PHARMACY INFORMATICS

Philip O. Anderson
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CRC Press
Taylor & Francis Group
A CHAPMAN & HALL BOOK

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CRC Press
Taylor & Francis Group
Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group an **informa** business
A CHAPMAN & HALL BOOK

Back cover image by Erik Matwijkow.

CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

Printed in the United States of America on acid-free paper
10 9 8 7 6 5 4 3 2 1

International Standard Book Number: 978-1-4200-7175-7 (Hardback)

Library of Congress Cataloging-in-Publication Data

Pharmacy informatics / editors: Philip O. Anderson, Susan M. McGuinness, Philip E. Bourne.
p. ; cm.
Includes bibliographical references and index.
ISBN 978-1-4200-7175-7 (hardcover : alk. paper)
1. Pharmacy--Information services. 2. Pharmacy--Data processing. 3. Medical informatics. I. Anderson, Philip O. II. McGuinness, Susan M. III. Bourne, Philip E. IV. Title.
[DNLM: 1. Clinical Pharmacy Information Systems. 2. Drug Information Services. 3. Information Storage and Retrieval. 4. Medical Records Systems, Computerized. QV 26.5 P5356 2010]

RS56.2.P48 2010
615'.1--dc22 2009036641

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http://www.crcpress.com

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Foreword

Sequencing of the human genome did not simply carry us into a postgenomic era; rather, it was a critical milestone in the start of genomic perspectives that will affect how we approach disease, diagnosis, and therapy. Similarly, the emergence of genomic information was a watershed development that led to the field of bioinformatics and will influence pharmacy practices and pharmaceutical research and development for the foreseeable future.

We have reached new levels in the information age in which contemporary informatics will enable us to collect and handle the explosion of data that can be mined from therapeutic outcomes. Personalized medicine and pharmaceutical care, with linkages to genomic information, will not begin to serve society optimally until they translate to the practitioners positioned to apply them to large segments of the world population. Sophisticated quantitative approaches to data handling and assessment are essential to future advances. Of equal importance, however, is the education of the practitioner who will be engaged in individualizing therapy and communicating outcomes to the patient.

Practicing pharmacists and physicians will be expected to use databases to ensure medication efficacy, patient safety, and confidentiality. Telepharmacy and telemedicine with patient information networks will become more common, and pharmaceutical research and development will assume more global positions. Such endeavors require new means of information transfer for which our academic institutions should be taking a leadership position.

Continual growth and increasing complexity of therapeutic information require our colleges and schools of pharmacy to prepare the practitioner not only for practice after licensure but also for a practice that can respond to the scientific advances over the four decades of an active career. In starting a new pharmacy school on a research-intensive campus with a burgeoning internal healthcare system, members of the faculty at the University of California, San Diego (UCSD), have attempted to address this issue. We feel that informatics not only will play a greatly expanded role in pharmacy education, but also will undergo substantive technological advances.

To develop a core course in informatics and apply its principles throughout the curriculum, we have asked faculty with expertise in drug information, library sciences, bioinformatics, and the computational technologies of high-performance computing to lead this endeavor. In turn, they have engaged a variety of faculty in different practice settings to consider applications as contributing authors. Curricular and textbook design encompasses what a traditional faculty might assemble, but is also informed by individuals outside pharmacy circles.

Doctors Phil Anderson, Sue McGuinness, and Phil Bourne have contributed to and edited this reference informatics textbook for the student pharmacists in their course. This course follows a prior introductory course that exposes the student to computer skills and biostatistics. The pharmacy informatics course is positioned to offer the basic principles for courses in study design, therapeutics, drug information, and pharmacogenomics delivered later in the curriculum. The diversity in backgrounds of the three editors has enabled them to fashion a textbook that extends beyond the UCSD curriculum and should serve as a treatise for the evolving curricula in pharmacy to refine over the years.

Palmer Taylor, Ph.D.
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Preface

Pharmacy practice, like all areas of healthcare delivery, is in a state of rapid change—some would say crisis. These changes are being driven by an aging population, new legislative initiatives, healthcare costs, the promise of genomic medicine, expanding roles for pharmacists in healthcare, and upheavals in the pharmaceutical industry that include company mergers, increased emphasis on biologicals, limited pipelines of new drugs, and drug recalls. Information technology is seen as both a driver of these changes and a response to the perceived crisis. It is timely, therefore, to introduce a book specifically on the subject of pharmacy informatics.

