Epidemiology today: Mitigating threats to an ecosystem

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ABSTRACT

Ecosystems comprise all the living and non-living things in a particular area (e.g., rain forest, desert), which interact and maintain equilibrium. Loss of equilibrium (e.g., clear-cutting trees in a rain forest) can mean the decline of the ecosystem, unless it is able to adapt to the new circumstances. The term “knowledge ecosystem” describes an approach to managing knowledge in a particular field; the components of this system include the people, the technological skills and resources, and information or data. Epidemiology can be thought of as a knowledge ecosystem and, like ecological systems, its existence can be threatened, from both internal and external forces that may alter its equilibrium. This paper describes some threats to the epidemiology knowledge ecosystem, how these threats came about, and what responses we can make that may serve to mitigate those threats.

KEY WORDS: Ecosystems; knowledge; epidemiology; risk

La traduction du résumé se trouve à la fin de l'article.

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What is an ecosystem? It's an ecological system that includes all the living things (plants, animals) in a specific neighbourhood, which interact with each other and with the non-living things in that neighbourhood: sun, water, earth, wind. In an ecosystem, every component plays a role, and the system has stability and energy flow. As long as the components of the ecosystem remain balanced, in equilibrium, then the ecosystem and the living things in it can continue to thrive. Upset the balance (e.g., melt the polar ice caps), and the ecosystem can decline. Maybe it will adapt, and reach a new equilibrium with an altered set of components, but it will certainly be different from what it previously was. A knowledge ecosystem is similarly a system in balance, a system of managing the knowledge in a particular sphere or field. Its components are not plants and animals, wind and water. Rather its components are people interacting with each other to foster development in their field. It's “an approach to knowledge management... that fosters the dynamic evolution of knowledge interactions between entities...” with the purpose: “to improve decision-making and innovation through improved evolutionary networks of collaboration.”¹ It also has been defined as “a complex, self-organizing system of people interacting with each other and their knowledge and technical environments for growing collective intelligence and capabilities.”² Figure 1 shows how Commons Rising depicts a knowledge ecosystem. While not specific to epidemiology, it displays what we do as practitioners of that discipline. We interact with colleagues, both within and outside the field; we bring technological and methodological advances to bear on problems of disease causation and prevention; we use and share our knowledge of epidemiology, biostatistics, biology, chemistry, physiology, medicine, social and behavioural sciences, environmental science, public health policy; and we generate valuable insights and new knowledge that can be used to improve the public health.

Threats to the knowledge ecosystem of epidemiology

In the last decades, there have developed some serious threats to the knowledge ecosystem of epidemiology. Some of these threats have plagued us for years, some are fairly new developments, but all are undermining the effectiveness of epidemiology and its historically central place in the population health landscape. I consider these threats to include fashion, specialization, de-emphasis on creativity, restrictions in research funding, competition for scarce resources, cohort effects and environmental stress.

Fashion

Fashion exists in just about every human endeavour. There is fashion in clothing, in automobiles, in books and films, in food. In all of these activities, there is development, activity rather than stasis, change. Sometimes the change is for its own sake. (Consider the clothing company that wants to continue to sell new and more clothing. Or the vodka distiller who adds new “flavours” to the product to bring people back to try more.) Sometimes the change is for the purpose of making improvement. (Think of the evolution of fabrics and equipment for people travelling to the South Pole, or of changes in the processing of foods to make them more healthful and accessible.) And, sometimes the change is for both reasons, to stay afloat, or on top, in a competitive market.

Often, the changes focus on one aspect of the product, one characteristic that is pushed further in a single direction: the heels

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Figure 1. Depiction of a knowledge ecosystem.

of women's shoes getting higher, the tail fins of cars in the 1950s and 1960s getting larger and longer without regard to function or meaning. Similarly, in epidemiology, we are sometimes tempted to focus on one part of the chain of causation – what we denote “risk factor” epidemiology – until that one detail takes on exaggerated importance, and we lose sight of the whole picture.

Certainly our desire to stand out, to sell our research ideas, to obtain research funding: these are central to, and necessary for, success in our realm. But what also happens is that we focus microscopically on some small details that may add to the minute accumulation of knowledge, but that won't put us outside the usual bounds, the current “fashionable” thinking about a particular disease, risk factor or health outcome.

To make real progress, is it really wise to focus exclusively on one detail in current fashion, one among the myriad available for investigation? In a somewhat simplified history of epidemiology, in the 1970s, epidemiologists studied hormonal factors; in the 1980s, they focused on nutrition, diet and micronutrients; in the 1990s, they started to consider physical activity and physical fitness, along with a more macro approach to food intake; in the 2000s, genes and their interaction with environmental factors gained ascendancy; and in the 2010s, we have proteomics, metabolomics and all the other -omics, which also lead us to Big Data and so-called “data science”. In some part, advances in methodology, measurement and analytic capacity have fuelled these changes, but to a large extent we're following the changing fashion in risk factor epidemiology.

