

PUBLIC HEALTH INFORMATICS: How Information-Age Technology Can Strengthen Public Health*

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ABSTRACT

The combination of the burgeoning interest in health, health care reform and the advent of the Information Age, represents a challenge and an opportunity for public health. If public health's effectiveness and profile are to grow, practitioners and researchers will need reliable, timely information with which to make *information-driven decisions*, better ways to communicate, and improved tools to analyze and present new knowledge.

"Public Health Informatics" (PHI) is the science of applying Information-Age technology to serve the specialized needs of public health. In this paper we define Public Health Informatics, outline specific benefits that may accrue from its widespread application, and discuss why and how an academic dis-

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cipline of public health informatics should be developed. Finally, we make specific recommendations for actions that government and academia can take to assure that public health professionals have the systems, tools, and training to use PHI to advance the mission of public health.

INTRODUCTION

The combination of the burgeoning interest in health, combined with health care reform and the advent of the Information Age, represent a challenge and an opportunity for public health. If public health's effectiveness and profile are to grow, practitioners and researchers will need reliable, timely information with which to make *information-driven decisions*, better ways to communicate, and improved tools to analyze and present new knowledge.

"Public Health Informatics" (PHI) is the science of applying Information-Age technology to serve the specialized needs of public health. Systems developed with PHI knowledge can help a county health office staff use surveillance data to estimate the number of doses of measles vaccine needed for an outbreak; make it easier for a regional planning commission to integrate census, surveillance, and hospitalization data to project the occupancy of AIDS hospice beds for a city, and prepare related funding requests for the state legislature; assist an epidemiologist in collecting and analyzing data to study malnutrition among homeless children and the impact of nutrition programs in different regions of the US; and facilitate a health educator's use of multimedia to communicate, in a compelling fashion, new knowledge to professional and lay audiences.

In 1990, Greenes & Shortliffe, in the *Journal of the American Medical Association*, presented an overview of Medical Informatics (10). In this paper we define Public Health Informatics, outline specific benefits that may accrue from its widespread application, and discuss why and how an academic discipline of public health informatics should be developed. Finally, we make specific recommendations for actions that government and academia can take to assure that public health professionals have the systems, tools, and training to use PHI to advance the mission of public health.

WHAT IS PUBLIC HEALTH INFORMATICS?

Public Health Informatics is the application of information science and technology to public health practice and research. Specifically, this means developing innovative ways to use inexpensive and powerful computers, on-line databases, the capacity for universal connection of people and computers, and multimedia communications to support the mission of disease prevention and health promotion. Practical PHI work, ideally guided by PHI professionals who are trained and experienced in both information technology and public health, involves bringing

together specialists in both fields to conceptualize new ways of applying information technology to solve public health problems. The practice of public health informatics goes beyond applying known "computer science." Rather, it involves synthesizing knowledge from both disciplines, which is leading to new ways of thinking about and practicing public health.

Software and hardware developed for laboratory science or business often lack features required for public health. For example, standard statistical packages cannot easily be used to perform standardization, fit mathematical models to disease patterns, or calculate sample sizes for case-control studies; commonly available data-entry programs cannot handle the very long or complex questionnaires common in public health; general-purpose graphing programs make bar and pie charts but not histograms or county maps. Public health data files often contain many millions of records, and quickly accessing these very large files requires special database designs. Finally, there is an increasing need to search the full contents of massive text databases such as publications, reports and recommendations, tables of summary data, information about the Healthy People 2000 Objectives, etc. Typically, these documents are not keyworded, and their diversity, dynamic nature, and the unavailability of appropriate key words in the MeSH (Medical Subject Headings) system would preclude doing so; one of the challenges for public health informatics is to develop streamlined ways to access complex textual data.