Taken separately, "pharmacy" and "informatics" are broad subjects. For the past 7 years, we have grappled with offering the appropriately focused doctor of pharmacy course that provides the training needed to cope with changes in pharmacy practice—whether future careers will be in community pharmacy, hospital pharmacy, the pharmaceutical industry, or other healthcare sectors. This book is a result of that process. Although it is intended as a textbook for our course, we hope that it appeals not only to the pharmacists of tomorrow, but also to pharmacists already in practice and interested consumers of pharmacy services.

We are part of the new and dynamic Skaggs School of Pharmacy and Pharmaceutical Sciences (SSPPS) at the University of California, San Diego. The doctor of pharmacy and doctor of pharmacy/doctor of philosophy programs reflect our unique association with the School of Medicine: Students undergo part of their training with medical students and the broader health sciences campus, as well as having access to UCSD's strengths in the biomedical and computer sciences. We are also fortunate that healthcare informatics is quite advanced in San Diego and that we are able to tap experts from other local institutions for our course and this textbook. We hope that our excitement in being part of a new enterprise, unafraid of pushing the boundaries while still providing all the fundamental elements of more traditional training, comes across in this book.

Given the breadth of topics that fall under pharmacy informatics, no one or two individuals could hope to provide the expertise needed in all areas. We have called upon all our course lecturers to participate in this work and, just as we seek continuity and relevance in the course material, we have tried to organize the book in the same way. Pharmacy informatics is learned by doing. Our course reflects this principle. Each class of two 3-hour sessions per week for 10 weeks consists of a prerequisite presentation of background material by the lecturer, followed by hands-on exercises.

It is fitting that we start with a foreword by the dean of our new school, Dr. Palmer Taylor, because his vision, more than anything else, saw the inclusion of this course as part of the core curriculum for all doctor of pharmacy students. The book is divided into five parts, each of which builds upon what has been discussed before. We hope that this organization will facilitate the use of this book as a textbook and also as a reference source where appropriate discussion can be found.

- Section I introduces the scope of the material to be covered and the motivators for the book. Drs. Susan McGuinness, pharmacy librarian, Philip Anderson, coordinator of UCSD's drug information course, and Philip Bourne, bioinformatics expert define what we mean by pharmacy informatics. This overview is followed by a discussion of information and biomedical technologies that are the drivers of change by Howard Asher, president and CEO of Global Life Sciences, Inc., and Philip Bourne, professor of pharmacology at UCSD.
- Section II provides the prerequisites for the effective use of the informatics resources discussed subsequently. Dr. Bourne discusses the basics of maintaining the reliability and security of computers in a connected world. Among both practicing pharmacists and our students, basic knowledge of computing varies widely and we have organized the material so that sections can be easily skipped. A theme that appears repeatedly is the need for standardization in the healthcare industry, including the information contained therein. Doctors McGuinness and Bourne discuss the standards and controlled vocabularies that pharmacists will confront throughout their careers. Dr. McGuinness discusses effective strategies for navigating, searching, evaluating, and managing the wide variety of information resources available today.
- Section III covers the types of information systems that exist in hospitals and pharmacies. The electronic health record (EHR) underlies all these systems and is discussed by Dr. Joshua Lee, associate clinical professor of medicine, who practices both clinically and in informatics at UCSD. Doctors Daniel Boggie, Jennifer Howard, and Armen Simonian, informatics pharmacists from neighboring affiliated healthcare institutions, review the basic elements of pharmacy information and automation systems. Bar coding, a relatively new technology for reducing medication errors, is described by Dr. Ashley Dalton, who was instrumental in implementing this technology at UCSD Medical Center. Dr. Simonian returns to describe how pharmacists and students interested in a pharmacy informatics career can prepare for and function in this role.

  A critical aspect of any of these systems is the need to avoid errors. Dr. Joseph Scherger, a professor of family and preventive medicine, and Dr. Grace Kuo, an associate professor of clinical pharmacy in our school, elaborate on medical errors and review how information technology can reduce errors in healthcare delivery. Drug information systems and Web-based resources are vital tools for pharmacists and their effective use is discussed by Doctors Anderson and McGuinness. Finally, Dr.