John Snow's ideas about water-borne disease; James Lind's non-randomized trial of scurvy; Joseph Goldberger's studies of pellagra before we knew what vitamins were: these people weren't following the fashion of their times, they were struggling against the current of popular medical thought.³ Closer to our own time, Warren Winkelstein proposed a hypothesis that tobacco smoke could cause cervical cancer.⁴ How unlikely that seemed at the time: tobacco was inhaled or chewed, so we looked for respiratory or gastrointestinal diseases, not diseases of the genitourinary system. Dental health affecting heart disease? Blood type related to heart disease and stroke? Cigarette smoking that protected against uterine cancer? These are ideas that existed outside the mainstream of etiological thinking, outside what is fashionable in epidemiology. But clearly they were and are ideas that should attract our attention.

Specialization

Elizabeth Barrett-Connor, writing in 1979,⁵ said “For some time I have been confused and irritated by the division of epidemiology and epidemiologists into subspecialties of infectious disease and chronic disease”. In this well-argued piece, she describes the extension of infectious disease methods into the study of chronic diseases, to the benefit of both, but unfortunately leading to their eventual segregation. We don't have to go far to find examples of the interlacing of infectious and chronic causes – think of Human Papilloma Virus and cervical cancer – to realize that any segregation is detrimental to our understanding of disease causation.

Barrett-Connor emphasized the benefits of sharing both experience and methodologies, and wrote: “we should discard the qualifiers and call an epidemiologist an epidemiologist”. We are “not separate and unrelated species, any more than acute and chronic diseases can be neatly categorized”. What, though, has happened since 1979, when Barrett-Connor was sounding her note of concern? We've gone much further into the adjective-epidemiology she warned against. Now we have specialists within the specialties. We've seen a proliferation of societies and journals relevant to epidemiology. We've come to the point that we often don't read the papers of our colleagues, because they're publishing in specialty journals we don't see, sponsored by organizations to which we don't belong.

De-emphasis on creativity

Linked with fashion, but with a somewhat different focus, is a de-emphasis on or lack of creativity in our work. This is due in part to the explosion of methodological advances that we and our students need to master, and in part to how difficult it is to “teach” people how to be creative. But it's also about letting one's mind wander, thinking laterally not just vertically. “Big Data”, the new “big thing”, is vertical thinking to a large extent. We shouldn't want the data to think for us; we should want to think first, to free associate, to dream about how, e.g., the benzene molecule could contain its complement of carbons and hydrogens. Maybe the story of August Kekulé's dreaming the benzene ring in the 1860s is apocryphal, but it serves as a signpost that not every new idea comes from focusing on the data. Sometimes letting one's mind drift, putting facts together in different ways, may allow new theories or concepts to emerge organically.

About 10 years ago, when a group of us were planning what has become the Ontario Health Study, we were trying to decide what data we should collect from participants. One faction in our meeting pushed for inclusion of variables for which we had strong justification. Others, while agreeing that we needed to collect data on some known risk factors and potential confounding variables, wanted the study to put more emphasis on things we *didn't* know: sleep patterns; blood type; dietary intake beyond food frequency questionnaires and 24-hour recalls; physical activity other than cardiovascular fitness; leaving room for new ideas to be thought of, and new variables to be incorporated. Since the Ontario Health Study was always intended to be a long-term cohort, could we really predict what exposures might emerge in 15 or 20 or 50 years?

More recently, I served on a review panel for a granting agency, reviewing Letters of Intent, the initial phase of a grant application process that aimed to screen out projects that seemed to be

Figure 2. The cycle of implementation science.

non-starters. On the basis of 1–2 page descriptions of research plans, we had to decide what ideas were worthy of requesting full proposals. Some members of the panel really liked projects that were well formed, that would provide useful data and that would incrementally move the particular field ahead. Others felt that, as with variable selection in the Ontario Health Study, we should encourage “outsider” ideas, higher-risk projects that could fail, but that if successful could add something new to knowledge, take the field in a new direction. These were very short letters of intent, and funding commitments were not being made at that stage. So why not take a leap, be bold, let someone try something new? Instead, we spend a large part of our working lives, as in the great film of World War II, *Casablanca*, simply rounding up the usual suspects.

Restrictions in research funding

There are, of course, some external threats. It’s certainly difficult to obtain funding to conduct our research. Even when we’re successful in moving a grant through the arduous process of preparation and review, the actual amount of money awarded often is less than we requested, maybe because the funding agency assumed we’d padded the budget. So we spend a lot of effort seeing how and where we can cut and still conduct the research with integrity.

