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Education and Training

Opportunities for Training in Biomedical Informatics at Vanderbilt University

1. Overview

The mission of the Vanderbilt University Biomedical Informatics Training Program is to provide predoctoral and postdoctoral trainees - physicians, nurses, librarians, computer scientists, engineers, allied health professionals, and others - with the necessary skills and experiences to lead in the development, evaluation, and implementation of informatics innovations related to health-care delivery systems, and teaching and research. The hallmarks of the training program are flexibility, diversity, and the opportunity for applied research in the clinical setting.

All trainees are expected to achieve an understanding of the following core areas of medical informatics: knowledge of medical informatics research, including practical experience working with an ongoing project within Vanderbilt University Medical Center (VUMC); knowledge of computer and information science, including competency in at least one programming language; knowledge of hardware, software, and networking environments in current use; knowledge of techniques for evaluating the function of medical informatics systems and the impact of medical informatics interventions on health-care practices; knowledge of hospital information systems and other practice-related clinical information systems; knowledge of basic and clinical sciences (anatomy, physiology, neuroscience, pharmacology, principles of internal medicine, and other domains of clinical practice); knowledge of traditional health-care delivery systems and their administration, including experience with managing the psychosocial changes associated with implementation of computer-based systems in the health-care environment; knowledge of legal and ethical issues and practices as they relate to medical informatics; knowledge of medical library operation, bibliographic searching techniques, and on-line medical databases; knowledge of statistics and principles of study design; knowledge of logic and decision theory, and knowledge of sources of research funding and how to apply for research support.

It is expected that graduates of the medical informatics training program at Vanderbilt University will be qualified upon completion of their training to undertake careers in medical informatics research, teaching, project management, or applied applications development. They will be expected to become faculty members in Medical Schools, Schools of Nursing, or other schools of the Health Professions; to serve as faculty in departments of Computer Science or Biomedical Engineering; or to fill positions of responsibility in research-and-development-oriented industrial settings (e.g., as managers of the information processing group of a hospital; in corporations developing hospital information systems; or as employees of health-care providers).

2. Background

Vanderbilt University offers a number of unique opportunities for training in Biomedical Informatics. Vanderbilt University Medical Center is an integral part of Vanderbilt University, which consists of the College of Arts and Science, Graduate School, Blair School of Music, Divinity School, School of Engineering, School of Law, School of Medicine, School of Nursing, Owen Graduate School of Management, and the George Peabody College for Teachers. The University has a faculty of more than 1,500 full-time members and a student body of about 10,000. The Medical Center consists of the School of Medicine, School of Nursing, and Vanderbilt University Hospital and Clinics. The School of Medicine has approximately 850 full-time faculty members in 28 departments. Postgraduate training in 23 clinical departments is available in certified specialties and subspecialties. Doctorate and master's degree programs are offered in 5 basic science departments. A joint MD/PhD program is offered through the medical school and graduate school. All the resources of Vanderbilt University are

potentially available to trainees, when relevant to their education and professional development.

The appointment in 1991 of Dr. William Stead as Associate Vice Chancellor for Health Affairs heralded the institution's new, substantial commitment to medical informatics. Dr. Stead functions as VUMC's chief information architect and has responsibility for all forms of information management within the health center complex. He has strengthened the basic VUMC information-processing infrastructure through construction of a modern academic biomedical library; development of an interdisciplinary Informatics Center; creation of a new academic unit, the Division of Biomedical Informatics within the School of Medicine; and upgrading the existing hospital-based Department of Information Management. Members of all of these units are linked into a cohesive team with diverse talents. Under Dr. Stead's guidance, the Department of Information Management has completed, over the past several years, a number of important infrastructure projects: installation of a campus-wide FDDI fiber-optic network; purchase and installation of new ADT software; entry into a joint development arrangement with a commercial order-entry system vendor; purchase of a new billing system; and obtaining the Medical Archival System (MARS) data repository from the University of Pittsburgh.

