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Charting a future for epidemiologic training

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ABSTRACT

Purpose: To identify macro-level trends that are changing the needs of epidemiologic research and practice and to develop and disseminate a set of competencies and recommendations for epidemiologic training that will be responsive to these changing needs.
Methods: There were three stages to the project: (1) assembling of a working group of senior epidemiologists from multiple sectors, (2) identifying relevant literature, and (3) conducting key informant interviews with 15 experienced epidemiologists.
Results: Twelve macro trends were identified along with associated actions for the field and educational competencies. The macro trends include the following: (1) "Big Data" or informatics, (2) the changing health communication environment, (3) the Affordable Care Act or health care system reform, (4) shifting demographics, (5) globalization, (6) emerging high-throughput technologies (omics), (7) a greater focus on accountability, (8) privacy changes, (9) a greater focus on "upstream" causes of disease, (10) the emergence of translational sciences, (11) the growing centrality of team and transdisciplinary science, and (12) the evolving funding environment.
Conclusions: Addressing these issues through curricular change is needed to allow the field of epidemiology to more fully reach and sustain its full potential to benefit population health and remain a scientific discipline that makes critical contributions toward ensuring clinical, social, and population health.

Background

The context for epidemiologic research, training, and practice is changing rapidly, due in part to emerging "macro trends" in society (e.g., Big Data, genomics, and team science) that are affecting the profession of epidemiology, as well as public health and medicine more generally. The sweeping changes brought about by such macro trends have already greatly changed sectors outside of public

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health and medicine, especially business and economics [1]. Often considered in strategic planning processes, macro trends involve some combination of changing demographics, economic factors, technological changes, and legal, political, or social conditions. In light of several important macro trends affecting epidemiology, there is concern that training in our discipline has changed very little over the past several decades, and therefore, the next generation of epidemiologists will be ill prepared to meet challenges posed by the changing landscape [2].

Training in epidemiology has roots in descriptive epidemiology, etiologic research, causal inference, and public health practice [3]. More advanced methods and their appropriate use are taught quite variably, and there are few textbooks covering material beyond the introductory level. Much of the instruction on emerging methods, for example, topics pertaining to Big Data and/or advanced analytics, is left in many programs to courses in biostatistics, bioinformatics, and computer sciences and may not be available at all in some programs.

Historically, training in epidemiology has benefitted from competency-based education, which has helped to shape educational programs [4,5]. Formally, a competency is defined as a cluster of related knowledge, attitudes, and skills that is important for the performance of a job activity and can be measured against well-accepted standards [6,7]. Employers and positions held by epidemiologists require certain competencies, and the degree to which one can define those competencies is also a determinant of the ability to hire, train, and retain the right people in a given position. For example, graduates of epidemiology training programs who have not mastered the competencies demanded by government agencies or private employers will not be competitive for employment in the current and future job markets.

Several previous efforts have defined competencies relevant to epidemiologic training in the United States. For master's level training, the Association of Schools and Programs in Public Health uses its MPH Core Competency Model to outline 10 competencies in epidemiology and additional competencies in the five traditional core areas of public health and seven interdisciplinary or cross-cutting areas [8]. In 2002, the American College of Epidemiology held a workshop to develop a set of competencies for doctoral education in epidemiology across 12 domains (e.g., descriptive epidemiology, study design, data analysis, communication) [9]. Ongoing work being led by the National Cancer Institute has developed recommendations for training in cancer epidemiology that seek to better position the science for challenges and opportunities in the 21st century [10–12]. For more applied training, the Centers for Disease Control and Prevention (CDC) and Council of State and Territorial Epidemiologists (CSTE) developed a set of competencies for individuals working in public health practice [13,14]. The CDC and CSTE competencies were designed to be comprehensive across four different skill levels and are linked to a toolkit to assess skill levels and tailor efforts.

