

7. Proctor RN. *Value-Free Science? Purity and Power in Modern Knowledge*. Cambridge, Mass: Harvard University Press; 1991.
8. Ziman J. *An Introduction to Science Studies: The Philosophical and Social Aspects of Science and Technology*. Cambridge, England: Cambridge University Press; 1984.
9. Rose H, Rose S, eds. *Ideology off in the Natural Sciences*. Cambridge, Mass: Schenkman Publishing Co; 1979.
10. Haraway DJ. *Simians, Cyborgs, and Women: The Reinvention of Nature*. New York, NY: Routledge; 1991.
11. Kaplan GA, Lynch JW. Whither studies on the socioeconomic foundations of population health? *Am J Public Health*. 1997;87:1409–1411.
12. Berkman L, Kawachi I, eds. *Social Epidemiology*. New York, NY: Oxford University Press. In press.
13. Evans RG, Marer ML, Marmor TR. *Why Are Some People Healthy and Others Not? The Determinants of Health of Populations*. New York, NY: Aldine de Gruyter; 1994.
14. Pamuk E, Makuc D, Heck K, Reuben C, Lochner K. *Socioeconomic Status and Health Chartbook. Health, United States, 1998*. Hyattsville, Md: National Center for Health Statistics; 1998.
15. Acheson D, Barker D, Chambers J, Graham H, Marmot M, Whitehead M. *Independent Inquiry Into Inequalities in Health*. London, England: The Stationery Office; 1998.
16. Wilkinson RG. *Unhealthy Societies: The Afflictions of Inequality*. London, England: Routledge; 1996.
17. Susser M. Does risk factor epidemiology put epidemiology at risk? Peering into the future. *J Epidemiol Community Health*. 1998;52:608–611.
18. Poole C, Rothman KJ. Our conscientious objection to the epidemiologic wars. *J Epidemiol Community Health*. 1998;52:613–614.
19. Shy CM. The failure of academic epidemiology: witness for the prosecution. *Am J Epidemiol*. 1997;145:479–484.
20. Walker AM. “Kangaroo court”: invited commentary on Shy’s “The failure of academic epidemiology: witness for the prosecution.” *Am J Epidemiol*. 1997;145:485–486.
21. Rothman KJ, Adami H-O, Trichopoulos D. Should the mission of epidemiology include the eradication of poverty? *Lancet*. 1998;352:810–813.
22. Savitz DA, Poole C, Miller WC. Reassessing the role of epidemiology in public health. *Am J Public Health*. 1999;89:1158–1161.
23. Schwartz S, Carpenter KM. The right answer for the wrong question: consequences of type III error for public health research. *Am J Public Health*. 1999;89:1175–1180.
24. Desrosières A. *The Politics of Large Numbers: A History of Statistical Reasoning*. Cambridge, Mass: Harvard University Press; 1998.
25. Tesh S. *Hidden Arguments: Political Ideology and Disease Prevention Policy*. New Brunswick, NJ: Rutgers University Press; 1988.
26. Hamlin C. *Public Health and Social Justice in the Age of Chadwick, Britain: 1800–1854*. Cambridge, England: Cambridge University Press; 1998.
27. Krieger N, Zierler S. What explains the public’s health?—a call for epidemiologic theory. *Epidemiology*. 1996;7:107–109.
28. Zierler S, Krieger N. Reframing women’s risk: social inequalities and HIV infection. *Annu Rev Public Health*. 1997;18:401–436.
29. Rose G. Sick individuals and sick populations. *Int J Epidemiol*. 1985;14:32–38.
30. Essed P. *Understanding Everyday Racism: An Interdisciplinary Theory*. London, England: Sage; 1992.
31. Feagin JR, Sikes MP. *Living With Racism: The Black Middle Class Experience*. Boston, Mass: Beacon Press; 1994.
32. Jackman MR. *The Velvet Glove: Paternalism and Conflict in Gender, Class, and Race Relations*. Berkeley, Calif: University of California Press; 1994.
33. Krieger N. Embodying inequality: a review of concepts, measures, and methods for studying health consequences of discrimination. *Int J Health Serv*. 1999;29:295–352.
34. Bijlmakers LA, Bassett MT, Sanders DM. *Health and Structural Adjustment in Rural and Urban Zimbabwe*. Uppsala, Sweden: Nordiska Afrikainstitutet; 1996.
35. Davey Smith G, Egger M. Understanding it all—health, meta-theories, and mortality trends [commentary]. *BMJ*. 1996;313:1584–1585.
36. Williams DR, Yu Y, Jackson JS, Anderson NB. Racial differences in physical and mental health: socio-economic status, stress, and discrimination. *J Health Psychol*. 1997;2:335–351.
37. Krieger N, Sidney S. Racial discrimination and blood pressure: the CARDIA study of young black and white adults. *Am J Public Health*. 1996;86:1370–1378.
38. LaVeist TA. Segregation, poverty, and empowerment: health consequences for African Americans. *Milbank Q*. 1993;71:41–64.
39. Rowley DR, Hogue CRJ, Blackmore CA, et al. Preterm delivery among African American women: a research strategy. *Am J Prev Med*. 1993;9(suppl 2):1–6.
40. Krieger N, Rowley D, Hermann AA, Avery B, Phillips MT. Racism, sexism, and social class: implications for studies of health, disease, and well-being. *Am J Prev Med*. 1993;9(suppl 2):82–122.
41. Williams DR. Race and health: basic questions, emerging directions. *Ann Epidemiol*. 1997;8:322–333.
42. Lillie-Blanton M, LaVeist T. Race/ethnicity, the social environment, and health. *Soc Sci Med*. 1996;43:83–92.

