utah. Under Dr. Clayton's leadership, the Center had attracted IAIMS funding from the National Library of Medicine [2, 3] and, by the early 1990s, had developed a systems architecture and had implemented a clinical information system that was in routine use by clinicians at Columbia Presbyterian Medical Center [4]. Our faculty and staff were also major contributors to research projects such as the Arden Syntax for Medical Logic Modules [5], the Unified Medical Language System [6, 7], and the Health Level 7 standard for medical data interchange [8].

As the Center matured as an organization for academic research and training as well as for clinical service, its faculty grew in number and breadth of expertise. Beginning in 1993, we began enrolling our post-doctoral students in courses of study leading to the MA, M Phil, and PhD degrees in Medical Informatics, and in 1995 we enrolled our first group of pre-doctoral students. By 1994, it was reasonable to propose the creation of a formal department and of a degree program to grant masters and PhD degrees in medical informatics. At the time of our previous article, this degree program had just been established and we had begun converting our training program to one that began to emphasize formal degree training rather than post-doctoral fellowships. We developed a curriculum in medical informatics and graduated our first PhD student, Dr. Justin Starren (now a member of our faculty), in 1997. Our first MA degree[1] was granted that same year. The department constitutes one of only a handful of university informatics departments in the US (it was the second when it was formed in 1994) and the only formal medical informatics education program in the New York Metropolitan Area.

An important feature of our department has been our link to the Clinical Information Services of the Columbia Presbyterian Medical Center (one campus of the New York Presbyterian Healthcare System since the merger of our hospital with Cornell Medical College's hospital in 1995). The department chair serves as Director of this hospital service, and our faculty members contribute innovations for the hospital's clinical information systems. A number of faculty members have full-time responsibility for operational systems. This close link is a major strength of our setting, for it allows trainees the opportunity to develop and evaluate projects in the context of a working hospital information system.

Since early 2000, several additional training changes have taken place as a result of the recruitment of Dr. Edward Shortliffe as Professor and Chair of the department. He assumed the position that Dr. Clayton had vacated when he returned to Utah in 1998. Dr. Shortliffe had created

[1] Columbia's Graduate School of Arts and Sciences offers MA rather than MS degrees.

the graduate training program in medical informatics at Stanford University in 1983, and therefore brought with him almost 20 years of experience in directing and evolving the degree program at that institution. The Columbia training program now reflects many changes in philosophy and organization that Dr. Shortliffe has instituted, including a requirement that essentially all trainees, including health-professional post-doctoral students, be formal degree candidates. Dr. Stephen Johnson continues as Director of Graduate Training, working closely with Dr. Shortliffe to implement the changes we have made and that we describe below. They are aided by a Training Executive Committee that oversees all educational programs in the department.

A Perspective on Medical Informatics

The Department of Medical Informatics (referred to as the DMI hereafter) has developed a reputation as a major center for research and education in clinical applications of informatics methods. One of Dr. Shortliffe's goals, with its implementation already underway, is to broaden the training and faculty expertise to include other areas of application. We view the phrase *medical informatics* as describing a set of methods, techniques and theories that have broad applicability in biomedicine (see Figure 1). Some people prefer to call the field *biomedical informatics* (choosing a term that seems to be more inclusive of the biological sciences), whereas others use the term *health informatics* (to use a term that is less tied to physicians and the traditional medical model of disease and treatment). But regardless of the terminology adopted, we are referring to an underlying science with associated methods and techniques. Thus a researcher or graduate student in our department is expected to develop new knowledge at that level – typically new methods that may be motivated by a single problem in biomedicine but that may in turn have broad applicability in other areas of biomedicine or even in totally different fields. Scholarly work in medical informatics is inherently motivated by problems encountered in a set of applied domains in biomedicine. Perhaps the first of these historically has been clinical care (including medicine, nursing, dentistry, and veterinary care), areas of activity that demand patient-oriented informatics applications. We refer to this area as *clinical informatics* and recognize that it is the field in which our department has had its greatest activities and impact in the past.