Building on these previous efforts, this project sought to (1) identify macro-level trends that are changing the needs of epidemiologic training and (2) develop and disseminate a set of competencies and recommendation for epidemiologic training that will be responsive to these changing needs [2]. We asked senior epidemiologists from a variety of sectors to identify macro trends and related competencies.

Data collection and synthesis

The present project began with the assembly of a working group (the coauthors on this article) that had a charge to conduct a series of interviews with epidemiologists working in various capacities to develop and disseminate a set of competencies and recommendations for epidemiologic training to address the changing landscape (macro trends). The working group consisted of leading U.S. epidemiologists who (1) teach and/or participate in research in various academic (medical schools, schools of public health), government, or industry settings; (2) represent various levels of public health practice (federal, state, local); and (3) have strong linkages to relevant professional groups (e.g., American College of Epidemiology, American Epidemiological Society, Association of Schools and Programs in Public Health, CSTE, Society for Epidemiologic Research). Although the focus of this effort was primarily on epidemiologic training in the United States, many of the issues described are likely to be applicable in other parts of the world.

Next, the initial relevant literature was gathered by the working group. The search began with a convenience sample of articles related to competencies and education in epidemiology identified by the core team (Brownson, Samet, Yarber) and then additional relevant literature was sought from the working group. An initial list of 12 articles [4,10,15–24] was identified.

At the third stage of the project, semistructured interviews with key informants were conducted. An interview guide was developed by the core team that included seven open-ended questions covering the respondent's background or experience in epidemiology, perceptions of the challenges facing epidemiologists as they enter the workforce, an assessment of the degree to which current training is addressing challenges, skills that are missing, other macro-level forces facing epidemiology, and competencies for training that the respondent has found to be useful in her or his career. The interview guide is available from the first author on request. Interviews were conducted with 15 experienced, active, future-oriented epidemiologists from both practice and research settings (including the working group). Most of the respondents worked in academic settings ($n = 10$), whereas two worked for the U.S. government (the CDC and the National Cancer Institute). Five participants either currently worked for a state or local health department or had previously worked in public health practice.

The interviews ranged in length from 15 to 45 minutes. From the interview notes, major themes were extracted and organized in a three-column spreadsheet with the following column headings: major macro trend, skills needed to address the trend, and other comments related to the trend.

The study was reviewed and approved by the Institutional Review Board at Washington University in St. Louis.

Findings

Twelve macro trends were identified and each is briefly described. In Table 1, associated actions for the field and educational competencies are listed. The actions are the broader steps to be taken by the field of epidemiology and other sectors; the competencies are those needed to begin to address many of the actions via specific types of knowledge or skills. Many of these competencies build on earlier efforts [4,8–11,13,25].

Macro trend 1: the growing availability of "Big Data" or informatics

The rapid growth in the scope and ability to link multiple large static and streamed data sets—such as electronic health care records—provides opportunities and challenges for epidemiologists. The U.S. government has invested $200 million to enhance Big Data research within and across federal agencies [26] and the U.S. National Institutes of Health has issued announcements for initiatives in this area. As data sets become increasingly larger and more complex, epidemiologists will need advanced skills to link, manage, map, analyze, interpret, display, and communicate their findings to

Table 1
Actions and educational competencies corresponding to macro trends affecting epidemiology