## Epidemiology in the 21st Century: Calculation, Communication, and Intervention

Over the past decade—perhaps in preparation for the much-hyped threshold to a new century and millennium—a number of thoughtful journal articles have mused about epidemiology’s limits and future.<sup>1–6</sup> Indeed, this does seem to be an opportune time to take stock of epidemiology’s historical progress, current status, and future challenges and to reflect on the links between epidemiology’s past and future.

### Roots of Modern Epidemiology

We tend to think of modern epidemiology as a relatively recent phenomenon, but in fact the observational insights that drive epidemiologic inquiry span centuries, not decades. Early examples of epidemiology include Greek miasmatic theories of disease

transmission that linked some febrile illnesses with environmental conditions (“marsh fever”) and the Romans’ recognition that the symptoms of plumbism were associated with wine sipped from lead-glazed pottery.

Then, as now, not all observations and conclusions were correct, since early practitioners of epidemiology fell prey to the errors of method and reasoning that we continue to commit today. Before our more recent better understanding of genetics and biochemistry, gout was associated with wealth and high living.<sup>7</sup> Even in the absence of large prospective cohort studies, observers as diverse as Maimonides<sup>8</sup> and Dickens<sup>9</sup> suggested that a physically active lifestyle conferred health benefits—one of many examples of partially to fully correct, imperfectly understood, but still useful observations.

Despite missteps, we can see in the long history of epidemiology some of the strong roots and tenets that distinguish the field today. Early epidemiologists broadly considered not only infectious disease epidemics like malaria, cholera, and plague, but also environmental hazards like lead and climate, occupational risks for disease, and chronic diseases such as cancer and heart disease. The roots of clinical epidemiology predate Kerr White, the McMaster group, and Alvan

---

This text was presented as the First Jonathan M. Mann, MD, MPH, Lecture at the annual conference of the Council of State and Territorial Epidemiologists on June 29, 1999. The Lecture will be an annual event sponsored by the Hoffman Family Foundation through the CDC Foundation in recognition of Dr Mann’s exemplary work as New Mexico State Epidemiologist.