Closely tied to clinical informatics is *public health informatics* (Figure 1), in which similar methods are generalized for application to populations rather than to single individuals. Thus clinical informatics and public health informatics share many of the same methods and techniques. We also identify two other large areas of application that overlap in some ways with clinical informatics and public health informatics. These include *imaging informatics* (and the set of issues developed around both radiology and other image-management and

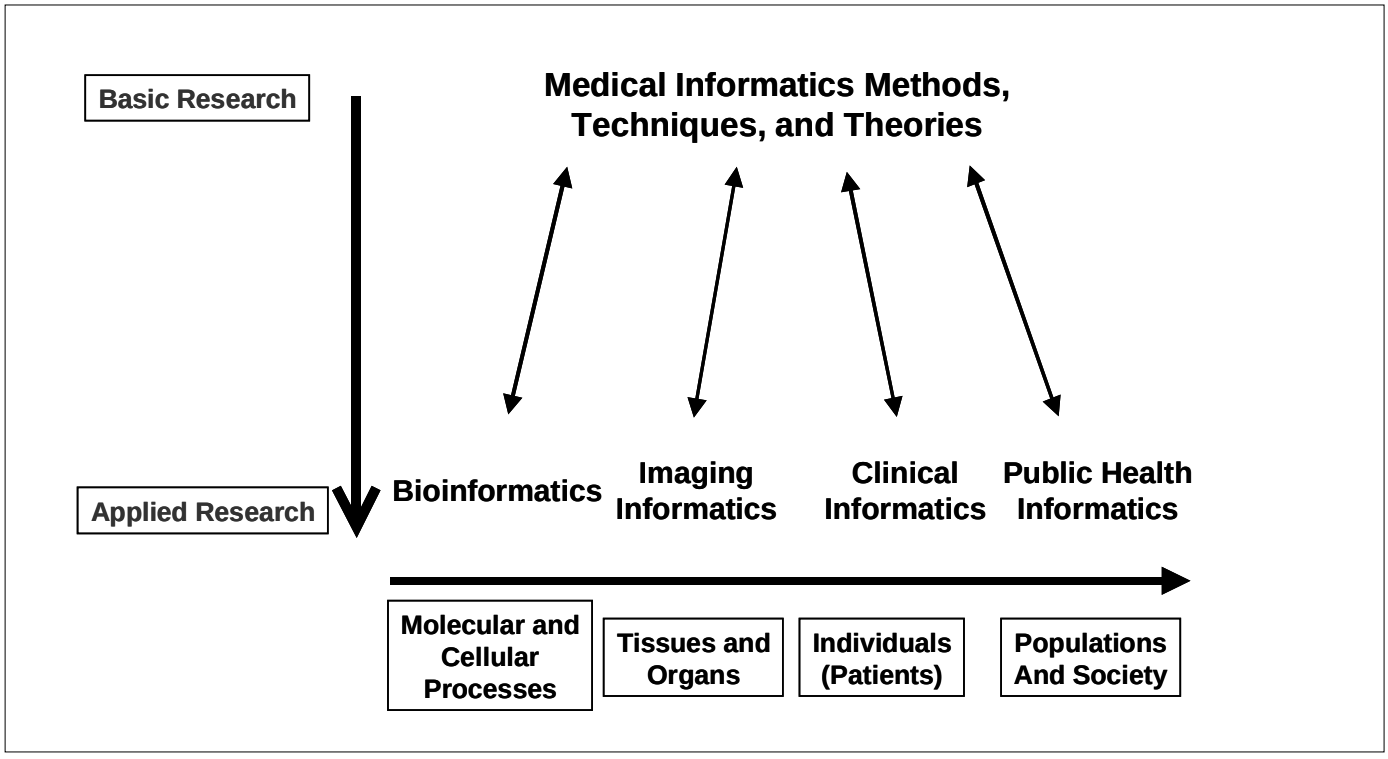

Fig. 1. The relationship of Medical Informatics to its Areas of Application

image-analysis domains such as pathology and dermatology). Finally, there is the burgeoning area of *bioinformatics*, which at the molecular and cellular level is offering challenges that draw on many of the same informatics methods as well.

As is shown in Figure 1, there is a spectrum as one moves from left to right across these application domains. In bioinformatics, workers deal with molecular and cellular processes in the application of informatics methods. At the next level, workers focus on tissues and organs, which tend to be the emphasis of imaging informatics work. Progressing to clinical informatics, the focus is on individual patients, and finally to public health, where researchers address problems of populations and of society. Thus there is a natural spectrum as suggested in the diagram, and informatics has important contributions to make across that entire spectrum. We accordingly believe that training in medical informatics requires a basic education in all four of these areas of application, followed by opportunities for specialization in one of them. Our redesigned curriculum reflects this plan, as do our current activities in faculty recruitment and departmental reorganization.