CDC and other government agencies increasingly consider information dissemination to be central to their mission. These activities could be enhanced by building information systems specifically designed for public health data and various users: Synthesized knowledge can be easily communicated to the public through specialized voice and video systems (in addition to standard radio and television); summary data can be provided to the manager or public inquiries specialist via on-line information systems; researchers may wish to use more sophisticated systems to manipulate complex databases. Developing diverse systems that meet the full range of public health needs requires developing a cadre of professionals with training and experience in both public health and information technology.

Medical informatics has forged an analogous link between clinical medicine and information technology, focusing on hospital and clinical research information systems (automating medical charts, linking laboratory data to clinical data, etc), computerized diagnostic systems, biomedical engineering, patient and student education, and medical library automation (10). Clearly there is overlap between medical informatics and PHI. However, because public health has its foundations in epidemiology and prevention, public health informatics must focus on speeding and simplifying the conversion of hypotheses about the distribution and determinants of diseases in *populations* into usable information, and help to disseminate new knowledge in ways that will support

public health practice. In addition, to the extent that clinicians of the twenty-first century incorporate epidemiology and public health principles into clinical medicine, and come to see the patient as part of a community, public health informatics will make important contributions to the work of practicing physicians (11).

Public health needs to make more effective use of information technology to support its mission. Modern businesses use information technology to update centralized databases from hundreds of retail stores located around the country several times a day, to predict and report elections as they are taking place, and to instantly make reservations on any airline in the world. Public health could make use of similar technology to enhance the timeliness and efficiency of survey and surveillance systems; rapidly and effectively communicate scientific findings to the public; and offer services (such as public health clinic appointments for childhood immunizations) to underserved populations. Public health leaders in academia and at all levels of government will thus be empowered to better evaluate prevention strategies, and allocate resources for services and research. This will require applying currently available knowledge, and making advances in: (a) data and information systems; (b) communications; and (c) specialized tools.

IMPROVED DATA AND INFORMATION SYSTEMS FOR INFORMATION-DRIVEN DECISIONS

Data Systems

Data systems are formal systems for data collection, collation, editing, and distribution. They benefit public health practice by standardizing data gathering and processing. Data systems produce data (i.e. raw observations or numbers). To generate reports (tables, graphs, or data subsets), the end-user must write computer programs. An example of a widely used data system is the National Vital Statistics System, which state vital registrars use to provide data to CDC for accumulation into a national data bank.

Data systems could be improved by making more effective use of technology to improve accuracy, timeliness, and confidentiality. Accuracy can be improved by more widespread use of computer-assisted personal interviewing, wherein the data are cross-checked as they are keyed (for example, if the interviewee is pregnant, then age = "73" cannot be entered). CDC has written and makes extensive use of programs that provide this feature, including Epi Info, SURVEY, and the data-entry modules of the AIDS Reporting System. Accuracy can also be enhanced by maintaining the data in databases during all phases of the data cycle, where records can be reviewed and edited upon receipt, and then can be used to update information systems. Timeliness can

be enhanced by electronic data transmittal; for example, states now transmit notifiable diseases data every Monday to CDC for publication in that Friday's *Morbidity and Mortality Weekly Report*. They are later added to CDC WONDER, CDC's on-line public health information system, where they are available for more detailed analysis.

Preserving confidentiality can be facilitated by making wider use of computer programs that generate a pseudonym based on the phonetics of an individual's name combined with other information (e.g. birth date). The AIDS Reporting System uses this method to assure that information that could identify an individual is never transmitted to CDC, yet it allows a case to be tracked over time. Another way to guarantee confidentiality is to transfer the data to information systems where the data are stored in aggregate (summary) form only, which is how several surveillance data sets are stored in CDC WONDER.

INFORMATION SYSTEMS

Information systems are computer systems that provide routine mechanisms for converting data into information (e.g. summary statistics, tables, graphs). In contrast to data systems, information systems can be accessed without any computer programming by the user; rather, results are accessed via menus or simple commands. Information systems benefit public health practice by providing easy and rapid access to information. One example of a widely used information system is CDC's AIDS Reporting System used for AIDS surveillance data, which allows state and local health departments to input, verify, and prepare reports via menus. The reporting area, which may be a state or county, can use menus to quickly and easily prepare a profile of risk factors among AIDS cases reported this year as compared to last year. Because this system integrates data entry and reporting, it promotes both the uniformity of the national database, and facilitates state-level analysis, thereby putting timely information in the hands of local decision-makers.