Joseph Ennesser, a graduate of the founding class of the Skaggs School of Pharmacy and Pharmaceutical Sciences and now a practicing pharmacist, describes the use of personal digital assistants (PDAs) and their roles in today's pharmacy practice.

- Section IV details the next step, where systems are used beyond the basic recall of information to help in decision support of patients. Dr. Laura Nicholson, a hospitalist from a neighboring institution, Scripps Health, has particular expertise in evidence-based medicine and discusses tools for use in evidence-based practice. Dr. Anderson returns with a review of computerized clinical pharmacokinetics methods as a decision support tool. Dr. Pieter Helmons, a pharmacoeconomics specialist at UCSD Medical Center with extensive experience in clinical decision support, elaborates on this promising technology. Dr. Robert Schoenhaus, a pharmacist specializing in pharmacoeconomics, discusses ways in which data contained in information systems can be mined to improve therapy, decrease adverse outcomes, and cut costs.
- Section V takes us to the future of pharmacy informatics and what will drive the field. Dr. Bourne discusses the various developments driven by the Internet, such as the emergence of virtual communities, video on demand, and changing publishing models. Dr. Richard Peters provides the perspective of a pioneer in advanced healthcare informatics on how current informatics solutions have developed and how they need to evolve to maximize their potential.

Taken together, the five sections of this book reflect a changing pharmacy profession in which information plays a central role if that practice is to be conducted in the most productive and efficient way for both producer and consumer of healthcare services. We have tried to capture what such a change means to the pharmacy student and the practicing pharmacist, as well as to prepare the reader for what lies ahead in a world characterized by only one certainty: It will be very different.

Philip O. Anderson
Susan M. McGuinness
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Editors

Philip O. Anderson is Health Sciences Clinical Professor of Pharmacy at the University of California, San Diego, Skaggs School of Pharmacy and Pharmaceutical Sciences, where he is in charge of the drug information course. Dr. Anderson is also a member of the coordinating faculty team for the pharmacy informatics and therapeutics courses and lecturer in the pharmacy practice course. He is also a partner in Healthware, Inc., where he helped develop T.D.M.S. 2000, and is the author of the National Library of Medicine's LactMed database.

Susan M. McGuinness is the pharmacy librarian at the Biomedical Library at the University of California, San Diego, and Assistant Clinical Professor at the Skaggs School of Pharmacy and Pharmaceutical Sciences. Dr. McGuinness is chair (2009–2010) of the Libraries and Educational Resources Section of the American Association of Colleges of Pharmacy. She is a member of the coordinating faculty team for the pharmacy informatics course and lectures in the drug information, pharmacy practice, pharmaceutical chemistry, and pharmaceutics courses.

Philip E. Bourne is Professor of Pharmacology at the University of California, San Diego, Skaggs School of Pharmacy and Pharmaceutical Sciences, where he is the lead faculty member for the pharmacy informatics course. Dr. Bourne is also currently the editor-in-chief of *PLoS Computational Biology* and associate director of the RCSB Protein Data Bank, a vital public resource used in drug discovery.

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I

Introduction

CHAPTER 1

What Is Pharmacy Informatics?

Philip O. Anderson, Susan M. McGuinness, and Philip E. Bourne

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PHARMACISTS PRACTICING TODAY IN the United States or other developed or developing countries will interact with technology in almost every aspect of their work. Government initiatives are driving healthcare systems toward the adoption of health information technology with the goal of higher quality, more cost-effective patient care.[1] At the University of California, San Diego (UCSD), Skaggs School of Pharmacy and Pharmaceutical Sciences (SSPPS), this recognition led to the integration of pharmacy informatics into the doctor of pharmacy curriculum in 2001.

Informatics affects all three curricular areas of emphasis: basic pharmaceutical sciences (e.g., pharmacogenomics, pharmaceutical chemistry, pharmacokinetics), pharmaceutical technology and management (e.g., pharmaceutics, pharmacoeconomics, study design), and clinical pharmacy practice (e.g., therapeutics, drug information, diagnostics, patient counseling). This textbook summarizes the content of a pharmacy informatics course developed by the editors. As such, it reflects a number of years of experience in defining what is relevant to teach in a course that meets the needs of the curriculum, with emphasis on the mission of SSPPS and the changing landscape of healthcare.

Informatics is the study of the best practices in information accrual, handling, dissemination, and comprehension using appropriate technology. Pharmacy informatics deals with the subset of informatics relevant to the practice of pharmacy. As such, it intersects with two other subdisciplines of information science that have a longer history.