We emphasize that we see medical informatics as more than medical computer science. Good work in informatics does often contribute new knowledge to computer science, and medical informatics researchers have sometimes developed generalized computational methods and techniques that have had broad applicability, even outside the area of biomedicine. But there are other component sciences as well, including mathematics/statistics and decision science, cognitive science, information science, and management science. Properly exposing students to these diverse fields, while assuring that they become especially competent in at least one, is a major challenge in informatics curriculum design.

Collaborations at Columbia

Columbia Presbyterian Medical Center (CPMC) is one of the largest voluntary hospital centers in the country, with over 1100 beds. It is located in the Washington Heights/Inwood section of northern Manhattan and is the only major medical center in this area. The population served is disproportionately composed of racial and ethnic minorities and the poor. The DMI is a department in the College of Physicians and Surgeons, one of the four schools in the Health Sciences Division of Columbia University, all of which are co-located with the hospitals and clinics of CPMC. We have close ties with programs and individuals in all the other Health Science schools:

- *School of Dentistry and Oral Surgery* - John Zimmerman, DDS, is one of our faculty members and oversees the dental informatics component of our training program.
- *School of Nursing* - Suzanne Bakken, RN, DNSc is jointly appointed in our department and is closely involved with both our research and teaching programs.
- *School of Public Health* - Rita Kukafka, DrPH, MA, is jointly appointed in DMI and the Division of SocioMedical Sciences in the School of Public Health; she is taking the lead in designing the public health informatics components of our curriculum.
- In addition, we have an active, ongoing relationship with the *Columbia Genome Center*. Our first bioinformatics faculty member, Andrey Rzhetsky, PhD is jointly appointed in the Genome Center and has his laboratory space in that building. We are recruiting three more faculty members in bioinformatics to work at the interface between DMI and the Genome Center. All faculty, plus their students, will be located in the Genome Center so that they can work closely with other scientists there.
- We also coordinate closely with the *Computer Science Department* in the Fu School of Engineering on the main Morningside Heights campus of Columbia University. Dr. Shortliffe has an appointment in that department, and we cross-list some of our courses in order to expose computer scientists and undergraduates to medical informatics topics. There are also several collaborative research projects between members of the two departments, including a large digital libraries project on which the principal investigator is Kathy McKeown, PhD (Chair of Computer Science) and for which several collaborators and experimental sites are drawn from the DMI and the health sciences campus.
- There are strong ties between the DMI and the *Department of Psychiatry*, with joint training opportunities and research collaborations. Our Division of Decision Making and Cognition, directed by Vimla Patel, PhD, sits at the interface between these two departments (in which she holds joint appointments), and her research group is actively involved in both research and education related to psychiatry and informatics.
- Our department is the home for Columbia's *Center for Advanced Technology* (CAT) *in Information Management*, funded by the State of New York through the NY State Office of Science, Technology, and Academic Research (NYSTAR). This program funds 15 centers in the state, each devoted to technology transfer activities aimed at creating new economic opportunities in New York. Dr. Shortliffe is director of Columbia's CAT, with Dr. James Cimino from DMI and Prof. Kathy McKeown from computer science as the co-directors. The deputy director, Dr. Vincent Tomaselli, oversees the day to day operation of the CAT, including its internal grants

program. Because the CAT is a collaboration among the DMI, Computer Science Department, and the Columbia Genome Center, it is an explicit indication of the active cross-disciplinary links that characterize our research and training environment.

- We have a close and important relationship with the Office of Scholarly Resources and the Health Sciences Library on our campus. Directed by Pat Molholt, MLS, PhD, the Office of Scholarly Resources has major research projects in educational visualization and provides an important site for projects by our students. Dr. Molholt and her colleagues, Dr. Hilary Schmidt and Dr. Celina Imielinska, have also been important contributors to our educational programs.
- We also have forged new but promising relationships with the New York Academy of Medicine (NYAM). The NYAM is the regional medical library for our part of the country, and it also has an active research program in urban health. With a large continuing education program and well-established ties into the community, including the public schools, the Academy is a promising site for collaborative research applying information technology to problems in urban health and information delivery to clinicians. Our newest faculty member, Dr. Maxine Rockoff, is based at the NYAM and leads the informatics research programs there.
- Finally, we have close ties with many of the clinical departments in the College of Physicians and Surgeons. Many of our faculty members have joint appointments in other medical school departments including Medicine, Anesthesiology, Psychiatry, and Radiology. Furthermore, since Dr. Shortliffe sits on the committees for the chairs of clinical departments, he interacts regularly with the chairs of all the other clinical departments on our campus. Interestingly, he also sits on the committees for basic science chairs because the DMI, unlike most clinical departments, has a strong graduate training mission. This has allowed opportunities for frequent interactions with basic scientists, leading to the ties to the Columbia Genome Center and to computational biologists at Columbia.