A second example is CDC WONDER, which provides menu-driven access to more than 40 large on-line databases (7). CDC WONDER has been used to perform tasks such as updating reports in a few minutes (14), pulling together data on older Americans from a dozen different surveys and surveillance data sets in an afternoon (a task that would normally require weeks of computer programming); or searching the full text of the *Morbidity and Mortality Weekly Report* for all articles during the past 10 years that mention AIDS and Washington State, an assignment that would be virtually impossible unless the data were in a system that offered full-text searching.

To take on new public health challenges, such as tracking progress towards meeting the *Healthy People 2000 Objectives*, and understanding why goals

are (or are not) being met, public health workers need to acquire and synthesize many more data about the public's health than are now available; information must be in formats that are directly usable for developing prevention strategies under frameworks such as those provided by the "Model Standards" (2). To be useful for the *Healthy People 2000* (6) and "Model Standards" processes (1), this information must contain concise, up-to-the-minute, age-, race-, and geography-specific syntheses of key data, recommendations, and supporting materials. Background tables and supporting documents must be available, but to facilitate rapid action, the bottom line needs to be crystal clear. PHI can be brought to bear on several aspects of data and information system development.

Information systems could be improved by increasing the number of data sets that are included, providing sophisticated facilities to help users identify pertinent data sources, and creating easier-to-use and more flexible statistical and graphing tools. Information systems vary in their objectives: CDC WONDER contains many data sets, but statistical analysis facilities are limited (7). In contrast, BWTRGR has data limited to Massachusetts births, but allows the user to perform regression (19); EPIGRAM provides access to detailed data about a single state (Texas) (9). Both kinds of systems have important roles to play.

Agencies that have had success in building public health information systems need to share their expertise. An unknown number of data-collection and information systems are currently in various stages of early consideration or planning, including a national system to track the immunization status of children, expanded cancer incidence surveillance, regional trauma registries (17), and registries of people exposed to substances suspected of being hazardous to health. Making any plans to develop similar systems widely known would promote collaborations, increase data accuracy, and reduce duplication.

Developing standards for communications protocols, data elements, interfaces (the appearance of the screen and keystrokes that a user needs to work a computer program), etc, will make both data and information systems easier to build and use. For example, if all public health systems used the same kind of modems, had compatible age groupings, and had screens that worked the same way, then encoding, transmitting, and accessing data would be greatly speeded, users would be less confused by programs that do not look and work alike, and user support costs would be reduced. With respect to interfaces, standardization would be promoted by moving towards the adoption of the emerging standard for commercial software (or using commercial products directly, when possible), which uses a graphical user interface with drop down menus, an enabled mouse, etc (as is found in Microsoft Windows, X-Windows, and the Apple Macintosh).

There are several systems created by various CDC departments to electronically collect, edit, analyze, and transmit laboratory, hospital-infection, human

Table 1 Recommendations for data and information systems

Time frame	Recommendations
Short term (1–2 Years)	<p><i>Data systems:</i> Implement more widespread electronic data collection and transmittal; link to information systems</p> <p><i>Information systems:</i> Increase number of data sets; enhance analytical and reporting features to support <i>Healthy People 2000 Objectives</i> process</p>
Long term (3–5 Years)	<p><i>Data systems:</i> Standardize data elements and equipment</p> <p><i>Information systems:</i> Standardize interfaces; combine duplicative systems</p>

immunodeficiency virus (HIV) and AIDS, and notifiable disease data from local and state health departments to CDC. These systems reduce the burden for reporting agencies and make data available sooner and in standardized form, which makes it easier to prepare timely reports and update information systems (3). However, they do not share common interfaces or communications protocols. France's computerized network for infectious disease surveillance has demonstrated that standardized equipment and data elements can greatly speed disease surveillance and feedback (18). Just as public health laboratorians have developed standard ways to manufacture vaccines, and the Advisory Committee on Immunizations Practices recommends doses and schedules, public health professionals are starting to hammer out proposed standards for technical features and implementation plans for data and information systems (12; Table 1).