Feinstein.<sup>10-12</sup> In 1753, James Lind conducted controlled studies demonstrating the value of citrus fruits in preventing scurvy.<sup>13</sup> In 1793, Benjamin Rush maintained that the cure for yellow fever during an epidemic in Philadelphia was bleeding and purging. A visiting British politician, William Cobbett, studied the bills of mortality and found an association between Rush's treatment and death. For Cobbett's contribution to epidemiology, he was convicted of slander and fined.<sup>14</sup>

As epidemiologists, we can admire the advances in data collection, analysis, and interpretation that these examples illustrate. We should reserve our highest accolades, however, for the public health giants of 19th-century Europe who melded their quantitative skills and techniques with social concerns and public health action. The Englishmen John Graunt, William Farr, and John Snow—among others—are in this lineage, along with the Frenchmen Pierre Charles-Alexandre Louis (developer of "la méthode numerique") and Pierre Laplace and the Germans Johann Peter Franck, who developed the concept of "medical police," and Rudolf Virchow, the investigational genius and sociopolitical activist.

In different ways, each of these men saw the vast potential for improving health that could be generated by linking accurate calculations to effective communication and intervention. As Alexander Langmuir said of William Farr, he "believed in the democratic tradition that making the facts known to those who need to know them is the basis of achieving effective action."<sup>15</sup>

## 20th-Century Contributions

In our own century, public health visionaries like Wade Hampton Frost<sup>16</sup> in the United States and Major Greenwood<sup>17</sup> in Great Britain coalesced diverse aspects of epidemiology into a more coherent discipline, creating schools of public health and a professional cadre for the application of epidemiologic principles. As a result of these cumulative contributions, epidemiology has played a major role in the public health triumphs of the last 100 years.

Let's consider epidemiology's part in a number of such accomplishments, as compiled by the Centers for Disease Control and Prevention and published in the *Morbidity and Mortality Weekly Report*.<sup>18</sup> Triumphs over immunizable diseases have depended heavily on disease surveillance and epidemiologic investigation. Infectious disease control has benefited from clean water, sewage disposal, better hygiene, and antibiotics but still relies on outbreak investigations and the

identification of major risk factors. Despite great skepticism and opposition, Dr Joseph Goldberger used epidemiology to decipher the nutritional deficiencies behind the "Southern scourge" of pellagra.<sup>19</sup> Innumerable epidemiologic studies demonstrated risk factors for cardiovascular disease, leading to marked lifestyle changes that, along with patient care advances, have led to a 50% decline in cardiovascular disease mortality. Declines in tobacco use and the morbidity and mortality associated with it can also be credited to epidemiologic studies by Richard Doll and A. Bradford Hill, E. L. Wynder and E. A. Graham, and others.<sup>20-22</sup> Likewise, Selikoff's study on asbestosis conclusively linked a substance, occupations, and adverse health outcomes.<sup>23</sup>

These achievements have depended on the complementary contributions of different facets of epidemiology: *calculating* disease trends and probabilities, *communicating* findings to the public and policymakers, and designing and implementing *interventions* based on the data. Advances in methods and techniques—logistic regression, multilinear analysis, the study of huge data sets made possible by computers, survey techniques—have made many of these contributions possible and have helped turn epidemiology into the discipline envisioned by Frost and Greenwood decades ago.

## Future Challenges

Despite these successes, the field of epidemiology faces some significant challenges for the years ahead. Epidemiologists must struggle to meaningfully communicate findings about risks to health, balance methods and applications, and incorporate social contexts into our understanding of the health of populations.

Given these challenges, what should we as epidemiologists do to strengthen our discipline and its potential contributions?

Like members of other successful institutions in our society, we have an image problem. For some, we've become the *kvetch* of science—the regular bearers of bad news or, even worse, the regular contradictors or modifiers of our own previous findings. In the process of trying to communicate our findings, we too often scare people, confuse them, or inadvertently promote guilt.

Some risks we have gotten quite right: tobacco *is* a serious health hazard. In other areas, our findings are less clear (to us and to others). Butter is bad, and margarine is good. No—margarine with high levels of *trans*-fatty acids is actually bad. Eat less red meat, but cook it well to kill potential lurking path-

ogens. Don't cook it so well that you charbroil it, though—that could create a carcinogenic coating.