Macro trend*	Actions for the field	Educational competencies (examples)
1. The growing availability of "Big Data" or informatics	• Support wider use of language processing and other data exploration or analytical approaches used in computer sciences. • Support the harmonization of data sets and the creation of study repositories. Appropriate ontologies are needed for this purpose. • Develop epidemiologic capacity for integration of data from basic, clinical, environmental, social, and population sciences. • Support the development of statistics that can analyze and enhance the use of diverse data when linked, and increase the ability to adequately analyze small sample epidemiologic data. • Refine existing and develop new guidelines for reporting epidemiologic research results based on secondary analysis and/or Big Data.	• Identify challenges, principles, and key details for data sharing. • Identify the challenges of large-scale data management. • Demonstrate the ability to identify clinically important research questions that can be tested by secondary analyses. • Demonstrate skill in collecting, cleaning, storing, distributing, and preparing data for public use. • Demonstrate the ability to use and protect complex, linked data sets from multiple sources and across levels of organization from the biologic to societal levels. • Demonstrate skills for integration of data from basic, clinical, environmental, social, and population sciences. • Demonstrate knowledge and understanding of the methodological and statistical problems inherent in the analysis of secondary and/or Big Data. • Demonstrate the ability to use data collected by other disciplines (e.g., administrative or billing purposes). • Use and interpret findings from data exploration tools and other analytics. • Demonstrate an understanding of the process of electronic data capture and the importance of information technology in data acquisition and management. • Demonstrate an understanding of and ability to perform meta-analyses of epidemiologic results.
2. The changing health communication environment	• Develop new methods for epidemiologic studies, surveys and surveillance that take advantage of new technologies (e.g., smart phone surveys, GPS tracking). • Integrate training in epidemiology more fully with other disciplines concerned with communication and dissemination (e.g., communication, marketing) • Work with biostatisticians and quantitative methods experts from other fields to develop new research methods, study designs, and data analysis procedures.	• Demonstrate skills (written and oral) to effectively communicate epidemiologic findings to multiple audiences including scientific peers, the public, decision makers, and the media. • Identify strategies to effectively communicate conflicting or highly uncertain findings. • Create brief and tailored reports and visual displays for nonscientific audiences (administrators, policy makers). • Use communication methods, such as mapping tools and social media.
3. The Affordable Care Act or health care system reform	• Collaborate with clinicians and health services researchers to identify key research and policy questions along with measurement needs. • Improve capacity in clinical epidemiology so as to monitor improvements in patient and population outcomes in "real time." • Continue to broaden the range of populations considered in epidemiologic research to encompass those within health care systems.	• Demonstrate skills in using data collected (sometimes for administrative or billing purposes) while considering inherent limitations of such data. • Demonstrate skills in linking epidemiologic outcomes (e.g., variations in practice and health indicators) with economic outcomes (e.g., cost-effectiveness). • Demonstrate skills in using contextual data to assess quality of health care processes and outcomes, including appropriate methods for case-mix adjustment.
4. Shifting demographics	• Improve the capacity to work with people and groups with different backgrounds and life experiences and to carry out research in a culturally meaningful and appropriate way. • Identify the role of cultural factors in disease etiology and prevention.	• Explain how the contexts of, gender, age or life span, race, ethnicity, sexual orientation, socioeconomic position, history or cohort, migration, and culture are important in the design of research and interventions within health care and public health systems. • Demonstrate skills in developing research instruments and data analytical approaches that are culturally relevant. • Demonstrate skills in small area or small population analyses.
5. Globalization	• Develop and enhance cross-national partnerships to enhance the infrastructure, quality, and scope of epidemiologic research. • Carry out multicountry studies that take advantage of the wide exposure gradients that may exist. • Develop new approaches for epidemiologic training for low- and middle- income countries.	• Demonstrate familiarity with global surveillance systems to monitor the geographic differences and spread of disease. • Understand how a range of issues (e.g., culture, climate, and economics) contributes to disease. • Use channels for information dissemination at the global level. • Demonstrate capacity to handle data in at least one non-Western context.
6. Emerging high-throughput technologies (omics)	• Articulate the opportunities and challenges presented by genomic and other "omic" research and how epidemiology and epidemiologists can help meet those challenges • Foster collaboration between epidemiologists, biostatisticians, and other quantitative methods experts to improve methods to quantify the risk and predictive abilities of genomic and other "omic" discoveries. • Work with toxicologists, molecular biologists, and other disciplines to use new technologies to assess cumulative environmental exposures (i.e., the "exposome") in epidemiologic studies.	• Explain how genetics and genomics as well as their interaction with environmental exposures affect disease processes and public health policy and practice. • Understand how "omic" tools can be integrated into an ecological model of health including social and environmental determinants. • Understand how to validate a surrogate marker and apply the principles of causal inference to "omic" tools. • Identify the role(s) of emerging "omics" technologies applicable to epidemiologic research and demonstrate the ability to incorporate them into epidemiologic research.

