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References

1. Mabry PL, Olster DH, Morgan GD, et al. Interdisciplinarity and systems science to improve population health: a view from the NIH Office of Behavioral and Social Sciences Research. *Am J Prev Med.* 2008;35(2):S211–S224.

2. Auchincloss AH, Diez Roux AV. A new tool for epidemiology: the usefulness of dynamic-agent models in understanding place effects on health. *Am J Epidemiol.* 2008;168(1):1–8.

3. Hammond RA. Complex systems modeling for obesity research. *Prev Chronic Dis.* 2009;6(3):A97.

4. Longini IM Jr., Nizam A, Xu S, et al. Containing pandemic influenza at the source. *Science.* 2005;309(5737):1083–1087.

5. Morris M, Kretzschmar M. Concurrent partnerships and transmission dynamics in networks. *Soc Networks.* 1995; 17(3–4):299–318.

6. Jones AP, Homer JB, Murphy DL, et al. Understanding diabetes population dynamics through simulation modeling and experimentation. *Am J Public Health.* 2006;96(3):488–494.

7. Hoffer LD, Bobashev G, Morris RJ. Researching a local heroin market as a complex adaptive system. *Am J Community Psychol.* 2009;44(3–4):273–286.

8. Levy DT, Chaloupka F, Gitchell J, et al. The use of simulation models for the surveillance, justification and understanding of tobacco control policies. *Health Care Manag Sci.* 2002;5(2):113–120.

9. Tengs TO, Osgood ND, Lin TH. Public health impact of changes in smoking behavior: results from the tobacco policy model. *Med Care.* 2001;39(10): 1131–1141.

10. Levy DT, Graham AL, Mabry PL, et al. Modeling the impact of smoking-cessation treatment policies on quit rates. *Am J Prev Med.* 2010;38(3 Suppl):S364–S372.

11. National Institutes of Health, Office of the Director, Office of Behavioral and Social Sciences Research. Videocasts. Available at: http://obssr.od.nih.gov/training_and_education/videocast/videocast.aspx#ssh. Accessed April 4, 2010.

12. Northridge ME, McElroy K, eds. Systems Thinking. *Am J Public Health.* 2006;96(3, theme issue):398–576.

13. National Cancer Institute. *Greater Than the Sum: Systems Thinking in Tobacco Control.* Bethesda, MD: US Department of Health and Human Services, National Institutes of Health, National Cancer Institute; 2007. NIH publication 06-6085. Tobacco Control Monograph Series No. 18. Available at: http://cancercontrol.cancer.gov/tcrb/monographs/18/index.html. Accessed April 4, 2010.

Lessons Learned From the Application of Systems Science to Tobacco Control at the National Cancer Institute

Nearly 10 years ago, the Tobacco Control Research Branch of the National Cancer Institute (NCI) at the National Institutes of Health (NIH) developed a transdisciplinary initiative to explore the application of systems thinking approaches and methods to research, practice, and policy in tobacco prevention and control. The Initiative on the Study and Implementation of Systems (ISIS)[1,2] was relatively new for NIH and resulted in much discourse among some scientists because of its sheer breadth and the scope of what it hoped to achieve: answers to the questions "Is it possible to understand the interplay of factors that both sustain and potentially disrupt tobacco use?" and "What structures and functions are essential for both understanding that complexity and improving our efforts in tobacco control?" We chose tobacco as an exemplar proof of concept for applying complexity theory and systems science to a wide range of behavioral and public health challenges.