The Informatics Center has three components: the Division of Biomedical Informatics, an academic medical informatics unit dedicated to research, teaching, and service; the Eskind Biomedical Library, which contains the Active Digital Library (ADL) as its research and technology center; and the Department of Information Management, a component of Vanderbilt Hospital and Clinics. Information Management has significantly evolved from what once was a strictly hospital-based information systems group. All three units of the Informatics Center collaborate closely, under the direction of Dr. Stead so that academic software projects, once mature, can be delivered directly to hospital wards or clinics in conjunction with programmers and managers from Information Management — the individuals who will be responsible for the long-term maintenance of such projects. Conversely, members of the Department of Information Management regularly involve members of the academic unit in their planning, development, and troubleshooting activities. A similar philosophy guides the relationships among the Division, the ADL, and the library units that directly support patrons. Thus, many of the political obstacles to implementation of academic informatics projects that exist at other institutions are far less of a problem at Vanderbilt. The Informatics Center also serves as an interdisciplinary unit for cooperation among faculty from the School of Medicine, School of Nursing, Computer Science, Electrical Engineering, Biomedical Engineering, and other disciplines on campus.

The Division of Biomedical Informatics is the academic component of the Informatics Center. It is a free-standing Division within the Vanderbilt University School of Medicine, and can appoint tenure-stream faculty directly (i.e., faculty appointments and tenure are in Biomedical Informatics, not in a different academic unit of the Medical School). The faculty are all committed to a shared vision of the overall architecture for information systems and common approaches to application development, while at the same time maintaining independent areas of individual expertise. Credentials of the staff of the Division are given in Appendix 1.

The Eskind Biomedical Library is a modern 78,000 net square feet (NSF) facility, dedicated in April 1994. The first three floors are devoted to traditional library functions. The fourth floor - 9600 NSF - of the Eskind Biomedical Library houses the core offices of the Informatics Center, the Division of Biomedical Informatics, and the Active Digital Library. Fellows in Medical Informatics at Vanderbilt are given large study carrels (8x12 ft) in this area, located adjacent to the faculty offices in the Division of Biomedical Informatics. Fellows are also provided with pentium-based workstations connected to the VUMC network backbone, as well as more specialized equipment as needed for specific research projects.

The Active Digital Library was established in 1994 as a new research branch of the Eskind Biomedical Library, and is initially funded by a subcomponent of the Vanderbilt University Medical Center IAIMS project. It serves as a laboratory for developing new approaches to assembling software relevant to health-care service and education, and for pioneering new methods for efficiently delivering such information to end-users. The ADL is actively involved in outreach activities, serving as a bridge interconnecting the different components of the Informatics Center and the rest of VUMC, the University at large, and the outside world. In this capacity, the ADL integrates the diverse skills of the Division of Biomedical Informatics (research in clinical decision support and knowledge acquisition), the Information Management Department (clinical computing, networking, and computing services), and the Eskind Biomedical Library (on-line and paper-based information services). The ADL is responsible for coordinating the entire VUMC Web pages effort. Members of the ADL staff have substantial experience in developing HTML-based applications and in training end-users. The ADL participates in the operation and maintenance of five medical school classrooms that have been fully equipped with com-

puters for instructional purposes. In this role, ADL members have also developed HTML-based examinations for the Pediatrics and Histology courses in the Vanderbilt University School of Medicine.

3. Biomedical Informatics Research and Development at Vanderbilt

3.1. Patient Care Information Systems

VUMC, through the Informatics Center, currently has under way an institutionally-funded, multi-million dollar patient care information system implementation (PCIS) project. The VUMC PCIS project provides the hardware, network, and production environment in which faculty and trainees can develop and implement applied research and development projects. The VUMC PCIS project also funds the production-level implementation of MARS at VUMC. In January 1995, Vanderbilt began its National Library of Medicine-sponsored, five-year long IAIMS Operational Phase project.

In 1991, the 100-member hospital-based Department of Management Systems was the central unit responsible for system support. The major focus of the Department was on support of mainframe applications — appointments, admission, discharge, transfer, and billing functions, together with a variety of interfaces to ancillary systems. The development staff was organized into groups based upon application areas, such as clinical, ancillary, and financial. During 1992 and 1993, that structure was replaced by a Department of Information Management within the Informatics Center. The new department is organized around skill-sets, not the application on which the skill is used. New job functions have been created and old ones have been redesigned. The Department is housed in a 20,000 NSF data center in the hospital.

A web of fiber optic cable interconnects each building within the Medical Center. The FDDI protocol is activated on the inter-building component of the backbone. Building-level routers translate the Internet and inter-building traffic on and off the backbone. Novell is the primary local area network operating system, and TCP/IP is also supported well. New workstations are attached directly to the appropriate riser system as they are acquired. All pre-existing hosts and local area networks are being migrated onto this backbone. A pool of 600 network-attached shared workstations (16 MB Intel 486/Pentium) have been installed throughout the hospital, clinic, library, and training facilities. Vanderbilt University provides a campus-wide backbone broadband Ethernet network. The Medical Center backbone is routed onto the campus network and uses that route to access the Internet.