		• Describe and address the ethical concerns associated with genetic and genomic screening and research. • Describe the practical implications of genomic discoveries for public health practice, clinical application, and policy. • Describe strengths and limitations of using "omic" technologies in measuring environmental exposures (e.g., the exposome).
7. A greater focus on accountability	• Extend the portfolio of epidemiologic research beyond etiology, treatment and outcomes research to dissemination and implementation research. • Develop a culture of accountability and health effect by facilitating practice of reproducing studies, sharing, and translation. • Understand the role of public reporting of health systems data related to quality and safety. • Understand the role of data stewardship in making data accessible and usable by the public.	• Demonstrate skills in translating findings into formats that are accessible and understandable to policy makers and the lay public. • Apply new metrics to assess the effect of epidemiology on health care, public health practice and policy and ultimately on population health and health care decision-making. • Describe cost-effectiveness, cost-benefit, and comparative effectiveness analyses and their place in the evaluation of interventions. • Apply tools that allow for sharing and consideration of study findings early in the research process and not only at the end. • Effectively communicate research progress and findings to study participants and their communities. • Develop effective skills and strategies for data sharing, data dissemination, and data stewardship across levels from data developers to consumers and lay public. • Understand the role of public reporting of health systems data related to quality and safety.
8. Privacy changes	• Work with those building clinical data "enterprise warehouses" to anticipate privacy and consent issues related to future uses of data and specimens for epidemiologic research. • Develop privacy and confidentiality systems that balance the rights of individuals with the needs of society.	• Demonstrate skills in how to leverage the federal program on "meaningful use" of electronic health records that will improve access to clinical data for epidemiologic research. • Apply epidemiologic judgment to available data. • Understand the definition of research versus public health and quality improvement. • Describe the evolution of the principles and key documents that ensure the protection of human subjects in human research. • Describe the ethical issues involved when involving vulnerable populations in research. • Summarize the principles and methods of distributing and balancing risk and benefit through selection and management of subjects in experimental studies.
9. A greater focus on "upstream" causes of disease	• Develop the capacity to translate science into action in venues ranging from local to global, especially policy translation. • Articulate how epidemiologic skills and research, survey and surveillance data can play a role in systems modeling studies. • Develop methods to link social and demographic characteristics into existing data systems (e.g., electronic health records).	• Review how to design and carry out studies that address upstream causes (e.g., multilevel modeling of policy influences). • Understand causal inference and ecologic associations to appropriately use terminology to describe factors and the level of evidence for a relationship between the factor and a health outcome. • Demonstrate the ability to design research that focuses attention on social and economic policies that affect health throughout the life span. • Demonstrate the ability to assess the strengths and weaknesses of applying the systems approach to public health problems. • Describe methods for framing a public health issue as a complex system with interacting parts. • Describe contextual variables (e.g., policy environment, organizational culture) that affect disease risk and intervention success.
10. The emergence of translational sciences	• Advance the role of epidemiology and epidemiologists within clinical and translational research. • Develop partnerships between epidemiologists and practitioners in community or clinical settings. • Develop new courses on translational science. • Continue to develop and improve analytical tools (e.g., systematic reviews, evidence portals) that link research and practice.	• Describe the role of epidemiology and the epidemiologist in the translation of knowledge into practice. • Demonstrate an understanding of the role of epidemiology in stages T1, T2, T3, and T4 research. • Identify qualitative case studies that provide examples and lessons on the translation of epidemiologic findings into practice and policy. • Define dissemination, implementation, and knowledge translation in the context of epidemiologic studies and the knowledge basis needed for epidemiologists to contribute effectively. • Demonstrate understanding of the approaches used to assess evidence (e.g., US Preventive Services Task Force, Canadian Preventive Services Task Force).

