Biomedical Informatics: Its Scientific Evolution and Future Promise

Edward H. Shortliffe, MD, PhD

Professor of Biomedical Informatics
Arizona State University

Professor of Basic Medical Sciences and of Medicine
University of Arizona College of Medicine

Phoenix, AZ USA

BIOSTEC 2009

International Joint Conference on Biomedical Engineering Systems and Technologies

Porto, Portugal

January 17, 2009

What is Biomedical Informatics?

- Is it a "real" academic discipline?
  - Scientific base?
  - Here to stay?
- Is it needed both in universities and in the world beyond?
  - Job opportunities?
  - Are people filling those roles now?
  - Are there enough of them?
- How does it relate to other disciplines?
  - Duplicative?
  - Different from computer science?
  - Interdisciplinary?

Historical Perspective

- Computers in medicine emerged as a young discipline in the 1960s
  - Most applications dealt with clinical issues
- No consistency in naming the field for many years
  - "Computer applications in medicine"
  - "Medical information sciences"
  - "Medical computer science"
- Emergence in the 1980s of a single, consistent name, derived from the European (French) term for computer science: *informatique*
  - Medical Informatics → Biomedical informatics

Biomedical Informatics

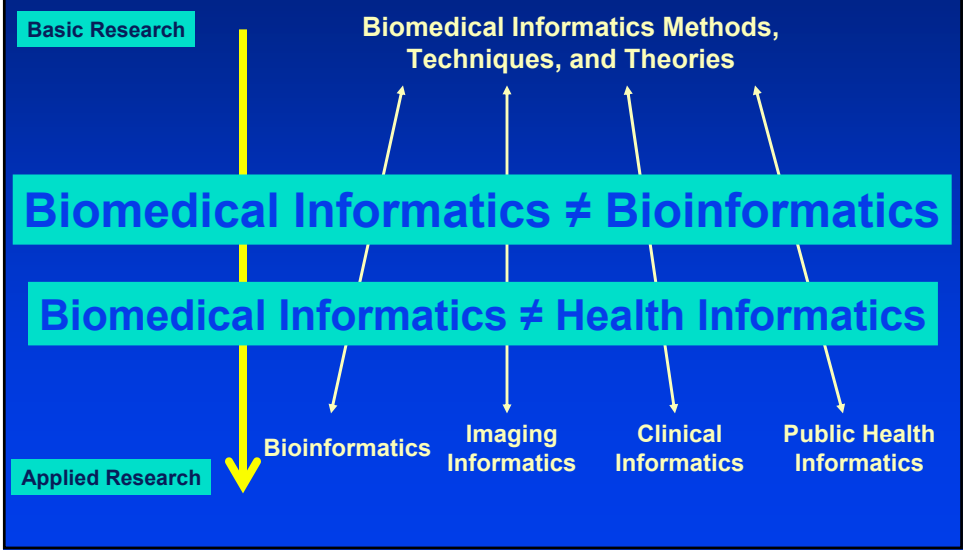
Biomedical informatics is the scientific field that deals with the storage, retrieval, sharing, and optimal use of biomedical information, data, and knowledge for problem solving and decision making.