3.2. Integrated Advanced Information Management Systems (IAIMS)

VUMC has adopted a fast track approach to IAIMS. That approach is based on the following objectives:

a. Demonstrate that an environment can be established that redirects and coordinates individual initiatives so they come together into an IAIMS. Core functions that support the environment include: organizational development; strategic and tactical planning; vision development and communication; architecture definition; information policy formulation; technology forecasting; and strategic alliance formation;
b. Demonstrate models of the core resources that are required as a foundation for the IAIMS, including the information technology infrastructure, the Active Digital Library, outcome data repositories, and mechanisms to support outreach and inreach;
c. Evaluate the effectiveness of strategies to overcome the obstacles to IAIMS implementation, by measuring progress against predefined milestones. Key strategies include interrelating IAIMS planning with process redesign, sequencing projects to reflect data dependencies, and mainstreaming user education and support.

VUMC IAIMS activities have resulted in four generalizable lessons beyond the demonstration of the effectiveness of the fast track approach. First, the ongoing IAIMS planning process must adapt rapidly and readily to changing circumstance. The VUMC planning process has been unique in that it has brought together each of the institution's key stakeholders monthly. These meetings have focused as much on the state of the planning effort as on approving results of that effort. Ideas surfaced regarding ways to use other medical center processes to get part of the job done. A synergy developed between planning processes that reduced the size of the information technology planning effort while increasing its responsiveness to the issues that face the institution. Second, the discipline involved in proposing formally hypotheses and strategies is effective. Each task or project can then be carried out as a test of an hypothesis. If things do not work well, the approach can be modified before trials with the next task. Lessons are learned that generalize across the many efforts that are brought together in the course of development of an IAIMS. Those lessons should transfer to other institutions. Third, short videos and applications built with prototyping tools are an effective vehicle for communicating the art of the possible to a broad audience. They are preferable to the

alternative of developing real world systems to demonstrate functional possibilities. Real demonstration systems are in and of themselves major implementation efforts. A single demonstration project may divert IAIMS implementation effort from core resources and functions that could support a multitude of such efforts. The videos have also eliminated the need for user fairs. They reach more people and present a clearer vision. Fourth, as with the planning effort, support of IAIMS implementation must be a mainstream medical center effort to the degree possible. A core IAIMS resource can then bring all of the medical center's resources to bear on the effort.

3.3. The Medical ARchival System (MARS)

The Medical ARchival System (MARS) has been developed since 1986 at the University of Pittsburgh Medical Center (UPMC) by John Vries and Russell Yount, and forms the basis of the electronic patient record system at UPMC. In March 1995, Vanderbilt University and the University of Pittsburgh signed a collaboration agreement by which Vanderbilt gained access to the MARS software for deployment at VUMC, and agreed in return to provide the University of Pittsburgh with detailed feedback about the effort required to customize and adapt the system to VUMC's specific needs, as well as with access to MARS-related software developed by Vanderbilt. Dr. Dario Giuse directs the VUMC MARS project.

MARS is a database management system based on distributed parallel processing, a strategy which provides inexpensive, very efficient access to patient records. MARS is a data warehouse in which every record is indexed on every word and every number, allowing extremely powerful search capabilities. The MARS query language supports arbitrary combinations of the Boolean operators AND, OR, and NOT. Data are fed into MARS over the VUMC network. Input can come from any clinical domain (e.g., various clinical laboratories, the radiology system, medical record transcription services, clinical pathology, cardiac catheterization and echo labs, MEDIPAC case abstracts, etc.). Data from reports are parsed and indexed as they arrive; MARS contains a set of customizable parsers that are used to convert the wide variety of records formats entering the system into one internal format.