The Columbia Program Today

The training program at Columbia has been funded by the National Library of Medicine since 1992. Initially aimed solely at support of post-doctoral trainees, the NLM support was broadened since 1997 to include pre-doctoral trainees as well. Our program is large (we currently have 51 degree candidates), and many of our students are not supported by the NLM training grant. The grant has played an important role in attracting eligible applicants and in facilitating their ability to pursue innovative research topics once they arrive at Columbia.

The design of our program reflects our belief that the evolution of the field of medical informatics, the need for trained informatics professionals, and the unique opportunities available at Columbia make it incumbent upon us to accept a wide range of responsibilities for training students in this area. Our decision to require formal degree programs of almost all trainees reflects a philosophical commitment to the development of medical informatics as a scholarly academic discipline as well as a field of practical importance in biomedicine. We believe that research leaders in the field will require broad formal course exposure in addition to intense research training.

Working with Leslie Perreault, MD, a graduate of the Stanford informatics training program, Dr. Shortliffe has collaborated with Drs. Gio Wiederhold and Lawrence Fagan to publish the second edition of a textbook in medical informatics [9]. This book was developed in response to the need for an introductory text in the field and has been adopted as the principal text for our first course for graduate students.

Our core faculty, all of whom have primary or secondary appointments in the Department of Medical Informatics include:

Edward H. Shortliffe, MD, PhD, (Professor and Chair)
George Hripcsak, MD, MS (Associate Professor and Vice Chair)
Suzanne Bakken, DSc, RN (Professor; also in School of Nursing)
Randolph C. Barrows Jr., MD, MS (Assistant Professor)
James J. Cimino, MD (Associate Professor)
Bruce H. Forman, MD (Assistant Professor)
Carol Friedman, PhD (Professor; also Professor of Computer Science at Queens College)
Celina Imielinska, PhD (Associate Research Scientist)
Robert A. Jenders, MD, MS (Assistant Professor)
Stephen B. Johnson, PhD (Associate Professor)
David Kaufman, PhD (Associate Research Scientist)
Rita Kukafka, DrPH, MA (Assistant Professor)
Yves Lussier, MD (Assistant Professor)
Pat Molholt, MLS, PhD (Senior Lecturer; Associate Vice President for Scholarly Resources)
Vimla L. Patel, Ph.D. (Professor; also Medical Psychology in Department of Psychiatry)
Maxine L. Rockoff, Ph.D. (Senior Lecturer)
Andrey Rzhetsky, PhD (Assistant Professor; also Investigator in Columbia Genome Center)
Soumitra Sengupta, PhD (Assistant Professor)
Justin Starren, MD, PhD (Assistant Professor)
David Wajngurt, MD, MA (Assistant Professor)
John L. Zimmerman, DDS (Associate Professor; also in School of Dentistry)

We also have several participating faculty who teach in our courses, work

closely with students, and/or perform research that attracts our trainees to their laboratory:

Conrad Gilliam, PhD (Professor, Genetics; also Director, Columbia Genome Center)
Richard Goldstein, MD (Assistant Professor, Medicine)
Donald P. Harrington, M.D. (Consulting Professor; Professor and Chair, Department of Radiology, SUNY Stony Brook)
Barry Honig, PhD (Professor, Biochemistry and Molecular Biophysics)
Desmond Jordan, MD (Associate Professor, Anesthesiology)
Andrew F. Laine, DSc (Associate Professor, Biomedical Engineering and Radiology)
Kathleen R. McKeown, PhD (Professor and Chair, Computer Science)
William S. Noble, PhD (Assistant Professor, Computer Science; also Investigator in Columbia Genome Center)
Burkhard Rost, PhD (Associate Professor, Biochemistry and Molecular Biophysics)
Hilary J. Schmidt, PhD (Assistant Vice President for Scholarly Resources; Assistant Professor, Psychiatry)
Lynn Vogel, PhD (Adjunct Assistant Professor in DMI; Vice President, Information Technology, New York Presbyterian Healthcare System)

Our students are free to identify other research mentors from any part of the university, and many have attracted the supervision of faculty from other parts of the medical school or the engineering school.