First, medical informatics came about as the healthcare system increasingly relied on information technology for data management, communications, decision support, and, ultimately, improved patient care. The American Medical Informatics Association (AMIA) defines medical informatics as “the use of information science and technology to advance medical knowledge and improve quality of care and health system performance.” The American Association of Medical Colleges defines it as “the rapidly developing scientific field that deals with resources, devices, and formalized methods for optimizing the storage retrieval and management of biomedical information for problem solving and decision making."

Later came bioinformatics, a field that sprang from the human genome project and used computers to analyze and interpret the vast amounts of data generated in the field of biology. *Stedman's Medical Dictionary* defines bioinformatics as "the scientific discipline encompassing all aspects of biologic information acquisition, processing, storage, distribution, analysis, and interpretation that combines the tools and technology of mathematics, computer science, and biology with the aim of understanding the biologic significance of a variety of data."

Putting it all together, the American Society of Health-System Pharmacists (ASHP) defines pharmacy informatics as an important subset of medical informatics in which pharmacists "use their knowledge of information systems and medication-use processes to improve patient care by ensuring that new technologies lead to safer and more effective medication use."[2] A recent ASHP survey of U.S. hospitals found that information technologies are used in all steps of medication-use processes and that pharmacists must understand these technologies.[3]

"Pharmacy informatics" has been defined in some contexts as the pharmacy specialty dealing with pharmacy computerization. Specialized residencies and standards exist for training a cadre of pharmacy informatics specialists.[4] Although this definition of pharmacy informatics is useful, the UCSD course and this textbook are designed primarily for pharmacist generalists and take a more expansive and general view of pharmacy informatics. Practicing pharmacists need to know not only the computer system in use where they work, but also how it relates to larger systems such as the hospital computer system and peripheral automation that is connected to these systems.

Our working model for the pharmacy informatics course is based on the idea that pharmacists must use information and technology skills to integrate information about drugs and information about patient-related issues from a variety of sources in order to achieve patient-centered care (see Figure 1.1).

Information about drugs includes primary literature and electronic information resources, hospital and pharmacy information systems, pharmacokinetics, and pharmacogenomics. Patient-related issues include medication safety, electronic health records, decision support systems, and the practice of evidence-based medicine. The skills needed to implement this knowledge in patient-centered care include effective literature and Web search skills, an understanding of databases, and the controlled vocabularies needed for interoperability between systems and for optimal searching of some databases. Additionally, pharmacists need to know how to access computerized medical information in various databases and to understand the underpinnings of these databases to use them most effectively.

Pharmacy students also need to know the current state of the art in hospital and pharmacy information and decision support systems, how to use these systems, and the components and functions needed to build efficient and effective systems. All of these information and technology skills should help the pharmacist clearly see the complex picture of medication management for each individual patient and make the best possible decisions for his

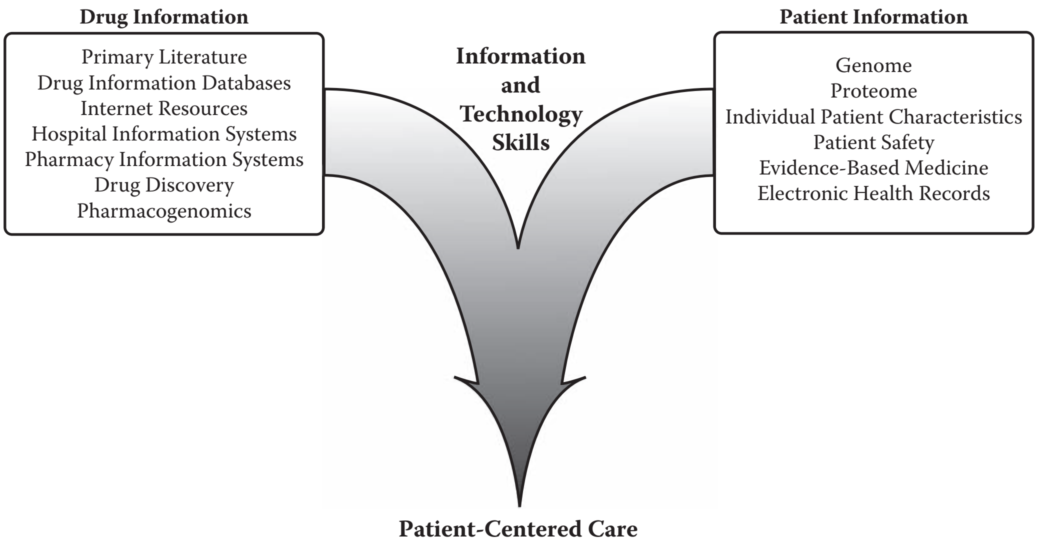

FIGURE 1.1 Working model for pharmacy informatics.