Following the initiation of the collaboration agreement, the MARS system was ported to VUMC and is now used as the integrated electronic patient record system. System customization included the development of an innovative OS/2-based graphical user interface, real-time and batch interfaces to several VUMC clinical data sources, and extensive monitoring and management tools. Integration into the VUMC production environment has been greatly facilitated by monitoring tools which check for possible abnormal conditions and automatically alert Information Management computer operators and Help Desk personnel, who are on duty 24 hours a day. After pilot testing in four units of the Vanderbilt Hospital (October through December 1995), MARS was released housewide in January 1996. It is now available on almost 600 workstations throughout the hospital and clinics, and more than 900 users have accounts on the system. More than 150 individual care providers use MARS every day to access the electronic patient record for clinical purposes. At present, MARS at VUMC stores more than 1.5 million records, including: lab results; anatomic pathology reports; radiology reports; discharge summaries; adult- and pediatric echo and cardiac catheterization reports; admission, progress, and operative notes; and physicians' letters to patients.

Work is underway to integrate additional sources of clinically relevant data into MARS (e.g., ECG data and pulmonary function test reports), as well as taking in "historical" clinical data (e.g., additional, older radiology, laboratory, and pathology reports) going as far back as 1979. The next phase of development will see the system used as a powerful query mechanism that will allow health-care researchers (with appropriate authorization) to perform such complex searches as "display all discharge summaries or progress notes between September 1995 and January 1996 which mention a diagnosis of Lupus, the finding of abdominal pain, and for which either Dr. Smith or Dr. Jones were the attending physician." At the same time, the system will be extended to support customized, automatic generation of printed reports for users who prefer a non-interactive querying approach.

3.4. Order Entry and Decision Support Systems

The development of the VUMC order entry application over the past three years has demonstrated the importance of installing vendor applications in conjunction with an overall architecture plan and a general-purpose information management infrastructure. As part of the joint development arrangement with the vendor of the order entry product, VUMC has independently developed three important components of the overall VUMC order entry system as elements of the information management infrastructure. First, an OS/2 desktop and sign-on processor was developed to provide seamless access to the complete set of VUMC systems, not just those provided by the commercial order-entry system vendor. Second, a generic interface subsystem was developed to sit between commercial order

entry product and the other VUMC systems. This subsystem is the first step toward the communications hub that is an integral part of VUMC's long-term architectural direction. Any data item generated by the commercial order entry product is passed to the generic interface subsystem, and it in turn controls what is passed to each of the other systems. This approach lets VUMC change the data requirements of its other systems without interfering with the commercial system. Third, information about VUMC's environment or processes, which would otherwise be contained in hard-coded commercial product screens, are being maintained in VUMC-built and controlled relational database (IBM/DB2) tables. The relationships between patient care units, workstations and printers are one example. Relational tables of orderable items to provide various clinically relevant pathways and order sets is another. This approach increases the maintainability of the commercial order entry application and provides direct access to that information by other systems.

In 1994-95, the Vanderbilt WizOrder Interface to the commercial vendor's order entry system was developed through a collaborative effort between the Division of Biomedical Informatics (Antoine Geissbuhler, M.D., project manager) and Information Management. This extraordinary project is one of the first undertaken by a medical informatics trainee at Vanderbilt, and represents an example of the profound impact a trainee can have on the clinical practices of the institution. This project was made possible by the steps taken by VUMC to externalize components of the otherwise proprietary commercial order entry product — specifically, the creation of a DB2 database containing the Health Terms Dictionary (which included all orderable items and their associated parameters), use of DB2 to store patient orders, availability of local servers which supported the VUMC Desktop interface, and the availability of the VUMC generic interface message-passing utility.

The WizOrder project was initiated in June 1994 as a response to concerns expressed by the medical housestaff regarding the initial version of the VUMC user interface for the commercial order entry system and the system itself. Major concerns centered on the lack of intuitiveness of the interface, and slow response time of the system. Due to the limited customizability of the proprietary system, it was decided to develop a new PC-based interface. The new interface made use of the VUMC externalized database of orderable items (the Health Term Dictionary or HTD) and "package" orders. The new interface was to interact with the user in a user-friendly manner and then transmit orders to the mainframe-based transaction system for processing. The WizOrder project was designed with the goal of improving both the user interface for order entry and the perceived response time of the system. Another major goal was to include, in the same software platform, decision-support capabilities that would be easily accessible during order entry.