In short, our improved tools and techniques have allowed us to explore new health questions but have made conclusions and interpretations much more difficult than finding cholera cases associated with drinking from the Broad Street pump. As Geoffrey Rose observed, "Epidemiology is but a feeble tool for investigating weak causes, and it is much constrained in the study of rare diseases. Necessarily, therefore, though to the advantage of public health, its principal successes relate to the major causes of common diseases, and this is where it finds its principal preventive applications."<sup>24(p101)</sup>

Calculation, communication, and intervention were once all features of the epidemiologist's calling. Most of the giants mentioned here considered each of these factors integral to their work, even before their work was given the name "epidemiology." Snow determined the who, where, and when of the outbreak (calculation), removed the pump handle (intervention), and posted a notice (communication).<sup>25</sup> Goldberger<sup>19</sup> did exhaustive studies, promoted dietary change, and communicated his findings to the health and welfare establishments, donors, foundations, and the lay public—persevering against many who opposed his ideas and conclusions. Tobacco epidemiologists from Wynder<sup>22</sup> to Peto<sup>26</sup> have documented the health hazards of tobacco consumption, actively communicated the results of studies in easily understandable terms, and advocated tobacco control and prevention.

Epidemiology may have become so complicated that a division of labors is appropriate. Indeed, all the skills involved in practicing well calculation, communication, and intervention may rarely coexist in one individual. The conceptual and analytic interests required to advance epidemiologic methodology may not include a passion for identifying particular causal relationships. A focus on causation may not be accompanied by the communication skills necessary to convey the findings in a way that doesn't overemphasize their importance (especially when such modesty seems to undermine national journal acceptance and press attention).

From this perspective, some of our current "conflicts"—between pure methodologists and those who advocate more applied epidemiology, for example—seem artificial. Epidemiology has become rather catholic, a natural evolution for a growing and maturing discipline. Epidemiologists can contribute whether they choose to concentrate on methodologic issues, large population studies, field investigations, or clinical studies. They can

make their goal journal publication, public interpretation of findings, or public health interventions. Some may choose to do all 3 of these jobs and do them well, whereas others will choose to emphasize one over the others.

Regardless of the emphasis one chooses within the field, epidemiology's full value is achieved only when its contributions are placed in the context of public health action, resulting in a healthier populace. This raises important issues that cut across research methods and practical applications. Our role is not only to collect and analyze data but also to interpret them so that they have meaning for the public, for clinicians, and for policy makers. Unfortunately, there is room for improvement if we are to fulfill our potential for synthesizing data and assessing the quality of evidence. A recent example is provided by Shaneyfelt et al., who reviewed a decade's worth of clinical practice guidelines published in peer-reviewed medical journals and concluded that these guidelines did not adhere well to methodologic standards.<sup>27</sup>

Another challenge with roots in epidemiology's history is the struggle to understand the influence of social contexts on the health of individuals and populations. Emerging research on social capital suggests that these contexts can be measured and—most important—changed in ways that improve the health of individuals and populations.<sup>28,29</sup>

Like others in epidemiology's rich history, we should keep our eyes on the prizes of preventing disease and promoting health. The following description of Joseph Goldberger's tenacious pursuit of the causes of pellagra could have been written just as accurately about many other epidemiologists and the diseases they pursued: "He was excited over the marvelous possibility of so easily saving thousands of lives and of preventing the misery of years of ill health and suffering. To him, it seemed possible that with enough nourishing food he could bring the dead to life."<sup>30(p86)</sup>

Saving lives and preventing misery will not always be so easily or quickly accomplished, but the prospect of doing so for populations through analytic prowess is what has drawn many great minds and consciences to this field and will no doubt continue to draw them in the century ahead. □

Jeffrey P. Koplan, MD, MPH  
 Stephen B. Thacker, MD, MSc  
 Nicole A. Lezin, MPPM  
 Centers for Disease Control and Prevention  
 Atlanta, Ga