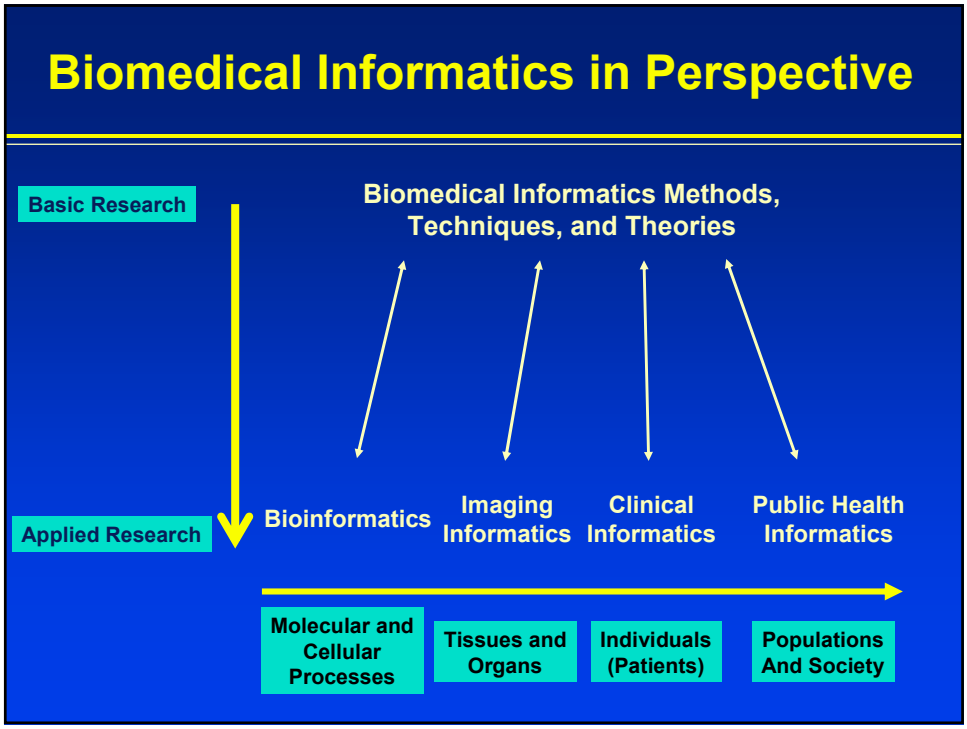
Biomedical informatics touches on all basic and applied fields in biomedical science and is closely tied to modern information technologies, notably in the areas of computing and communication.