An initial prototype was developed using IBM C++ for OS/2 Presentation Manager in July 1994, based on suggestions from the users of the mainframe-based system and observations made on the wards by the members of the Division of Biomedical Informatics (who voluntarily spent time during the summer of 1994 as part-time medical receptionists to help with, and observe directly, the order entry system). The WizOrder prototype then evolved, based on the comments of potential end-users (i.e., medical housestaff, nurses, pharmacists, and others) during weekly and bimonthly 3-hour-long test sessions. Suggested changes were implemented between successive sessions, and reviewed by the next group of potential users. After four months and more than ten iterations, a stable prototype emerged. The major requirements expressed by the users included: a single screen layout that remains stable during the session, with as few pop-up screens as possible; a list of current active orders, visible at all times, displayed in a clinically relevant sequence; a way to enter orders in a manner similar to handwritten orders; problem-driven sets of orders that look like preprinted order sheets; and, seamless access to decision-support tools.

WizOrder's user interface embodies the above-mentioned user-defined desirable features, as well as the following additional components: a constant geographic layout that embodies a single location for user prompts and user keyboard input; a step-by- step, one-question-at-a-time approach for gathering information; the support of both pointing-device and keyboard entry; various shortcuts for experienced users; and, access to context-sensitive help. An "intelligent" completer makes use of the information stored in the HTD to match relevant parameters while building orders, so that "gen 80 IV" matches to gentamicin intravenous, since it is the only medication given IV that comes with 80-mg as one of its default dose sizes (information stored in the HTD). The user can enter orders in a manner similar to handwritten orders ("PTT STAT"), have the orders checked for consistency against the HTD definitions, then be queried about fields missing information that, per the HTD template, are required to build a complete order (e.g., when to draw the stat PTT). Structured problem-based order sets are also available (post-cardiac catheterization orders; rule out MI; acute MI; unstable angina; and others). Order sets now include decision support capabilities such as questionnaires to establish which arm of a branching protocol is most appropri-

ate for the patient, and patient-specific medication dosing, based on parameters such as age, calculated ideal body weight (from actual weight and height), creatinine (or creatinine clearance), and other clinical parameters availble from the MARS data repository or through questioning the user.

The WizOrder system is based on three components: a client, a server, and the mainframe. The client, residing on the OS/2 based care-provider's workstation, provides the graphical user interface and handles the communication with the mainframe using a 3270 emulation based protocol. The server, running on an OS/2 based microcomputer, provides the logic for building orders and for decision-support tools. It uses: a copy of the HTD, downloaded daily from a mainframe-based DB2 table; a VUMC pharmacy database containing drug monographs, drug-drug interactions and allergy alerts; laboratory test information provided by the pathology department in electronic form; and, a literature references database created by members of the project team by extracting portions of MEDLINE using the VUMC OVID search engine. The synchronicity of the various databases is maintained automatically, at the server level - downloads of the various databases are transported to the server at regular intervals (or, in some cases, on demand through the generic interface engine). The mainframe-based commercial order entry program, whose interface has been customized by Vanderbilt, processes the orders sent by the WizOrder system in the same manner it processes orders directly entered by users directly interacting with it. The commercial system also provides demographic information. The list of active orders, and recent laboratory results are available from the external (to the commercial product) DB2 database and from the MARS system, respectively.

WizOrder's current decision-support capabilities include: a single-key access to recent lab results on the "current patient"; single-key access to drug monographs, therapeutic-class based allergy and drug-drug interaction alerts for the "current patient"; a drip-rate calculator and infusion compatibility tables; and, an ICD9 completer for diagnoses and procedures. WizOrder also provides an automated link to literature references related to the patient's diagnoses and treatments, derived in part from work on the UMLS-related POSTDOC project, using the UMLS Metathesaurus as a mapping tool between ICD9 codes, drug names, and MeSH terms.

As a result of the WizOrder project, MARS, and other Division activities, members of the Division of Biomedical Informatics have a strong presence on the clinical wards. Faculty and fellows in Biomedical Informatics participate in training and ongoing interaction with clinical faculty and housestaff regarding their use of biomedical informatics systems. Division members also interact daily with staff of various clinical areas such as patient care services (nursing), radiology, laboratory, and pharmacy. Faculty and trainees (including Computer Science and Biomedical Engineering Graduate Students, as well as Fellows in Biomedical Informatics) work closely with members of many other units within the health center complex. It is only through regular interactions with others in the clinical arena that feedback can be obtained on how to rapidly prototype, implement, and modify innovative systems successfully. It is only through such interactions that medical informaticians can maintain a credible presence in the clinical setting. This presence has become well established at Vanderbilt.