IMPROVED COMMUNICATIONS FOR DYNAMIC ACCESS TO INFORMATION

Improved communications encompasses the technology and practices of enhancing, speeding, and simplifying the flow of information, whether that information is held by a human being or a machine, and whether the information is a number, a picture, a sound, or another representation of a fact or idea. PHI should enable the public health community to communicate more effectively in three domains: (a) human-to-human; (b) human-to-machine; and (c) machine-to-machine.

The application of new *human-to-human* communications technologies has already benefited public health by improving work efficiency. Electronic and voice mail eliminate telephone tag and make it easy to send the same message or computer file to many individuals simultaneously. For example, The Director of CDC uses electronic mail to transmit to all CDC staff the text of selected speeches and the minutes of executive staff meetings, thereby helping to unify

CDC. Another example is CDC's Voice Information System, which the public uses to access prerecorded information on hundreds of topics, including Chronic Fatigue Syndrome, Lyme disease, vaccination requirements for travelers, and AIDS. Since its inception in 1988, this system has been accessed millions of times; its benefits include giving more consistent information on a 24-hour basis, which frees CDC staff to answer more complex queries from health professionals.

Increased benefits will accrue by connecting more people to electronic mail; integrating electronic mail with bulletin boards and other information services; and by making wider use of video teleconferencing (which allows participants at both ends to see each other on a television screen) and satellite-based instruction (wherein the instructor appears on a television screen at remote sites). Video teleconferencing is used between CDC and other PHS offices in Atlanta, Washington, DC, and Cincinnati to reduce travel time and expense for meetings and classes; this technology also allows more people to participate, and thus speeds decision-making and reduces miscommunications. At the state level, Alabama's Department of Public Health is currently piloting satellite televised instruction to local health departments; early results are encouraging.

Improved *human-to-machine* communications have facilitated public health work by making user-friendly interfaces more widely available, a result of the availability of microcomputers, which are usually easier to use than mainframes. Increased benefits to public health will accrue during the next 2-4 years as more mainframe interfaces are supplanted by cooperative processing, wherein a microcomputer and mainframe work jointly on a single task. Under this system, the user has access to the power and massive storage of a mainframe computer (where the data are centrally stored and updated), but can manipulate data via the user-friendly microcomputer, which can offer a mouse, windows, color selection, and access to higher-resolution printers (8). Finally, because systems that look and work in a consistent fashion are easier to learn and use, human-to-machine communications will be promoted by standardizing interfaces.

The impact of messages directed at professional and lay audiences can be strengthened by more sophisticated use of sound, video, and modern graphics. During the next few years, putting large amounts of information in easy-to-use form into the hands of all public health workers will be facilitated by multimedia workstations (which integrate sound, video, and computerized databases). The challenge to public health leaders will be to channel this evolving technology for public health practice, by training staff to think in PHI terms, providing up-to-date workstations and software, and making it clear that new technology may require abandonment of old work patterns (and maybe some software and hardware that has not evolved).

Table 2 Recommendations for communications

Time frame	Recommendations
Short term (1–2 Years)	Make more widespread use of e-mail, bulletin boards, and voice information systems Develop cooperative processing for public health, video teleconferencing, and invest in better workstations and communications lines
Long term (3–5 Years)	Develop multimedia public health applications for public health Make cooperative processing widespread Develop and implement standards for interfaces and equipment

Improvements in *machine-to-machine* communications have benefited public health by providing increased reliability and reduced costs for data transmission and machine-to-machine connections. This is a result of the widespread availability of faster and less expensive modems, fiber-optic communications, and sophisticated electronic networks. In the future, machine-to-machine public health communications will benefit from faster data transmissions between data collection and synthesis/analysis points, and reducing the errors, labor, and losses associated with mailing disks and tapes. Clearly, the internet, although currently not suitable for transmitting sensitive information, will have an important role to play. PHI is being used to develop new surveillance systems, wherein computers receive data around the clock and automatically update the database, send an electronic mail message notifying both sender and recipient if the data contained errors (or failed to arrive), and return an edited report to the sender (8). These systems will speed the availability of accurate data for inclusion in truly timely information systems and reports (Table 2).