In recent years, an increasing number of trainees have developed interests in biomedical imaging and have wished to pursue research and dissertations in this area. We have accordingly developed a more formal track in imaging informatics, building on cooperation between our department and the new Department of Biomedical Engineering, which was created in the last year as a joint department between the engineering school and the medical school. Our program has also collaborated closely with other departments in the health sciences and the engineering school to develop a new Center for Computational Biology and Bioinformatics. We have a dynamic and growing environment for bioinformatics research and education, with three additional faculty recruitments underway in this area. Finally, in an effort to build a program in public health informatics, we have partnered with the School of Public Health to recruit a new faculty member, Dr. Rita Kukafka, with a joint appointment between that school and the DMI.

The Training Program

It is our goal that Columbia help shape the evolving discipline of Medical Informatics by establishing a rigorous, academically-oriented training program that offers complementary exposures to real-world systems, in clinical settings here at CPMC, in public health projects in the community, and in the biological sciences. Our training program seeks to further the development of the field, and the quality of future research, by demonstrating to its students, and to the biomedical community, that medical informatics addresses fundamental issues of biomedical knowledge and information, their representation, and their biomedical application. We have accordingly developed a curriculum that assures that our graduates will be familiar with a broad range of pertinent topics in the field. Each trainee then selects an area of subspecialization, with the established tracks being clinical informatics, public health informatics, imaging informatics, or bioinformatics. Our degrees generally require a minimum of two years for the MA and four years for the PhD, although most students take longer as described below.

We offer two types of MA degrees. Some students take an Applied MA (AMA), which principally consists of course work followed by a final project. Trainees in the AMA program are often employed outside the University, and participate in the degree program on a part-time basis. They may take 2-3 years to complete their training. We offer a second MA degree, referred to as our Research MA (RMA), which requires a full-time commitment to study and approximately half-time involvement in research from the time of entry into the program. Students generally require three years to obtain this degree. The majority of our post-MD post-doctoral trainees have been RMA degree candidates. Research training is a key element in our program's design for RMA and PhD candidates.

We put heavy emphasis on written and verbal presentation of research results, including experience adapting such descriptions to varied audiences. Our weekly student seminars are given by trainees, as are many research colloquia. In addition, RMA and PhD students typically write several papers before they graduate.

All students (both RMA and AMA trainees before graduation, and PhD students before they can apply for doctoral candidacy in their third year) are required to take a DMI oral examination, generally at the end of their second year. This exam is designed to assure that the student has synthesized the diverse topics of the DMI's curriculum and can relate them to one another, has developed verbal skills and can effectively discuss broad topics in biomedical informatics, and has picked up practical knowledge of the field.

Approximately six months into their third year, all PhD candidates are required to present an hour's seminar in which they present proposed research in response to a mock "request for proposals" (RFP) that is prepared in collaboration with their research advisor. This exam is meant to be an exercise in researching a topic thoroughly and presenting a cogent plan for how one might attack the problem in a formal research project. The RFP topics are selected to correspond to the trainee's developing area of research interest and to help the student to gather background and

experience that will be pertinent to their formal dissertation proposal.

All PhD candidates are expected to submit a formal thesis proposal (generally a written document of 75-100 pages), ideally by the end of their third year. Each doctoral thesis in Medical Informatics must balance the three following goals: provide significant innovative insights and new results that add to the knowledge of medical informatics; implement an information system that illustrates the practical applicability of the ideas; and evaluate the system to demonstrate generalizability or impact on the intended users.

They then defend their proposal before their thesis committee and in a public forum. The formal thesis proposal defense is intended to occur when the student's research is beginning to mature and become well defined, but when there are still 10-12 months left before completion of the dissertation is expected. This serves two purposes: (a) it establishes a required intermediate milestone that helps assure that the student keeps on schedule for completion of the PhD in 4-5 years, and (b) it allows for intensive review of research plans by the dissertation committee and "mid-course correction" while there is still substantial time left before completion of the degree. A final University-mandated thesis defense is then presented at the end of PhD training, at approximately the same time that the dissertation document is submitted to the university.