3.5. Library-related Informatics Activities

3.5.1 HIV/AIDS Project

The Active Digital Library (ADL), in conjunction with members of the Eskind Biomedical Library staff, has developed an outreach pilot project for the dissemination of knowledge about HIV/AIDS resources, in order to influence AIDS care awareness among health-care providers in the Middle Tennessee area. This effort is supported in part by a grant from the regional library program of the National Library of Medicine (NLM). The objectives of this project are to: (a) increase the dissemination of AIDS-related information in the target geographic area; and (b) increase awareness of the on-line information sources developed by the NLM, and how they can be used to improve health-care for HIV/AIDS patients. This project has helped in establishing and maintaining a local network of contacts within Middle Tennessee, using the Vanderbilt University Eskind Biomedical Library as the hub. Contacts have been established with groups and organizations that are currently involved in caring for AIDS patients, or that have a potential interest in the management of AIDS-related information. This project leverages the considerable expertise in the care of AIDS patients already available at VUMC, and makes that expertise available to the entire Middle Tennessee area.

3.5.2 Integrating Health Sciences Librarians into Biomedical Practices

The Informatics Center/ADL was one of the seven sites that received a "Planning Grants for Education and Training of Health Science Librarians" from the NLM. The objective of this grant is to establish the foundations for a model postgraduate and post-doctorate training program for health sciences librarians. Participants from Peabody College are closely involved in this activity. To address the changing role of biomedical librarians and the surrounding changes in the health sciences, the model training program will emphasize intensive practical training within an established

academic health-care center. Volunteer trainees from VUMC have already undergone practical training in different areas of biomedical informatics and health sciences librarianships. Using this model will facilitate learning-in-context; moreover, the model will allow for trainee health sciences librarians to become integral players in existing teams involved in clinical and research activities. As a complement to the more traditional and theoretical aspects of the training of health sciences librarians, this practical training will emphasize active management of information, problem solving skills, and direct participation in research, with the aim of integrating current and future librarians more closely within the diverse fabric of the health-care professions. In addition, the model will provide the opportunity for advanced academic pursuits. During the planning phase, currently underway, the project is analyzing the requirements and objectives of the model training program. The pilot project is concentrating specifically on: (a) refining the current understanding of the roles that health sciences librarians occupy, relative to careers and activities in biomedical informatics and education; (b) developing educational models that provide librarians with a basis for expanding their roles; (c) planning for an evaluation process that will allow the educational model to be validated; and (d) planning for support of the program beyond the initial planning grant.

3.5.3 WWW-based ADL Databases

An information database is under development for the purpose of fostering collaboration among Cancer Center investigators, which include VUMC researchers as well as researchers in affiliated health-care settings. This database will use a World-Wide Web interface as the front end, and the MARS database system as the back end to store data. Core information being represented includes the central research questions explored by each investigator, the biological test systems, specific techniques used, and main reagents utilized. The database will let investigators store, update, and search information through the Web interface, providing an integrated repository that facilitates collaboration among different participating sites.

The VUMC faculty research interest database has been converted into an HTML-based resource for use by students in selecting research preceptors. This format makes the information easy to access from any hardware and software platform. The content of the physician directory is also being converted to a searchable text and image database for access over the Internet by referring physicians. In this case, the MARS system provides the underlying repository and search capabilities, and an HTML interface provide access from any Web browser.

3.5.4 Implementation of Sirsi

Eskind Biomedical Library personnel are involved in both the local and university-wide implementation of Sirsi, the new on-line library catalog system. The Sirsi system utilizes client/server technology via the TCP/IP protocol. Eskind staff are involved in the review and design of the public interface, defining system parameters, data conversion, and network design. Sirsi fully adheres to the Z39.44 standard, and therefore will facilitate intra- and inter-institution exchanges of catalog information.