or her care. This textbook covers prerequisite information and technology skills, information systems currently used in hospitals and pharmacies, what a career in pharmacy informatics involves, and what the future of pharmacy informatics might look like. We hope that others find this information helpful and relevant.

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CHAPTER 2

Drivers of Change

Emergent Information and Biotechnologies

Howard R. Asher and Philip E. Bourne

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2.1 INTRODUCTION

Pharmacy and pharmaceutical sciences have been affected, and will be more so in the future, by information technologies and biotechnologies. This book details some of the outcomes of that impact and how they affect pharmacists' professional lives. This chapter introduces some of the elements that comprise these technologies as well as their implications. What is apparent is that these technologies represent drivers of change in a healthcare industry that is considered a late adopter with a low tolerance for risk, particularly with respect to information technology. However, we now speak of this era of digital medicine as if these technologies are about to precipitate major change. Some would argue that we are now, to use a phrase popularized by Malcolm Gladwell, at a "tipping point."[1]

As we describe the gains that can be made by greater adoption of information and biotechnologies against the backdrop of the current state of our healthcare industry (with particular reference to the United States), it is easy to believe that we are at this tipping point. By one estimate by the Rand Corporation, if 90% of U.S. hospitals and physicians were to adopt hospital information systems over the next 15 years, the industry would save $77 billion per year from efficiency gains.[2] If health and safety gains are considered also, these savings could double to 6% of the $2.6 trillion estimated to have been spent on healthcare in 2009. These savings are compelling and it is not surprising that governments are attempting to control escalating healthcare costs through the adoption of better information and biotechnologies. The bottom line is that these changes will have an impact on pharmacists and pharmaceutical scientists because the current system of healthcare is simply not sustainable.

What is the current state of healthcare? What are these drivers of change? How will changes affect healthcare and the pharmacists that provide that care? These are some of the questions addressed in this chapter.

2.2 THE CURRENT SITUATION

We begin by briefly summarizing the state of healthcare in the United States and the state of the drug industry at large to emphasize the scale of the current problems.

2.2.1 The Current State of Healthcare in the United States

The following data on the state of healthcare in the United States surely must be drivers of change because, as was stated previously, the current system is simply not sustainable:

- The $2.6 trillion the United States will spend on healthcare this year represents 17.6% of the U.S. economy; if unchecked, this percentage will rise.[3]
- Of the total money spent on healthcare worldwide, the United States spends 54%.
- Compared with five other developed nations—Australia, Canada, Germany, New Zealand, and the United Kingdom—the U.S. healthcare system ranks last or next to last on quality, access, efficiency, equity, and healthy lives—five dimensions of a high-performance health system. The United States is the only country of the five without universal health insurance coverage; this partly accounts for its poor performance on access, equity, and health outcomes. The inclusion of physician survey data also shows the United States lagging in adoption of information technology and use of nurses to improve care coordination for the chronically ill.[4]
- Overall, the United States ranks 37 out of 191 countries in the quality and performance of healthcare (see Table 2.1).[5]
- The United States ranks 30th in life expectancy.[6]

TABLE 2.1 World Health System Rankings[7]

1. France	11. Norway	21. Belgium	31. Finland
2. Italy	12. Portugal	22. Colombia	32. Australia
3. San Marino	13. Monaco	23. Sweden	33. Chile
4. Andorra	14. Greece	24. Cyprus	34. Denmark
5. Malta	15. Iceland	25. Germany	35. Dominica
6. Singapore	16. Luxembourg	26. Saudi Arabia	36. Costa Rica
7. Spain	17. Netherlands	27. United Arab Emirates	37. *United States*
8. Oman	18. United Kingdom	28. Israel	38. Slovenia
9. Austria	19. Ireland	29. Morocco	39. Cuba
10. Japan	20. Switzerland	30. Canada	40. Brunei

Source: World Health Organization (www.who.int/whr/2000/media_centre/press_release/en/index.html).