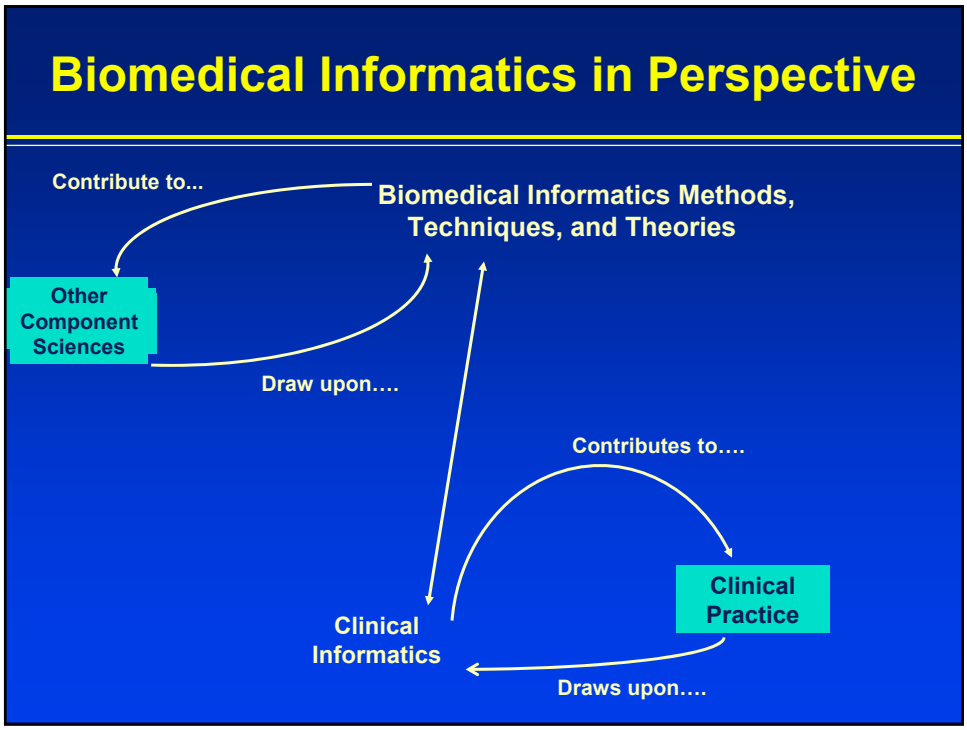
The Last 25 Years

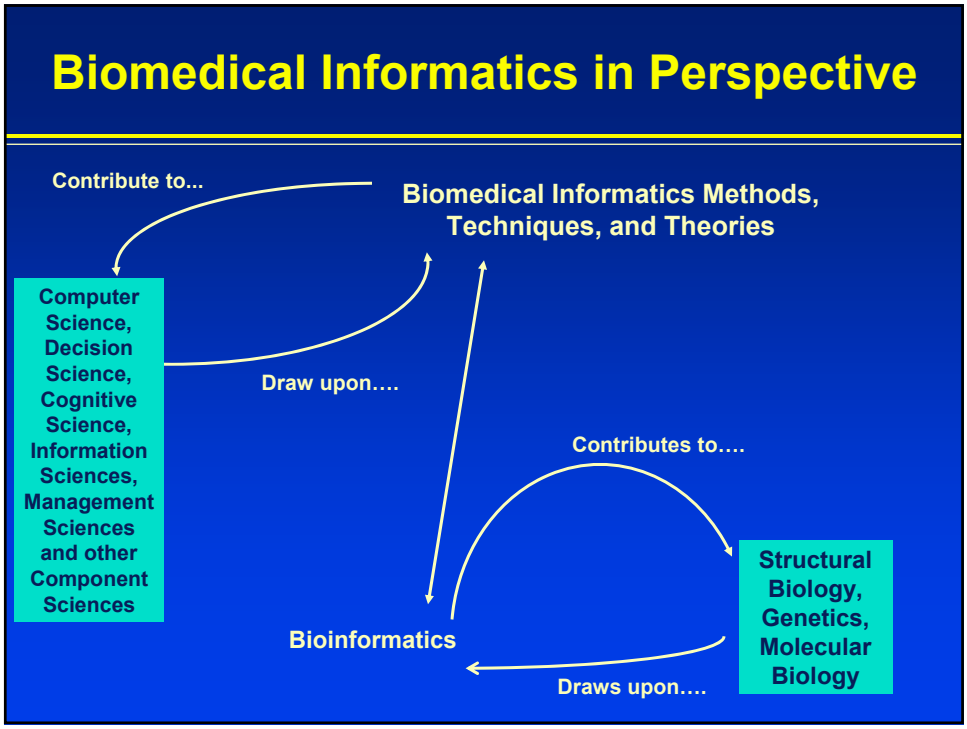
- Biomedical informatics training programs at many universities around the world
  - Application areas broadened in recent years to include biological sciences, imaging, public health, and other biomedical domains
- Creation of professional societies, degree programs, quality scientific meetings, journals, and other indicators of a maturing scientific discipline
- Broadening of applications base, but with a growing tension between the field's service role and its fundamental research goals