4. Training Opportunities in Biomedical Informatics at Vanderbilt

The followinging medical informatics training modalities are available to individuals:

1. Predoctoral trainees can obtain formal degrees (Master's or Ph.D.) through existing Vanderbilt programs in Biomedical Engineering or Computer Science. Faculty from the Division of Biomedical Informatics offer graduate courses in biomedical informatics cross-listed through these departments, and serve as primary or secondary advisors on the thesis committees of students in these departments who are concentrating on biomedical informatics thesis projects. In addition, Vanderbilt has a Ph.D. track that allows individuals to create their own independent degree program, so long as it is approved by the Graduate Faculty.
2. Fully trained clinicians and other individuals with advanced degrees in the health sciences (Ph.D. level biostatisticians, librarians, biomedical engineers, computer scientists, or others) are given the opportunity to join ongoing research projects in medical informatics and to take courses related to medical informatics without obtaining a formal degree. It is expected that such candidates will have completed strong preparatory backgrounds in one of the basic disciplines of medical informatics prior to applying to the training program - e.g., Bachelor's or Master's Degree in Computer Science, Bachelor's or Master's in Biomedical Engineering, Master's in Information Science, or similar degrees, with demonstrated practical ability to develop and complete projects. Such individuals will be encouraged to take up to one graduate course per semester to supplement their existing knowledge of medical informatics, but they will be encouraged to work on their applied projects as the major focus, rather than obtaining an advanced degree. These individuals will be expected to complete a medical informatics research project of their own design during their fellowship

training, and to participate, if interested and qualified, in limited clinical activities as made available through their respective clinical departments.

Medical Informatics, by its very nature, is interdisciplinary. Course requirements will vary with the background and interests of the individual trainee. Selected courses from the Graduate School Bulletin of Vanderbilt University relevant to training in Biomedical Informatics have been identified from departments as diverse as Anthropology, Biomedical Engineering, Computer Science, Economics , Business Administration, Education, Human Resources, Electrical Engineering, Management, Mathematics, Philosophy, Psychology, and Sociology. Courses are also offered, as previously noted, by faculty from the Division of Biomedical Informatics, for example: Introduction to Medical Informatics; Hospital Information Systems; Medical Informatics Architectures; Medical Expert Systems Seminar; and, Applied Research in Medical Informatics. It is expected that a trainee's advisor will help the trainee to select an appropriate course load and sequence of courses. The advisor will guide the individual to implement practical projects in conjunction with faculty researchers. All trainees in Medical Informatics are required to attend a bi-weekly Medical Informatics Seminar, which includes discussions of ongoing research by faculty and trainees, relevant journal articles, program objectives and operation, and presentations by invited speakers from outside the University. All trainees are expected to participate in medical informatics research projects as part of their studies. Current research in medical informatics at Vanderbilt University includes: Hospital information systems / IAIMS, Outpatient record systems, Computer-based diagnostic systems, Medical knowledge acquisition, Medical/Bibliographic information retrieval, Evaluation of computer-based medical decision making systems, Medical databases, Nursing informatics, Medical expert systems, and Continuous quality improvement/Total quality management. The selected references below are included as representative of faculty members' research interests.

Trainees at Vanderbilt have the opportunity to learn from the experienced biomedical informatics faculty, and from talented individuals from other areas of the University academic community. They interact on a regular basis with diverse members of the health center complex. A key strength of the program is its interdisciplinary nature, whereby members of the Department of Information Management serve as both instructors and colleagues in implementing pragmatic projects. Both the Eskind Biomedical Library and the clinical facilities of Vanderbilt Hospital and Clinic serve as real-world laboratories in which to develop, implement, and evaluate innovative projects in biomedical informatics. The opportunities for career development in Biomedical Informatics offered by Vanderbilt are unique.

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Appendix 1.

Randolph A. Miller, M.D., who is responsible for training in Biomedical Informatics at Vanderbilt, is Professor and Chairman of the Division of Biomedical Informatics, and Associate Director of the Informatics Center. Dr. Miller is also Past President of the American Medical Informatics Association and Associate Editor of its journal, JAMIA. Dr. Miller has a long-standing interest in medical decision-support systems, representation of medical information, evaluation of medical informatics systems, and training and education in medical informatics.

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Amy Apon, Ph.D.,Research Instructor in Biomedical Informatics, recently completed her doctoral work in Computer Science and joined the faculty in June 1995. Her interest is in system architectures and modeling the function and efficiencies of large-scale systems.

Antoine Geissbuhler, M.D., is a fully trained internist and talented medical informatician who has completed two years of fellowship training in Biomedical Informatics at Vanderbilt and joined the faculty in May 1996 as Research Assistant Professor. His interest is in the development and evaluation of systems that integrate patient specific information with computer-based medical information resources.

Steve Brown, M.D., is a Visiting Assistant Professor in the Division of Biomedical Informatics. Jeffrey Huber, who has a Doctorate in Library Science, will join the faculty of the Division of Biomedical Informatics in the summer of 1996.

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