(*continued on next page*)

Table 1 (*continued*)

Macro trend*	Actions for the field	Educational competencies (examples)
11. The growing centrality of team and transdisciplinary science	• Encourage academic institutions to promote career advancement that rewards team science. • Encourage academic institutions to reward publication efforts that span fields in its career advancement procedures. • Encourage funding of team science. • Develop metrics within funding mechanisms to evaluate and ensure effective reviews of transdisciplinary science. • Identify the role of epidemiology along the research continuum, from basic to applied research.	• Demonstrate skills in working across disciplines including those outside of the health sector. • Discuss the perspectives, language and terminology of different disciplines. • Identify core variables for measuring progress in team and transdisciplinary science projects. • Integrate findings from other lines of research in interpreting and drawing inferences from epidemiologic evidence.
12. The evolving funding environment	• Encourage the leveraging of existing resources. • Make the case more effectively for the necessity and consequences of epidemiologic research. • Link training programs more closely with research programs to more efficiently use resources. • More effectively link epidemiologic research programs with public health practice and health care systems.	• Identify a broad set of funding sources for supporting epidemiologic studies. • Demonstrate skills in communicating about the value of epidemiologic research to diverse funders.

GPS = global positioning system.
* The ordering of the macro trends is not hierarchical or ranked in priority.

both lay and professional audiences and in both oral and written formats [27]. The growing availability of such data suggests that epidemiologists will do less conventional data collection and will need new skills (e.g., translational research, knowledge integration) [28].

Macro trend 2: the changing health communication environment

Findings from epidemiologic research and public health surveillance often have direct implications for the health of the population. Advances in technology have created an environment where practitioners, researchers, and members of the public can access such epidemiologic information almost instantaneously. However, the large number of epidemiologic studies being published, often with seemingly inconsistent or conflicting findings, likely leads to confusion among decision makers and the general public [29]. Social media and the increase in communication sources and channels might compound this challenge (and opportunity) even further [30].

Macro trend 3: the Affordable Care Act or health care system reform

The demand by society to improve health care quality, reduce costs, and improve population health outcomes creates many opportunities for epidemiologic research and practice in the future. The Affordable Care Act seeks to (1) increase access to health care for millions of Americans, (2) strengthen disease prevention efforts, and (3) build more public health activities into the health care system [31]. The Affordable Care Act is part of a larger trend toward rewarding value rather than volume in health care and acknowledges the role of behavioral, social, and environmental determinants of health in health outcomes [32]. There are opportunities for funding certain types of epidemiologic studies ranging from the "upstream causes" of health disparities to patient-centered outcomes and from primary prevention to the comparative effectiveness of alternative treatments. There will be a need for involvement of epidemiologists in measuring the effect of the Affordable Care Act and other community, social, and health systems changes and also in targeting prevention efforts to meet the population health requirements of the Act.

Macro trend 4: shifting demographics

The changing demographics (e.g., aging, increased racial or ethnic diversity, sexual orientation) present new challenges for epidemiology. The rapidly expanding older population may lead to emphasis on new areas of research and practice, which will be given priority for funding (e.g., brain science, chronic disease prevention, health maintenance, the effect of comorbid conditions). In addition, the changing racial, ethnic, sexual orientation, and cultural composition of the U.S. population will require a greater emphasis in population health toward measuring and identifying effective approaches to narrow health inequities.

Macro trend 5: globalization

Globalization is a process that leads to increased cross-country interactions and integration of markets and systems (business, health, communication) [33]. Globalization has already increased the risk of global spread of communicable diseases, epidemics and pandemics (e.g., SARS and Ebola), with implications for epidemiologists who will need to be well trained in the use of new methods for case finding, of innovative methods to control exposures, and of culturally sensitive strategies to implement prevention methods. At the same time, globalization will, in the absence of significant

changes in policies and health care or public health systems, bring the chronic diseases that are common in developed countries to the low- and middle-income countries (e.g., tobacco-related diseases, diabetes). Globalization offers opportunities for epidemiologists to conduct informative cross-national studies, to transfer skills, and to allow for exchange of scientists, practitioners, and technology [34].