The ISIS team led or supported pilot tobacco control projects in three main areas: systems modeling; professional and organizational network development, implementation, and analysis; and knowledge management and informatics. To date, ISIS has developed numerous products, including an NCI monograph; multiple peer-reviewed articles, presentations, and workshops; 3 networks of researchers and policy analysts; and a prototype Web 2.0 collaborative online workspace. These products are important steps for addressing the complex problem of tobacco prevention and control, and they reflect priority areas identified in the 2007 NCI Tobacco Control Monograph "Greater Than the Sum: Systems Thinking in Tobacco Control," the first government document to lay out a systems approach to the field of tobacco control and prevention.[1]

However, far more work is needed to optimize knowledge, and serious attention to understanding the tobacco system itself is essential as well. ISIS made initial efforts to analyze the stocks and flows of the complex and dynamic system of tobacco initiation, use, and control but never completed a thorough network analysis that could serve as a starting point for much more in-depth analyses. Although funding opportunities for such research are improving across the NIH, more reviewers are needed who have the familiarity with and experience in network analysis and systems science in general.

WHAT DID WE LEARN?

Essentially, ISIS opened the door for looking at public health science in a way that seldom occurs. ISIS allowed us to investigate simultaneously how knowledge flow can be improved to advance science; in what way fostering a network-centric approach to science might improve and speed knowledge flow; and whether it is possible to understand the

interplay of factors of the tobacco system that might allow us to intervene in more effective ways. ISIS emphasized that systems thinking is an ecological process rather than a cluster of methodologies. The vision presented in the ISIS monograph[1] is that by integrating conceptual frameworks and multilevel dynamic causal models with the approaches and methods of systems science, tobacco control organizations will be able to work more collaboratively and use evidence-based best practices more effectively in the field.

Beyond the contribution individual pilot projects made to our understanding of the role of systems science in population and public health, ISIS demonstrated how current systems research can be leveraged to create a bold new approach to integrating science and practice to achieve desired health outcomes. ISIS was a product of increasing recognition of systems as a priority at the NIH, and in several critical areas it helped characterize the complexity of public health issues and challenges and delineate the research infrastructure and practice needs of public health. It helped demonstrate how systems science can be used to identify the most effective policy levers at the individual and population levels.

WHERE DO WE GO FROM HERE?

Although we have not yet witnessed a serious focus on analyzing and understanding tobacco control as a system, we believe the day for that is nearing, as evidenced in part by the publication of this theme issue of the *Journal*. Moreover, there are other positive signs of change.

For example, NIH's Office of Behavioral and Social Sciences Research (OBSSR) has identified the analysis of systems science relevant to health as one of their strategic priorities and has been working to expand awareness, skills, and funding opportunities in this area. The OBSSR has issued a program announcement for systems science approaches to policy-resistant health problems and incorporated systems approaches into several other NIH funding opportunity announcements. Moreover, there is a growing awareness within the research and policy communities of the potential opportunity for systems science approaches and methods to advance public health, as evidenced by the number of recent conferences and workshops devoted to the subject.[3] For example, the OBSSR is hosting a second training institute on systems science and health in the summer of 2010.

In addition, the recent release of a new NIH program announcement to support funding for social network analysis to better understand health problems is a tacit acknowledgment of the ISIS conclusion that we cannot effectively address many public health problems without understanding and affecting the social networks that cause or can potentially improve a public health threat. If this increased attention to understanding and optimizing systems for tobacco prevention and control can expand further to additional thought leaders, perhaps a tipping point will be reached. The hope is that this will lead to a far greater understanding of the complexity of the tobacco system and, more important, to ways to intervene in the system to rapidly advance improvements in preventing and treating tobacco use and thus improve public health.

Moreover, the NCI continues to expand on an informatics infrastructure first designed and implemented under ISIS that has a very real chance to benefit tobacco control. The PopSciGrid[4,5] is a web-based proof of concept developed on the NCI's cancer Biomedical Informatics Grid[6] to facilitate the sharing, analysis, and dissemination of public health and population sciences data. Tobacco control was selected as a starting point for the PopSciGrid. This web portal uses state-of-the-science information technology to link nationally representative tobacco-related data from the Health Information National Trends Survey and the National Health Interview Survey with accompanying analytic and visualization applications. Through these linkages and synergies, online collaborations of data collectors and users can be created, maximizing opportunities for data to inform public health practice and policy and accelerate the reduction of tobacco-attributable morbidity and mortality. Finally, and of particular significance, the Association of Schools of Public Health now considers systems thinking to be an interdisciplinary and crosscutting public health competency.[7,8]