All RMA candidates are required to complete a research project before graduation. The research is not considered complete until the student has finished a formal paper on the topic, one that the research preceptor believes is suitable for submission to a peer-reviewed journal. Students are taught that biomedical informatics papers must be more than system descriptions; they are encouraged to extract general lessons and principles and to communicate what they have learned in a form so that others in the field may draw on their results.

Medical Informatics Curriculum

The Medical Informatics curriculum is designed to meet the needs of a wide range of students with different backgrounds and career goals, while providing a uniform foundation in the essentials of the field. The educational objectives addressed by the curriculum fall into four

Table 1. Number of courses required to meet educational objectives in each program

Objective			AMA	RMA	PhD
Basic	**Biomedical Knowledge**	Is conversant with concepts, terminology, institutions, professionals, and methods of biomedical domain	1	2	2
	Data Management	Can apply computational techniques to organize and manage large collections of data	1	1	1
	Software Engineering	Can apply computational techniques to develop integrate and test software systems	1	1	1
	Statistics	Can apply mathematical techniques to analyze data	1	1	1
Core	**Overview**	Is familiar with theories, methods, and results in Medical Informatics	1	1	1
	Data Representation	Can analyze, develop, and apply representations of biomedical data	1	1	1
	Information Systems	Can analyze, develop, deploy and manage complex information systems	1	1	1
	Formal Models	Can analyze, develop, and apply formal models of biomedical objects and processes	0	1	1
	Information Presentation	Can analyze, develop, and deploy visual presentations of biomedical information	0	0	1
	Decision Making	Can analyze, develop, and apply formal models of biomedical decision making	0	0	1
	Evaluation	Can analyze, plan and carry out formal evaluations of information systems	0	0	1
General	**Research**	Can conduct independent research in Medical Informatics	1	4	6
	Teaching	Can prepare educational materials, deliver lectures, and evaluate students	0	2	2
Specialized	**Application**	Can apply theories and methods of Medical Informatics to area of specialization	2	2	5
			10	**17**	**25**

main areas: basic, core, general, and specialized (described below). Table 1 lists objectives within these areas, and indicates the number of courses related to each objective in the three degree programs (AMA, RMA, and PhD).

The *basic objectives* relate to fundamental areas of biomedicine, computer science and mathematics that are prerequisites for further study in Medical Informatics. A few students may enter the program meeting all of these objectives, but most will lack one or more areas. The basic objectives ensure that students coming from very different backgrounds obtain the necessary breadth to continue study in the field.

Core objectives define the essential skills required by all Medical Informatics students. All students must obtain working familiarity with the field of Medical Informatics, and an ability to work with representations of biomedical data and complex information systems. RMA and doctoral students must understand these systems through various formalisms. Doctoral students must also be able to develop visual representations, to model decision processes, and formally to evaluate such systems.

General objectives include the ability to conduct research and participate in the educational activities of the field. Current courses that support basic, core, and general objectives are listed in Table 2.

Specialized objectives concern the application of general methods and theories in four different areas: bioinformatics, imaging informatics, clinical informatics, and public health informatics. This portion of the curriculum is still evolving, and detailed objectives have not yet been defined. Courses in the four tracks are listed in Table 3. Courses that must be taken by all students in a track are marked as required, while optional courses are marked as elective.

Table 2. Current courses that support educational objectives

Objective	Relevant Courses
Biomedical Knowledge	G6300/G6301 Biochemistry and Molecular Biology of Eukaryotes, G4011 Acculturation to Medicine, E3001/3002 Quantitative Physiology, P6313 Physiology, P6400 Epidemiology, P6530 Issues and Approaches in Health Policy and Management
Data Management	W4111 Database Systems
Software Engineering	W4156 Software Engineering
Statistics	P6104 Introduction to Biostatistical Methods
Overview	W4001 Introduction to Computer Applications in Health Care and Biomedicine
Data Represenation	G4020 Representation and Coding of Medical data
Information Systems	G4040 Health Information Systems Architecture, P8534 Introduction To Information Management
Formal Models	G4002 Methods in Medical Informatics
Information Presentation	G4030 User Interfaces in Medicine, G4031 Understanding Visual Information
Decision Making	G4050 Quantitative Models For Medical Decision Making, G4051 Clinical Decision Support, P8740 Social and economic factors in clinical decision making, W4701 Artificial Intelligence, G5043 Cognitive Science and Medical Informatics
Evaluation	G4060 Evaluation Methods in Medical Informatics, P8116 Design of medical experiments
Research	G6001 Projects In Medical Informatics
Teaching	G8010 Teaching Experience