Macro trend 6: emerging high-throughput technologies (omics)

The scope of genome-based research is expanding rapidly along with other "omics" such as proteomics, metabolomics, exposomics, and microbiomics [19,35]. Epidemiologic research now has the potential to use human and pathogen genetic sequencing and complex biomarkers to identify and track the clinical course of disease. For example, large-scale biologic databases, powerful methods of characterizing patients, and new computational tools may lead to more individualized prevention and treatment for some diseases (e.g., cancers, diabetes) [36] New "omic" discoveries call for new approaches for collaboration, team science, data sharing, data analysis, and integration of effort across different disciplines and platforms. For epidemiologists to play a meaningful role in these collaborative efforts, they must be able to speak the language of the other team members. That will mean that epidemiology training programs will have to make available to trainees the opportunity to learn (at least) the basics and the languages of the biomedical and data sciences.

Macro trend 7: a greater focus on accountability

Many factors are driving a call for accountability and sharing of data, in the face of the large expenditures of public funds on epidemiologic and biomedical research. Additional drivers include the rapid exchange of information, participatory approaches, privacy, confidentiality, data security, and ethics [37]. This can take numerous forms including data stewardship, stewardship of funds, reporting epidemiologic findings back to stakeholders, sharing data for public use, and understanding the potential impacts (including benefits and harms) of research.

Macro trend 8: privacy changes

The data explosion and the hacking of personal data from large private as well as public data sources has and will continue to bring changes to privacy laws (e.g., Health Insurance Portability and Accountability Act) and contractual agreements that regulate accessibility to certain health information. These changes have profound implications for epidemiologic research, particularly for those epidemiologists engaged in analytics which requires more and finer grained data on individuals. Epidemiologists need to understand the limits on the use of such data and will need to participate in efforts to improve data systems to balance the needs for individual privacy with broad societal goals for information while maintaining appropriate privacy, confidentiality, and security protections.

Macro trend 9: a greater focus on "upstream" causes of disease

Public health problems—such as violence, mental illness, and obesity—have complex "upstream" causes, including, often interrelated, social determinants of health (e.g., a group of highly interrelated factors including poverty, education, housing, and employment) [38]. Numerous authors have expressed concerns that epidemiologists have not adequately focused on these broader societal factors that shape population health [39–43]. Addressing these variables involves aligning structures to optimize health (e.g., improving the built environment), shifting social norms, or developing and assessing evidence to address the well-established "causes of causes" including large and powerful industries (e.g., alcohol, tobacco, and firearms). Epidemiologists are central in generating, evaluating, and interpreting evidence related to this trend, but struggle in motivating action with their findings.

Macro trend 10: the emergence of translational sciences

The U.S. National Institutes of Health, foundations, and authoritative bodies (e.g., the Institute of Medicine) are placing greater emphasis on translational science (including dissemination and implementation research) [44,45], broadly defined as the process of applying ideas, insights, and discoveries generated through basic scientific inquiry to the treatment or prevention of human disease. The goal is to move scientific advances as quickly as possible from the laboratory to the bedside and from the bedside to the community to improve access, reduce disparities, and improve the health of the population [46,47]. Epidemiology is a critical methodological foundation for translational research [10,17].

Macro trend 11: the growing centrality of team and transdisciplinary science

Team science is a collaborative, transdisciplinary effort that leverages the strengths and expertise of professionals trained in different fields to address a scientific challenge [48]. A transdisciplinary approach focuses teams from varied disciplinary backgrounds (inside and outside of biomedical science) on a single, often complex, research problem [49]. Because epidemiologists have a broad range of skills, ranging from study design to development of measures to analytical strategies, they are central to the transdisciplinary research team [16].