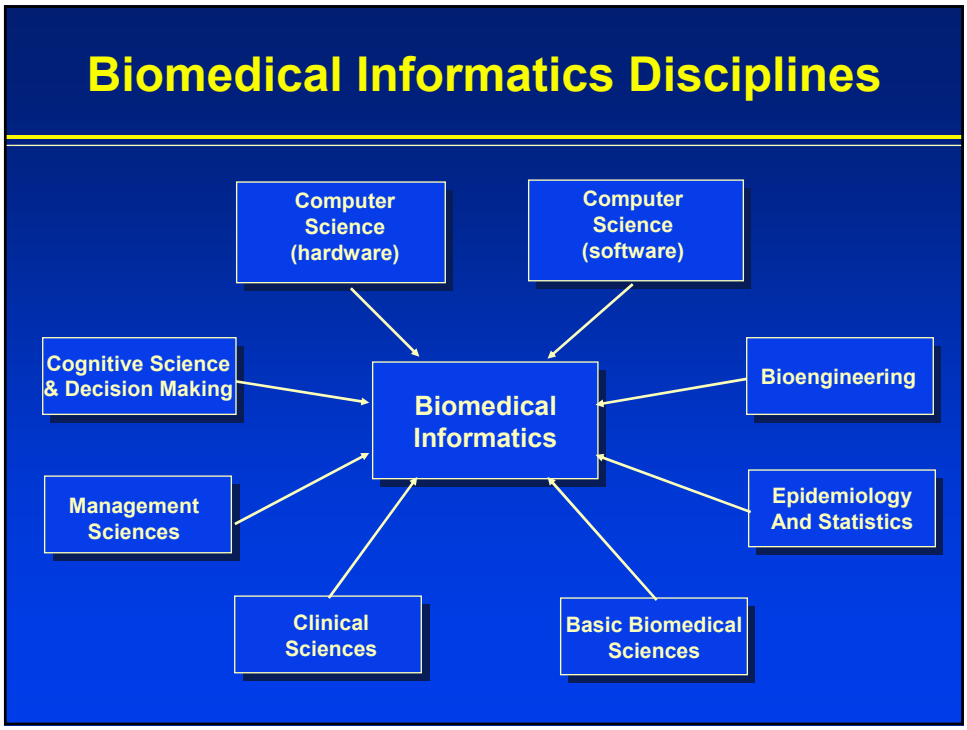
Biomedical Informatics in Perspective



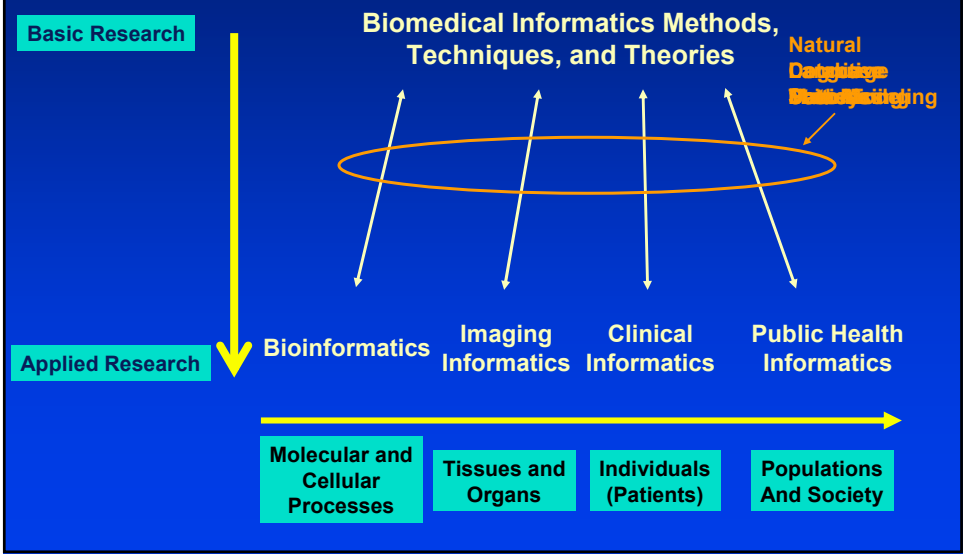








Biomedical Informatics in Perspective



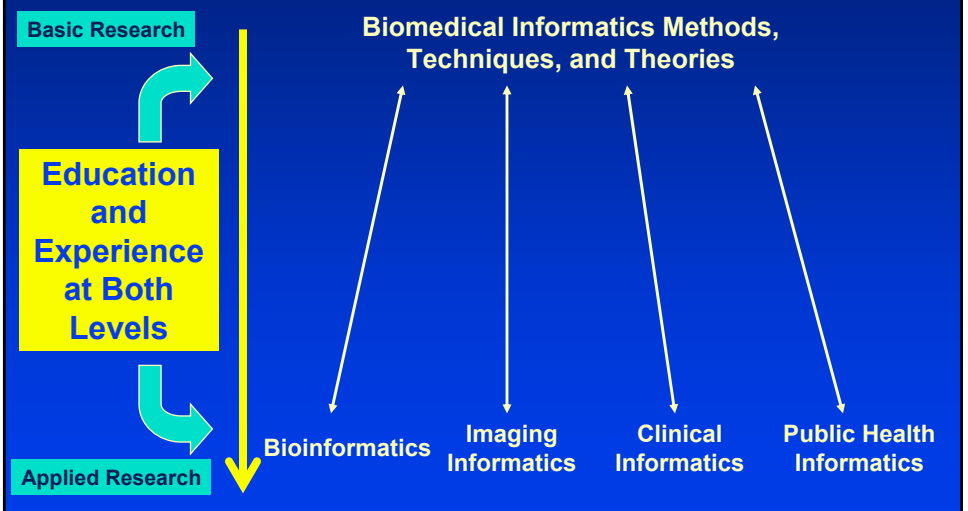
Academic Units in Biomedical Informatics

- Tend to have arisen as grass roots activities, stimulated by individual, interested faculty members
- Most are based in medical schools
- May be divisions in other departments or, increasingly, stand alone departments
- Tend to have characteristics of both basic science and clinical departments
  - At many institutions, have clinical systems design and implementation responsibilities
  - Many have graduate trainees (masters and PhD) and postdoctoral fellowships