- Of each dollar spent on healthcare, 10 cents goes toward medical liability and defensive medicine.
- An estimated 60 million people in the United States have no health insurance.

These statistics represent enough woe as to the state of healthcare and must be incentives to change. Let us now look at the state of drug discovery as another issue that will affect healthcare, including pharmacy practice.

2.2.2 The Current State of Drug Discovery

The following points are taken from the 2009 Outlook Report from the Tufts Center for the Study of Drug Development[8]:

- Through a concerted effort at the Food and Drug Administration (FDA), the time to approve a new drug has dropped in recent years, but seems to have stabilized at 8 years. Drugs that are developed are most often used to treat complex diseases and are not necessarily that effective.
- The cost of bringing a drug to market can be US$1 billion.
- New drug output has stagnated; fewer than 30 drugs were approved in 2007.
- The introduction of therapeutic monoclonal antibodies is increasing and having a positive impact on the rate of drug discovery.

2.3 HISTORICAL EXAMPLES OF PRECIPITATORS OF CHANGE

The preceding facts sound like doom and gloom; although it is fine to say that this will drive the United States to change, is that possible? One way to answer that question is to consider how change has been wrought in the past. Here are a few examples in chronological order:

- Stethoscope (1816). Rene Laennec of France invented the first stethoscope to protect the modesty of one of his female patients. In 1837, Dr. Oliver Wendell Holmes returned from medical studies in Paris and urged his fellow American physicians to increase their use of stethoscopes. By the mid-1840s, the stethoscope had become integral to the practice of medicine in the United States.

- Thermometer (1867). Sir Thomas Allbutt introduced the first thermometer meant to take the temperature of a person.
- X-rays (1895). Wilhelm Conrad Röntgen accidentally discovered x-rays upon seeing an image cast from his cathode ray generator. The announcement of Röntgen's discovery was illustrated with an x-ray photograph of his wife's hand. The x-ray became one of the defining technological devices to move the art of medical diagnosis to a scientifically based medicine in the early 1900s.
- Blood pressure cuff (1901). Harvey Cushing introduced a version of the modern blood pressure cuff (sphygmomanometer) to U.S. physicians.
- Penicillin (1929). Sir Alexander Fleming's discovery of penicillin in 1929 went undeveloped until the 1940s, when Howard Florey and Ernst Chain isolated the active ingredient from *Penicillium* mold and developed a powdery form of the medicine. Under the pressure of World War II, pharmaceutical manufacturers rapidly adopted mass production methods, reducing the production costs to 1/1000th of the original.

Interestingly, these innovations, which we take for granted in today's provision of healthcare, share similar characteristics: an extended period before wide adoption was seen. It may be that even in the accelerated pace of a modern healthcare world, there will be a marked lag time before the technologies introduced subsequently become commonplace. First, we have to reach the tipping point. Assuming these changes do come eventually, which of them will have an impact on pharmacy practice?

2.4 CHANGES EXPECTED TO RESULT FROM INFORMATION TECHNOLOGY

Information technology (IT) remains underused in healthcare. This fact is surprising given that providing adequate healthcare involves managing and effectively using information. It is not that the need for information has not been recognized. For example, the American Medical Informatics Association (AMIA; www.amia.org) has existed for over 30 years and has over 4,000 members. So, why has the uptake of IT within healthcare been slow? In the 1970s, information technology was expensive and alien to most healthcare providers. Centralized mainframe computers provided billing services, but little else.

The emergence of so-called minicomputers saw a diversification of use in a distributed model of computational operation. Thus, for example, the radiology department began using image processing, and various departments began developing and using databases for diverse information ranging from patient records to pathology samples to the tumor registry. These systems required expert personnel and in no way communicated or interoperated with each other.

The late 1970s and early 1980s saw the emergence of intranets: internal computational networks that started to allow these computers to communicate. This was certainly one of the early drivers of medical informatics because it was soon realized that common naming conventions for items of information needed to be used if the information located on these respective computers were to be used collectively (see Chapter 4). In the early 1980s, IT slowly migrated into back office, to inventory control, central supplies, as well as management of pharmaceuticals and other prescribed medical products. The early 1980s also saw the emergence of the personal computer (PC) and a real opportunity to distribute healthcare information. It seems strange now, but only a small fraction of people were adept at using the PC at that time and, in general, healthcare providers were resistant. Further, the cost per PC station was approximately 10–100 times what it is today.