BETTER TOOLS FOR PUBLIC HEALTH PRACTICE

Public health informatics has been used to develop tools that serve public health's special needs for population-based information and communications. Examples that demonstrate the utility of such systems include:

- *Patient Flow Analysis*, a statistical analysis and graphing system based on software-driven simulations, is used in family planning clinics to optimize schedules and the order of service delivery, thereby reducing waiting time and increasing productivity;
- *Epi Info*, a microcomputer database and statistics program used by epidemiologists to collect, verify, and analyze epidemic data in the field (rather

than sending the data to a central office for analysis), thereby allowing quicker formulation of recommendations for control (4);

- *SUDAAN*, a statistical analysis system provides programs to analyze data from complex cluster surveys;
- *SETS*, a system to distribute CDC survey data and specialized analysis software on CD-ROM, which facilitates data analysis and saves mainframe resources for its users;
- *Arkansas' Early Intervention Services System*, which links several databases and integrates remote communications, facilitating the delivery of public health services (18);
- An "electronic" *extramural course in epidemiology* developed in Canada, which uses computer conferencing for distance-based education, allows students to continue their public health education without needing to move or change work schedules (16).

These examples demonstrate that PHI's function of applying information technology to public health practice can facilitate work at Federal, state, and local levels. Proposed new PHI applications include: better tools for authors of multimedia based training courses; public health clinic management software that emphasizes "walk-ins" and follow-up, and that is integrated with surveillance systems; mapping software that can be used to correlate information about health effects and the location of putative environmental risk factors (e.g. contaminated ground water or sources of radiation); improved systems to identify sources of survey data and associated laboratory samples that may be available for further analysis; and quick ways to get expert consultations.

It must be emphasized that the vast majority of public health software and hardware systems have been, and should continue to be, based on commercially available products. The best commercial products have large numbers of users. This large user base enables those manufacturers to provide customer support and upgrades, and to sponsor training and user groups. Large companies that stay in business tend to adhere to (or develop) emerging standards. Economies of scale tend to control prices, especially as compared to custom-built systems, in which most of the actual cost may go for specialized training or postpurchase modifications. PHI projects should build on what is available and tested whenever possible. New software should only be developed when a commercial alternative is not available or is too expensive (especially for very large scale applications when hundreds or thousands of copies may be required), or when modifying existing software to suit public health needs is not feasible.

Federal, state, and local agencies that have been successful in using information technology should now extend technical assistance to locales that are just getting started, with a special emphasis on promoting *local* systems development, which can be designed to suit specific local needs. For example,

Table 3 Recommendations for better tools

Time Frame	Recommendations
Short term (1–2 Years)	Develop new applications for public health practice: clinic management software, mapping tools for environmental exposures, etc Develop capacity for software development in state and local health departments
Long term (3–5 Years)	Develop and implement interface standards Assure that PHI is integrated into all public health activities

Washington State's Department of Health has developed a system to track its progress towards meeting the *Healthy People 2000 Objectives* that emphasizes the State's concerns (8). One problem with all this rich activity has been the resultant diversity in interfaces, tools, and underlying technology. If systems are too particularistic, they may fall into disuse (10). Standardizing interfaces and underlying technologies may promote the development of tools that have a lasting impact (17; Table 3).