- Applicant pools are strong, as are job opportunities for graduates (industry, health care, academia, government, military)

Issues For Academic Informatics

- Conveying the fundamental issues in the field to medical school colleagues who equate "true science" with life-science discoveries, typically in the wet-bench laboratory
- Finding the right mix between research/training and service requirements
- Dealing with the challenges of an interdisciplinary field that demands peer relationships with individuals in the computer science and biomedical fields as well as within biomedical informatics itself

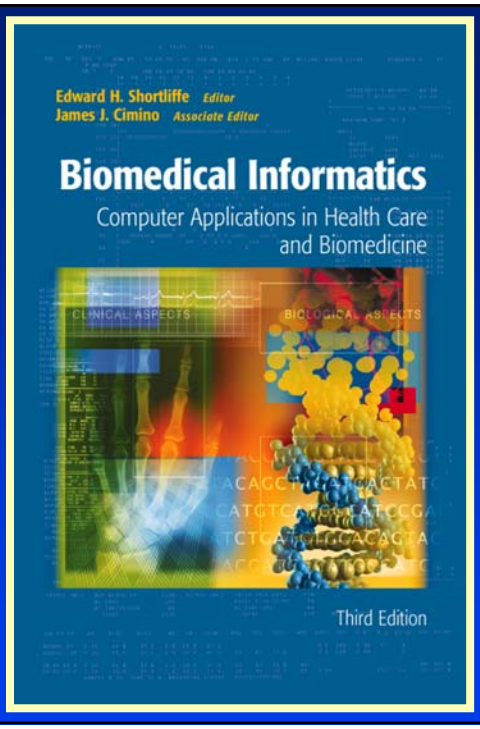
Education of Biomedical Informatics Professionals