The 1990s changed all that (as further elaborated in Chapter 3). With computer power doubling for the same cost every 18 months and the advent of widespread Internet use by both patients and providers, the stage was set for change. In the early 1990s, IT began a slow adoption within prescription management, processing, prescription label generation, pharmacy billing, and work flow. In the mid-1990s, the Internet began to be recognized as an expedient source of some medical and pharmaceutical information. The late 1990s saw an important pharmacy innovation from a small company in San Diego, California. Pyxis introduced products for automated and controlled medication dispensing and pharmaceutical supply management.

Still, the human factor persists and should not be underestimated in the adoption of any technology. Often people are happy with the old way of doing things and do not see the more institutional (and often global) implications of their inertia. Institutional mandates come into play here. For example, the insistence that the U.S. Veterans Administration hospitals adopt a single, universal system could not be resisted by care providers if they wanted to keep their jobs.[9] Such systems have a sufficiently successful track record and the problems of global health are so pressing that more rapid adoption of IT in all healthcare sectors seems inevitable.

2.4.1 Electronic Health Record

The electronic health record (EHR) is perhaps the single most important component of medical and pharmacy informatics and is discussed in detail in Chapters 6 and 7. Here we focus on one particular driver of change related to the EHR. That change (tipping point) is, we believe, the point at which the patient demands control of his or her health record. Many of us in the United States have had the time-consuming and awkward experience of requesting information from our own medical record that is often dispersed in paper form across a number of institutions. Why should we not have immediate access to our records and, if we choose, share elements of that record with whomever we see fit?

After all, many of us now spend considerable time each day in front of a computer, where we have access to our bank records and other personal data. Why should we not have that access to our EHRs and even add to our patient records ourselves to update our care providers? Consider a resource like Patients Like Me, where people choose to share and discuss their conditions with each other.[10] As more of the Web 2.0 generation (i.e., those familiar with sharing and communicating online) take interest in their EHR, the demand will likely increase for availability and access.

Before, we focused on the broader adoption of the EHR from the patient's perspective, which we see as a driver. However, savings from error reduction, apparent efficiency gains, and government regulation will all drive broader adoption of the record from the institutional perspective as well.

2.4.2 Smart Devices

The term "smart device" is catchy, but what does it mean to healthcare and the provider? If patients and care providers alike were asked, each would likely come up with different devices as examples of smart devices and of what each one means to healthcare. Let us offer a patient-centric view that suggests that it is a device trusted in some way to improve efficiency and quality of life—in some respects, an automated teller machine (ATM) for healthcare. We all trust an ATM to give us the right amount of money and update our accounts correctly. Given the ATM analogy, it is clear that such devices do not have to be "whiz-bang" new technologies; they could be something as ubiquitous as the mobile phone. In parts of the developing world, the mobile phone is emerging as a valuable tool in reporting and receiving healthcare information, so why do we not see more of this in the developed world?

With these definitions of simplicity and efficiency, a smart device might simply be a device for measuring glucose levels in an unobtrusive way. To a physician, it might be a device for good voice-to-text translation that negates the need for a transcription service. On the other hand, it could be something more comprehensive that provides the ability to access x-rays, MRIs, the latest laboratory results, or the patient history on a smart handheld device that allows a physician's notes to be hand written and correctly understood!

All these devices are in place or on the near horizon. Once we reach the tipping point, they will become mainstream.

2.4.3 Visualization Devices

As stated earlier, healthcare is information rich, and that information must be visualized in a way that makes it most meaningful. Our example of the x-ray as an emergent technology that changed healthcare is one illustration of how visualization was a driver of change in healthcare. Today, microscopy, magnetic resonance imaging, endoscopy, and others are all forms of medical visualization in common use. A major breakthrough is not the visualization devices and techniques themselves, but rather the quality of the image, the speed of the networks, and the variety of devices from which the images can be viewed and analyzed.

Today, it is not uncommon for a tomogram to be embedded within the EHR and recalled by the patient at home or by a variety of specialists using a variety of devices, including those that are handheld. There is no technical impediment to providing this kind of visualization today—only the right price point, awareness, and desire. The future will likely include three-dimensional viewing and new forms of interaction with the images, including tactile control.