These activities and developments, although important, represent only the beginning application of systems science to complex public health problems. What else is needed? First, there remain major needs to build multilevel and multiscale theories and conceptual models and to analyze, using a variety of innovative analytical approaches, the many interacting, complex, and dynamic phenomena that make it so difficult to make rapid advances in tobacco control and other major public health problems such as obesity, drug abuse, and communicable disease. More opportunities are needed to study these complexities. Second, greater emphasis on understanding and fostering collaborative networks that have the potential to make more rapid science advances is needed. There are many examples of interdisciplinary and collaborative research being supported across the NIH, including several NIH Roadmap initiatives and the Transdisciplinary Tobacco Use Research Centers program.[9] However, greater funding of collaborative research networks would strengthen the science infrastructure in the United States. Third, incentives to maximize the use of existing or secondary data are needed—along with more robust ways of data sharing—so that the science community and the public can benefit more rapidly and efficiently from society's large investments in science.

Improvements in data sharing, network development, and systems analysis are essential to improving the translation of science-to-practice and practice-to-science. With the added impetus of this theme issue of the *Journal*, we are confident that the movement toward a systems approach to addressing complex public health problems will continue to build momentum.

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References

1. National Cancer Institute. *Greater Than the Sum: Systems Thinking in Tobacco Control.* Bethesda, MD: US Department of Health and Human Services, National Institutes of Health, National Cancer Institute; 2007. NIH publication 06-6085. Tobacco Control Monograph Series No. 18. Available at: http://dccps.nci.nih.gov/tcrb/monographs/18/index.html. Accessed April 26, 2010.

2. Best A, Tenkasi R, Trochim WT, et al. Systemic transformational change in tobacco control: an overview of the Initiative for the Study and Implementation of Systems (ISIS). In: Casebeer AL, Harrison A, Mark AL, eds. *Innovations in Health Care: A Reality Check.* Houndmills, UK: Palgrave MacMillan; 2006:189–205.

3. National Institutes of Health, Office of the Director, Office of Behavioral and Social Sciences Research. Videocasts. Available at: http://obssr.od.nih.gov/training_and_education/videocast/videocast.aspx#ssh. Accessed April 26, 2010.

4. National Cancer Institute. Division of Cancer Control and Population Sciences, Behavioral Research Program, Health Communication and Informatics Research Branch Web site. Available at: http://dccps.cancer.gov/hcirb/cyberinfrastructure/popsci.html. Accessed April 26, 2010.

5. Shaikh AR, Contractor N, Moser R, et al. PopSciGrid: Using cyberinfrastructure to enable data harmonization, collaboration, and advanced computation of nationally representative behavioral, demographic, and economic data. Paper presented at: American Public Health Association Annual Meeting; November 11, 2009; Philadelphia, PA.

6. National Cancer Institute. Cancer Biomedical Informatics Grid. Available at: https://cabig.nci.nih.gov. Accessed April 26, 2010.

7. Association of Schools of Public Health Education Committee. Master's Degree in Public Health Core Competency Development Project. Version 2.3. Available at: http://www.asph.org/userfiles/version2.3.pdf. Published August 2006. Accessed April 26, 2010.

8. Association of Schools of Public Health. Systems Thinking—Phase 2 Competencies. Available at: http://www.asph.org/document.cfm?page=898. Accessed April 26, 2010.

9. National Cancer Institute, Division of Cancer Control and Population Sciences, Behavioral Research Program, Tobacco Control Research Branch. Transdisciplinary Tobacco Use Research Centers. Available at: http://cancercontrol.cancer.gov/tcrb/tturc. Accessed April 26, 2010.