Biomedical Informatics Textbook

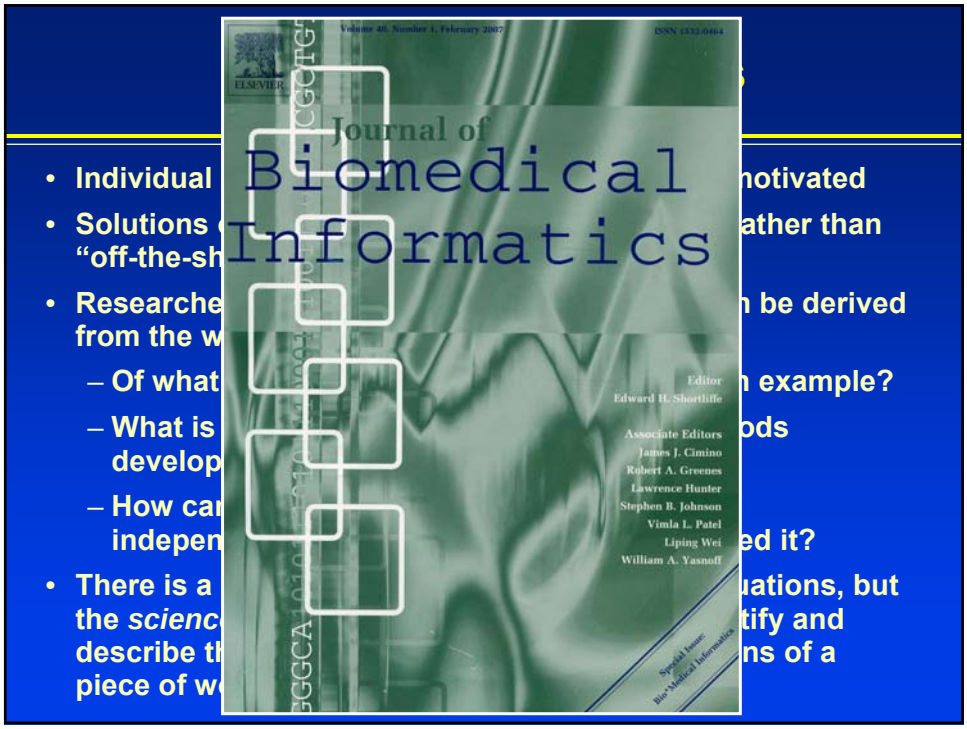
(3rd edition)

Springer - 2006



Fundamental Research in Informatics

- Although projects are inspired by biomedical application goals, basic research in biomedical informatics typically:
  - offers methodological innovation, not simply interesting programming artifacts
  - generalizes to other domains, within or outside biomedicine
- Inherently interdisciplinary, biomedical informatics provides bridging expertise between computer scientists and biomedical researchers and practitioners



- Individual
- Solutions
  "off-the-sh
- Researche
  from the w
  - Of what
  - What is
    develop
  - How ca
    indepen
- There is a
  the *scienc*
  describe t
  piece of w

notivated
ather than
n be derived
n example?
ods
ed it?
uations, but
tify and
ns of a

Suggested Change for BIOSTEC 2010

2009:

"The International Joint Conference on Biomedical Engineering Systems and Technologies, BIOSTEC, is composed of three component conferences, namely HEALTHINF, BIODEVICES and BIOSIGNALS"

2010:

"The International Joint Conference on Biomedical Engineering Systems and Technologies, BIOSTEC, is composed of three component conferences, namely BIOMEDINF, BIODEVICES and BIOSIGNALS"

Some Lessons

- Informatics needs to become part of the "culture" of medicine, and thus must be interwoven with learning throughout the years of medical school (and other health professional schools)
- A great transitional challenge is to engage all faculty (both preclinical and clinical) so that reinforcement of the concepts of informatics occurs consistently in a variety of learning and skill-acquisition settings

More Lessons

- Need to be able to demonstrate that informatics is as much a part of the fabric of medicine as are the traditional biomedical sciences
- Must make it clear that informatics provides a way of thinking and problem solving, and should not be viewed simply as "computers in medicine"

Decision Support and Informatics

- Brief review of clinical decision support over the last five decades
- Identification of "Myths" that once were strongly held beliefs but now have fallen into disfavor
- Emphasis on the key role that *integration* plays in assuring the effective delivery of decision-support functions to decision makers
- Implications of Biomedical Informatics for the emerging cycle of clinical and translational research

Decision Support Lies at the Heart of Our Field

- Essentially all clinical applications of computing are intended to provide decision support
- Biomedical informatics is inherently aimed at enhancing the quality of decisions made by health professionals and patients

Computer-Assisted Decision Support

Examples of functionalities

- Generic information access tools (e.g., Medline)
- Patient-specific consultation systems
  - Diagnosis, workup, therapy or patient management
  - Critiques: reactions to users' impressions or plans
- Browsing tools that mix generic and patient-specific elements (e.g., "electronic textbooks of medicine")
- Monitoring tools that generate warnings or advice as needed (advice as a byproduct of patient care and data recording)