THE DISCIPLINE OF PUBLIC HEALTH INFORMATICS

There are several reasons to develop a new academic discipline in informatics (10). First and foremost, it will help assure that new information technology and practices are developed to serve public health's specific needs, and that technology and an understanding of how best to use it will evolve along with public health itself. Second, having PHI in an academic setting will promote basic research. Third, a discipline provides a locus of expertise and support for students who need to be trained in subjects not currently well represented in public health faculties. Finally, it provides a career path, thus attracting talented students and professionals who can help build the field.

Supporting the triad of teaching, research, and service is a powerful way to encourage the growth of a new science. The components of service have been outlined in this paper. Teaching would include developing instructional and degree-granting programs in schools of public health, and offering seminars and courses in public health agencies and to academic collaborators. For those working in government or business, it means serving as adjunct faculty, precepting students in epidemiology, biostatistics, preventive medicine, nursing, information science, and engineering. CDC staff who work in this field teach an entire course at the Emory School of Public Health on using information systems, and one of Epi Info's developers teaches it to the epidemiology students. CDC has several engineering students from the Georgia Institute of

Technology working part-time on various projects; this experience has provided an exposure to public health that they would not otherwise have had and has stimulated career interests in human services.

Research activities should include investigating the applicability of new technology to public health via formal hypothesis generation and testing, and implementing new ideas and technologies. There is a need to insert basic research, rigor, and peer-review into a field that otherwise could become overly focused on meeting day-to-day needs. For example, CDC is collaborating with the University of Michigan to investigate new communications architectures for databases, and with the Georgia Institute of Technology on networking.

Traditional academic activities will be key to building credibility for public health informatics as a discipline, and will also greatly promote external collaborations. The preparation of results for publication and presentations at professional meetings is as important for PHI as it is for other disciplines. Much of the medical informatics literature is in paired articles: one for the medical result, another for the informatics significance; this model is directly applicable in public health.

Public health informatics programs in government and academia should develop the capacity to carry out consultations and collaborations on subjects ranging from the choice of appropriate software to the development of complex systems. Historically, an important engine of public health has been the injection of experts into new environments, such as Federal assignees to state and local health departments, schools of public health, and the World Health Organization; and university scholars coming to public health service agencies for sabbaticals. This results in cross-fertilization between government, academia, international agencies, and foreign governments.

A logical extension of consultation would be the creation of centers of academic and applied excellence in PHI to assure the development and sharing of expertise (Table 4). This model has been used by the National Library of Medicine, National Institutes of Health, which has funded academic medical centers to develop enterprise-wide information management systems under the Integrated Academic Information Program Management System (15). This project has contributed to nationwide interest in using medical informatics in medical centers and has helped move many projects out of the medical informatics laboratory into clinical use. Public health is poised to emulate this model, assuming sufficient funds are made available. One way to develop centers of excellence in PHI could be via promoting partnerships made up of Federal, state, and local governments; private foundations and nonprofit agencies; and private for-profit corporations. These Centers could evaluate and develop PHI strategies that would then be widely shared. One highly successful example has been the Georgia Information Network for Public Health Officials (INPHO) project, funded by a \$5.2 million grant from the Robert W. Woodruff Foundation.

Table 4 Recommendations for the discipline of Public Health Informatics

Time Frame	Recommendations
Short term (1–2 Years)	The public health community should establish academic programs and centers in excellence in PHI PHI professionals should involve themselves in practice, teaching, and research; and publish and present their findings Academia, government, and business should develop collaborative and consultative activities
Long term (3–5 Years)	Consider establishing departments of PHI in schools of public health, and a journal Develop more formal programs for the exchange of scholars, sabbaticals, etc

Collaborators include the foundation; academia (Emory University, Medical College of Georgia, and Georgia Institute of Technology); and government (the Georgia Department of Public Health, CDC). This project has developed new strategies for networking, disease surveillance, and disseminating information, and represents a model that can be exported to other states.

CONCLUSION

Gaps in public health information and weaknesses in communications will be only partly ameliorated by the development of new technology. Rather, important gains will depend more on bold long-range planning, concerted and well-led efforts at standardization, documenting the contributions of PHI towards the improvement of public health, and garnering and properly aiming new resources. This, in turn, will require that governmental and academic public health leaders develop a commitment to public health informatics. A fully developed academic discipline must be the foundation stone of this initiative. To do less will make public health outmoded and will place it at risk.