## References

1. Savitz DA. In defense of black box epidemiology. *Epidemiology*. 1994;5:551–552.
2. Susser M, Susser E. Choosing a future for epidemiology, II: from black box to Chinese boxes and eco-epidemiology. *Am J Public Health*. 1996;86:674–677.
3. Gordis L. Challenges to epidemiology in the next decade. *Am J Epidemiol*. 1988;128:1–9.
4. Stallones R. To advance epidemiology. *Annu Rev Public Health*. 1980;1:69–82.
5. Trichopoulos D. The future of epidemiology. *BMJ*. 1996;313:436–437.
6. Colditz G. Epidemiology—future directions. *Int J Epidemiol*. 1997;26:693–697.
7. Reiser SJ. *Medicine and the Reign of Technology*. Cambridge, England: Cambridge University Press; 1978.
8. Maimonides M. *The Guide for the Perplexed*. New York: Dover Press; 1950.
9. Dickens C. *American Notes*. New York: Modern Library; 1996.
10. White KL. *Healing the Schism: Epidemiology, Medicine, and the Public's Health*. New York: Springer-Verlag, 1991.
11. Sackett DL, Haynes RB, Tugwell P. *Clinical Epidemiology: A Basic Science for Clinical Medicine*. Philadelphia: Lippincott-Raven Publishers, 1991.
12. Feinstein AR. *Clinical Epidemiology: The Architecture of Clinical Research*. Philadelphia: WB Saunders Co; 1985.
13. Lind J. *A Treatise of the Scurvy in Three Parts, Containing an Inquiry Into the Nature, Causes, and Cure of That Disease, Together With a Critical and Chronological View of What Has Been Published on the Subject*. Edinburgh, Scotland: Sands, Murray, and Chochran; 1753.
14. Shyrock RH. *The Development of Modern Medicine*. New York, NY: Hafner Publishing Co; 1969.
15. Langmuir AD. The surveillance of communicable diseases of national importance. *N Engl J Med*. 1963;268:182–192.
16. Frost WH. The age selection of mortality from tuberculosis in successive decades. *Am J Hygiene*. 1939;30:91–96.
17. Greenwood M. *Epidemics in Crowd-Diseases: An Introduction to the Study of Epidemiology*. New York: MacMillan Co; 1935.
18. Centers for Disease Control and Prevention. Ten great public health achievements of the 20th century. *MMWR Morb Mortal Wkly Rep*. 1999;48:241–243.
19. Goldberger J. The cause and prevention of pellagra. *Public Health Rep*. 1914;29:2354–2357.
20. Doll R, Hill AB. Smoking and carcinoma of the lung. Preliminary report. *Brit Med J II*. 1950:739–748.
21. Doll R, Hill AB. Mortality in relation to smoking: ten years' observations of British doctors. *Brit Med J II*. 1964:1399–1410, 1460–1467.
22. Wynder EL, Graham EA. Tobacco smoking as a possible etiologic factor in bronchogenic carcinoma, a study of six hundred and eighty-four proved cases. *JAMA*. 1950;143:329–336.
23. Selikoff IJ, Hammond EC, Churg J. Asbestos exposure, smoking, and neoplasia. *JAMA*. 1968;204:106–112.
24. Rose G. *The Strategy of Preventive Medicine*. Oxford, England: Oxford University Press; 1992.
25. *Snow on Cholera*. New York: Commonwealth Fund; 1936.
26. Peto R, Mathews J. Smoking and cancer. *Lancet*. 1973;1(7812):1126.
27. Shaneyfelt TM, Mayo-Smith MF, Rothwangi J. Are guidelines following guidelines? The methodological quality of clinical practice guidelines in the peer-reviewed medical literature. *JAMA*. 1999;281:1900–1905.
28. Yen IH, Kaplan GA. Neighborhood social environment and risk of death: multilevel evidence from the Alameda County study. *Am J Epidemiol*. 1999;149:898–907.
29. Kawachi I, Kennedy BP, Lochner K, et al. Social capital, income inequality, and mortality. *Am J Public Health*. 1997;87:1491–1498.
30. Etheridge E. *The Butterfly Case: A Social History of Pellagra in the South*. Westport, Conn: Greenwood Publishing Co; 1972.