Proactive Computer-Assisted Decision Support

Examples of available methodologies:

- Protocols and algorithms ("clinical guidelines")
- Clinical databanks
- Mathematical models (often physiologic)
- Statistical pattern recognition and neural networks
- Bayesian statistics and Bayesian networks
- Decision analysis
- Artificial intelligence ("expert systems")
- Syntheses of various techniques

1950's

- Earliest broad recognition of statistical issues in diagnosis and the potential role of computers
- "Reasoning foundations in medical diagnosis:
  - Classic article by Ledley and Lusted appeared in Science in 1959

1960's

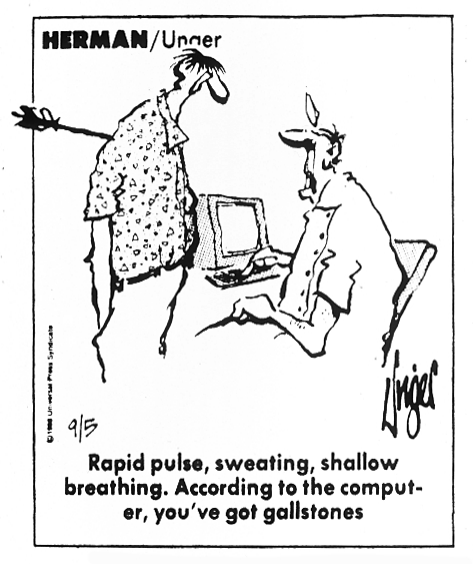
- Bayesian diagnosis systems and statistical pattern recognition
  - Homer Warner's work on congenital heart disease diagnosis
  - Gorry and Barnett: sequential diagnosis introduces notions of *value* in addition to probability (presaging decision analysis programs of early 1970's)
- Early AI work in non-medical domains
  - Production rules (Newell and Simon)
  - General problem solving systems
  - Theory formation and early machine learning

Myths Regarding Decision-Support Systems

Myth:

Diagnosis is the dominant decision-making issue in medicine

Limitations of Computer-Based Diagnosis



1970's

- Applications of flowcharting, logical diagrams, and complex algorithms
  - Acid-base program of Howard Bleich
  - Use of clinical algorithms for triage and primary-care management
- Decision-analysis programs
  - Tools for analysts
  - Pre-formulated decision analyses
- Mathematical modeling

Myths Regarding Decision-Support Systems

Myth:

Clinicians will use knowledge-based systems if the programs can be shown to function at the level of experts

The Nature of Expertise

- Tremendous variation in practice, even among "experts"
- Need to understand better how experts meld personal heuristics and experience with data, and knowledge from the literature, in order to arrive at decisions
  - Can we better teach such skills?
  - How could improved understanding affect the way decision-support systems offer their advice or information
  - How will such insights affect our under-standing of clinicians as computer users?

1980's

- "Overselling" of artificial intelligence
- Resurgence of interest in Bayesian approaches
  - Belief networks and influence diagrams
- Neural networks
- Major changes due to new hardware and software technologies
  - Macs and PCs: viable delivery model
  - Graphical interfaces: rethinking the nature of user interactions with computers
  - Networking: new options for integrating advice systems with their environment
- "Greek oracle" model falls into disfavor

Myths Regarding Decision-Support Systems

Myth:

Clinicians will use stand-alone decision-support tools

1990's

- Integration and networking become central issues
  - World Wide Web revolutionizes our thinking about distributed information access
- Knowledge-representation research matures
  - Ontology development and tools
  - Challenges of temporal representations and reasoning finally begin to yield to researchers
- Integration of decision-support features with databases arrives in some commercial products
- Standards emerge as a major issue
  - terminology, representation of decision logic, data models
  - crucial to promote sharing and collaboration