Public health informatics is viewed today in the same light as were chronic disease epidemiology and advanced statistics 20 years ago: obscure, forbiddingly complex, something for the specialist, impractical, expensive, of doubtful general utility. Just as these other advances had salutary and indeed revolutionary impacts on epidemiology, so too could Public Health Informatics have profound benefits on public health practice.

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Literature Cited

1. American Public Health Association. 1991. *Healthy Communities 2000: Model Standards*. Washington, DC: Am. Public Health Assoc.
2. APEXPH Work Group. 1991. *Assessment protocol for excellence in public health*. Natl. Assoc. County Health Off.
3. Bean NH, Martin SM, Bradford H. 1992. PHLIS: an electronic system for reporting public health data from remote sites. *Am. J. Public Health* 82:1273-76
4. Dean AG, Dean JA, Burton AH, Dicker RC. 1991. Epi Info: a general purpose microcomputer program for public health information systems. *Am. J. Prev. Med.* 7:178-82
5. Eatmon JM. 1991. Hardware and software needs for coordination of early intervention services (Public Law 99-457). *Proc. Public Health Conf. Records Stat.*, pp. 514-19, July 15-17. Washington, DC
6. Friede A, Freedman MA, Paul JE, Rizzo NP, Pawate VI, Turczyn KM. 1994. DATA2000: a computer system to link HP2000 objectives, data sources, and contacts. *Am. J. Prev. Med.* In press
7. Friede A, Reid JA, Ory HW. 1993. CDC WONDER: a comprehensive on-line public health information system of the Centers for Disease Control and Prevention. *Am. J. Public Health* 83: 1289-94
8. Friede A, Rosen DR, Reid JA. 1994. CDC WONDE/PC cooperative processing for public health informatics. *J. Am. Med. Inform. Assoc.* 1:303-12
9. Goldman DA. 1994. The EPIGRAM computer for analyzing mortality and population data sets. *Public Health Rep.* 109:118-24
10. Greenes RA, Shortliffe EH. 1990. Medical informatics, an emerging academic discipline and institutional priority. *J. Am. Med. Assoc.* 263:1114-20
11. Greenlick MR. 1992. Educating physicians for population-based clinical practice. *J. Am. Med. Assoc.* 267:1645-48
12. Hughes JM, Teutsch SM, Stroup NE, Friede AM, Garbe P, et al. 1991. *Surveillance Coordination Group Report: Recommendations for Electronic Systems for Public Health Surveillance*. Atlanta, GA: Cent. Disease Control
13. Kelso S. 1991. Developing a system to trace health objectives and indicators. See Ref. 5, pp. 534-38
14. Kleinman JC, Kiely JL. 1991. Infant mortality. *Stat. Notes* 1:1-11. Hyattsville, MD: Centers for Disease Control; US Dept of Health, Education, and Welfare Publ. 92-1237
15. Lindberg DA, West, RT, Corn M. 1991. IAIMS: an overview from the National Library of Medicine. *Bull. Med. Lib. Assoc.* 80:244-46
16. Østbye T. 1989. An "electronic" extra-mural course in epidemiology and medical statistics. *Int. J. Epidemiol.* 18: 275-79
17. Pollock DA, McClain PW. 1989. Trauma registries: current status and future prospects. *J. Am. Med. Assoc.* 262: 2280-83
18. Valleron A-J, Bouvet E, Garnerin P, Menares J, Heard I, et al. 1986. A computer network for the surveillance of communicable diseases: the French experiment. *Am. J. Public Health* 76: 1289-92
19. Wartenberg D, Agamennone VJ, Ozonoff D, Berry RJ. 1989. A micro-computer-based vital records data base with interactive graphic assessment for states and localities. *Am. J. Public Health* 79:1531-36