Table 3. Existing (numbered) and proposed courses in the four areas of specialization

	Bioinformatics	Bioimaging	Clinical Informatics	Public Health Informatics
Required	G4012 Introduction to Genomics	E4894 Biomedical Imaging	G4061 Economics of Informatics	P6513 Hospital Organization & Management
	E4761 Computational Genomics	E6400 Analysis and quantification of medical images	M8018 Project Management	P6781 The use of large scale national health care data sets
	Sequence Analysis	E440 Wavelet applications in biomedical image and signal processing		
Elective	Statistical Genetics	G4031 Understanding Visual Information	M8122 Interactive Health Communication	P6710 Health Communications
	Phylogenetic Inference	E4410 Ultrasound in Diagnostic Imaging	M8120 Informatics for Evidence-based Practice	P6503 Introduction To Health Economics
	Protein Folding	E6480 Computational Neural Modeling and Neuroengineering	M8123 Introduction to Databases and Data Mining	P8514 Healthcare E-Commerce
	Micro Arrays and Regulatory Networks	MRI and MRS Imaging		Social and Behavioral Foundations for Informatics
	Biological Databases	Graphics and Visualization		Information Ethics

Conclusion

The program in Medical Informatics at Columbia has matured from a loose confederation of courses in multiple departments to a highly integrated curriculum with a large number of courses taught by core departmental faculty. The initial focus on patient care and clinical applications has been expanded to embrace the entire biomedical spectrum, from the molecular level to whole populations. The faculty has diversified as well to implement this vision, and to forge new alliances with other schools and departments. We have also formalized the educational objectives for the curriculum across our three degree programs, with specialization in one of the four biomedical tracks. These objectives elucidate how the Medical Informatics program is distinct from programs in Computer Science, Public Health, Nursing, Engineering, and Biology, while clarifying points of overlap, which provide opportunities for interdisciplinary training and research. In this way, the training program is a step towards articulating a framework for the field as a whole, and provides guidance for its future practitioners.

Acknowledgement

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References

1. Cimino J, Allen B, Clayton P. Medical informatics training at Columbia University and the Columbia-Presbyterian Medical Center. In: van Bemmel J, McCray A, editors. IMIA Yearbook of Medical Informatics. Stuttgart: Schattauer; 1995. p. 125-9.
2. Johnson S, Clayton P, Fink D, Sengupta S, Shea S, Bourne P, et al. Achievements in Phase III of an Integrated Academic Information Management System. Proceedings of the Seventh World Congress on Medical Informatics. Geneva, Switzerland: International Medical Informatics Association; 1992.
3. Clayton P. Integrated Advanced Medical Information Systems (IAIMS): Payoffs and problems. Methods Inf Med 1994;33(4):351-7.
4. Johnson S, Forman B, Cimino J, Hripcsak G, Sengupta S, Sideli R, et al. A technological perspective on the computer-based patient record. In: Steen E, editor. Proceedings of the First Annual Nicholas E. Davies CPR Recognition Symposium. Washington, DC: Computer-Based Patient Record Institute; 1995. p. 35-51.
5. Hripcsak G, Ludemann P, Pryor T, Wigertz O, Clayton P. Rationale for the Arden Syntax. Comput Biomed Res. 1994;27:291-324.
6. Cimino J. Auditing the Unified Medical Language System with semantic methods. J Am Med Inform Assoc 1998;5:41-51.
7. Cimino J. Using the Unified Medical Language System in patient care at the Columbia-Presbyterian Medical Center. Methods Inf Med 1995;34:158-64.
8. Sideli R, Johnson S, Weschler M, Clark A, Chen J, Simpson R, et al. Adopting HL7 as a standard for the exchange of clinical text reports. In: Miller R, editor. Proceedings of the 14th Annual Symposium on Computer Applications in Medical Care. Washington, DC: IEEE; 1990. p. 226-9.
9. Shortliffe EH, Perreault LE, Wiederhold G, Fagan LM, editors. Medical Informatics: Computer Applications in Health Care and Biomedicine. New York: Springer; 2000.

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