2000-2010

- Integration of decision support with workflow continues to be viewed as a central requirement
- Patient safety and error reduction become major motivators
- We see increasing incorporation of decision-support functionalities in commercial products
  - CPOE
  - EMR/EHR Systems
- New issues arise regarding relationships between vendors and hospital IT staffs, especially in the incorporation of decision-support and knowledge-management tools that are fully supported by the institution's clinical staff

Challenges

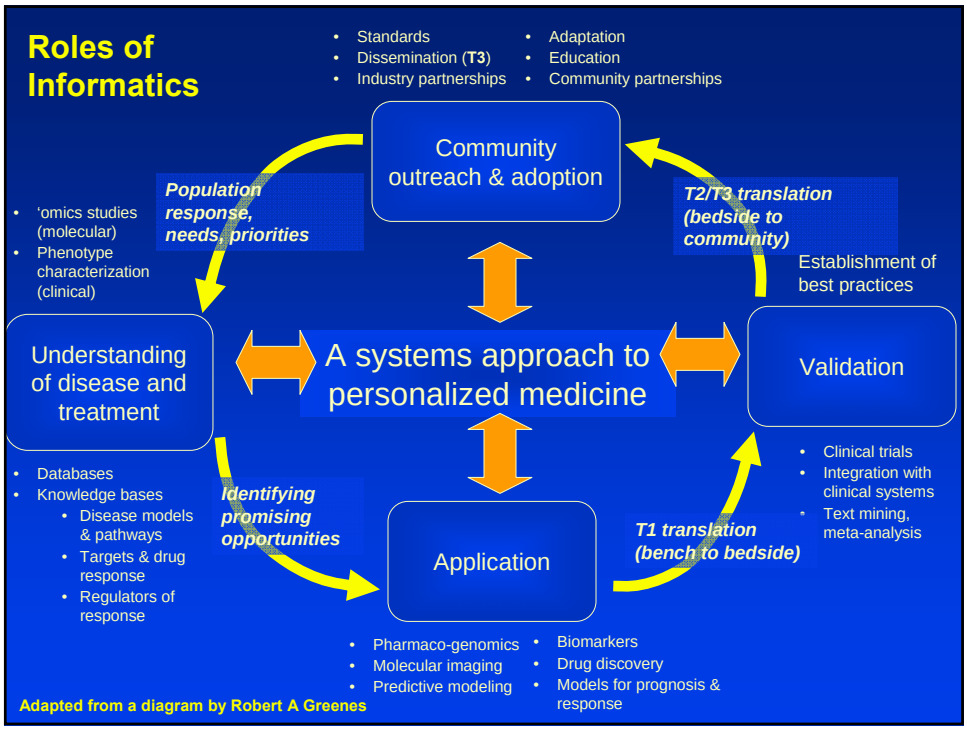
- Identifying context-specific information needs
- Modeling patients and the care process
- Integration of systems
- Terminology translation
- User education
- Technical expertise that is sensitive to the clinical environment

Conclusions: Decision Support

- Integration with routine workflow is the key
- Transparency helps to assure acceptance
- The Web is a great facilitator of integration
  - Does not avoid the need for standardized terminologies and data-sharing protocols
- Implementation of vendor-supplied clinical information systems can present new challenges when attempting to integrate locally-produced decision-support functionalities

The Big Picture, Looking Forward

- Ubiquitous uses of informatics methods and tools at all stages of the clinical care, prevention, and translational research spectrum
- Roles of the full range of biomedical informatics applications and concepts in the clinical translational research world



Trends for Academic Informatics

- Creation of several new biomedical informatics departments or independent academic units
- Strong job market for graduates of informatics degree programs
- Government programs are helping to drive the recognition of informatics as an important contributor to the academic medical milieu
- Increasing acceptance of biomedical informatics as a subspecialty area by biomedical professional societies
- Increasing recognition that biomedical problems can drive the development of basic theory and capabilities in information technology research

Thank You!

ted.shortliffe@asu.edu

http://www.u.arizona.edu/~shortlif