Macro trend 12: the evolving funding environment

Federal agencies, particularly the National Institutes of Health and the CDC, have historically played an important role in supporting a wide variety of epidemiologic research and the graduate training of epidemiologists. With the NIH budget now stable for five years, there is less funding available for grants and success rates are at record lows. With likely future restrictions on federal funding [50], there is a need for new and creative approaches for funding the typically large data collections in epidemiology at the federal level and private sectors. Will there be large national studies that will be made available to epidemiologists? It is also important for epidemiologists to play a role in the policy process (e.g., educating members of Congress and others on the value of epidemiologic research and epidemiologic staff in public health practice).

Implications for epidemiologic training

Within population health and medicine, epidemiology is the methodologic discipline for etiologic research, planning and evaluating interventions, public health surveillance, and health policy formulation [51]. Epidemiologic training has as its core a focus on research and analytical methods and needs to be supplemented by knowledge in many domains such as pathobiology, biostatistics, data science, health communication, and sociology. It is perhaps the only biomedical research discipline that advances knowledge at levels ranging from molecular to global in seeking to understand the drivers of health and disease. For the unique perspective of epidemiology to keep pace with the macro trends highlighted here, educational competencies developed by training programs need to expand. Based on the familiarity of the authors with existing

curricula in epidemiology, the results from the current project suggest an inadequate match between existing curricula and training activities in epidemiology and the future skills sets needed for epidemiology to remain an effective and credible discipline in the 21st century. Importantly, the project's findings point to a need for lifelong learning by epidemiologists, a topic that has received too little attention to date and one that should be addressed by professional organizations and academic institutions in partnership with other key stakeholders.

There are further considerations in using the findings on the 12 trends to broaden the competencies. The examples listed in Table 1 are intended as a starting point for further discussions. These competencies could apply to graduate training at the MPH, MS, PhD, or DrPH levels and also to ongoing training for researchers and practitioners already working in epidemiology. They should also be considered when developing undergraduate public health curriculum, in courses based on the concept of "Epidemiology 101" [52]. Critically important to the future of the discipline is the recognition that the depth, focus, and importance of mastering the core competencies differ according to setting (e.g., research vs. practice) and level (e.g., master's vs. doctoral) [9,13,53].

The next stage for this work will involve dissemination of these findings and recommendations to a broad range of potential users. Not every training program should or could cover material beyond the introductory level corresponding to all the educational areas outlined in this article. Some degree of specialization within programs is to be expected, and it is hoped that training programs will focus on achieving excellence in those domains that are of greatest importance to their students and to the populations they serve.

Differences in training strengths between institutions create a number of challenges but at the same time open up opportunities for the discipline's professional organizations (e.g., the American College of Epidemiology; the Society for Epidemiologic Research, the epidemiology section of American Public Health Association, the American Heart Association). These organizations can provide advanced and specialized training through on-site workshops and seminars and online short courses or webinars. These alternative forms of training may be especially important for those engaged in public health practice, particularly individuals in smaller health departments or in lower level positions with nongovernmental organizations who have had limited opportunities for epidemiologic training to address many of the specialized needs outlined in this article. Such innovative programs could enable epidemiologists practicing at even the smallest health department or a masters or doctoral student in the smallest program greater access to advanced and specialized training.

To implement new competencies, a shift in focus needs to occur not only in the classroom but also through one-to-one mentoring in research and practice settings. Mentoring has been shown to have clear and numerous benefits (in particular research productivity and career success [54]) and should follow a set of evidence-informed competencies to enhance effectiveness [55,56] and bridge with disciplines outside of health [11].

A call to action

Based on our review of macro trends, the next generation of epidemiologists will need a set of skills that goes beyond the training currently being delivered. We should seek out innovative and creative ways of delivering epidemiologic training to keep pace with these trends [23,24,57] and extend the venues in which training occurs. We anticipate that the current findings will stimulate engagement and actions by numerous sectors and organizations. Addressing the issues raised in this article should allow epidemiology to more fully reach and sustain its full potential and remain a scientific discipline that makes critical contributions toward ensuring clinical, social, and population health.

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