Service-driven research is what many formerly creative funding organizations are doing these days. It’s the fashion to talk about implementation science, translational science, science from bench to bedside, programmatic research: research that seeks to be relevant to the current state of knowledge. A diagram of the cycle of implementation science⁶ is shown in Figure 2. It’s called “Integrating evidence into research, practice and policy”, and is

described as being useful for “aligning science with policy and practice”. The cycle moves between what are labeled “Practical progress measures”, “Implementation process”, and “Program or policy changes”, with so-called “Stakeholders” sharing a central locus with “Evidence”. It probably is consequential science. But, nowhere in the model is there a place for “New Ideas”, and the loser is investigator-initiated work, from which creative advances might come. Many public health and disease agencies in Canada are redirecting their investigator-driven funding dollars towards service research and implementation science. Leaving the field of innovative epidemiology, in order to work towards implementation of better public health policy, is to create a vacuum in scientific advancement. Yes, someone needs to do the work of moving the public health agencies in good directions, but epidemiologists are nearly the only scientists who can move the state of knowledge in creative and innovative ones.

Competition for scarce resources

Where is the competition for scarce resources coming from, aside from the perceived losses of research funding and personnel support? Two causes are the proliferation of schools of public health, and the pressure on universities to increase enrolment in order to bring more money (i.e., tuition) into the institutions. As a society we haven’t done the market analysis to know how many of “us” we can afford to employ. Even now, some of our masters’ degree graduates – not yet the case in epidemiology or biostatistics I’m glad to say, but in related fields – aren’t finding employment that uses their skills and training.

You could say that we have such broad skills and knowledge, they’ll be able to find new areas of application and thus new job

opportunities. To an extent, this is probably true: we find excellent work in industry, in government, in research institutes and academies. But there may be a limit on growth of the field, as there has been in just about every other discipline. There are now too many lawyers, too many occupational therapists, and probably too many MBAs. It may take the equivalent of a mass extinction to rebalance the numbers needed with the numbers we train in any discipline. Should we wait for that to happen in epidemiology, or make the difficult choice to restrict training if market forces so dictate?

Cohort effects

The threat from cohort effects is more subtle, and possibly more subjective, but it relates to fashion and to creativity. In the 1960s, students demonstrated against the war in Vietnam. In the 2010s, the children of those activists demonstrated for better funding levels in graduate school. To me, this difference in focus and agitation is a marker of a small-p political change. As an overgeneralization, the current generations are more conservative in outlook. Some of the reasons are linked to previously-noted threats: decreased funding and competition for scarce resources. But there also are generational differences based in larger societal changes that are leading young people to law and banking, not the Peace Corps or the Arts.

Environmental stressors

Increasing fear for our futures and our careers is a natural concomitant of funding losses, and competition for resources that are disappearing.

What happens when we can no longer withstand the stress within our ecosystem? Epidemiologists describe this as “eating our young”. What really does this mean? It’s a zoological phenomenon which occurs in many species, species as diverse as fishes, mammals, spiders and birds. Scientists are not sure of all the reasons why some species commit ovicide or infanticide, but some of the explanations include these:

- Increased opportunity for reproduction among those still alive;
- Increased access to limited resources in periods of food scarcity;
- Increased reproductive success by eliminating competition; and
- Reduced misdirection of parental care and energy.

How do epidemiologists engage in this metaphorical practice? Let’s hope that we don’t use some of the more draconian measures employed by other species. But, students might complete their degrees faster than others in their cohort, for increased access to scarce job resources. And we engage in increasingly critical and harsh peer review of competing applications for operating grants and personnel awards. These strategies are related to many aspects of the knowledge ecosystem I’ve already discussed.

A Model that connects the various threats in the cycle within our ecosystem is shown in Figure 3. Starting with the decrease in research funding, this increases competition for scarce resources, specialization in order to stand out in a smaller sphere, with a parallel decline in creativity, and an increase in following fashion

Figure 3. A model of the cycle of threats to the epidemiology ecosystem.

rather than taking chances with new ideas. Specialization leads to a decline in shared experiences and less cross-fertilization among epidemiologists, smaller and smaller incremental achievements from any one research grant or project, and a decline in epidemiological advances that are important to the public health. In my view, this will feed back into a further decline in funding, as agencies decide that the cost/benefit ratio is increasing. While funding agencies require us to describe innovative aspects of our projects, they’re often just asking us to pay lip service to the idea, since creative proposals may be down-rated.

Mitigating threats to the epidemiology knowledge ecosystem

While the foregoing can be very depressing, it’s not the end of the story; to a large extent the threats may be mitigated. I propose some practical strategies that may be implemented; these include accepting risk, increasing interactions and broadening the funding base.

Accepting risk

A few years ago, summarizing a workshop we ran at a meeting of the American College of Epidemiology (ACE), and subsequent discussions of a Task Force established by the ACE, colleagues and I wrote that “there is a fine, sometimes indiscernible, line between scientific innovation and creativity on the one hand, and crackpot science on the other. Fear of crossing that line can stifle the kind of bold thinking that may lead to great discoveries”.^{7,8} In that light, what about a grant panel for “outrageous” ideas? Ideas that may appear to be high risk, but also may be associated with high reward?

Many funding agencies claim to support this sort of research, but in practice: not so much. The mechanism of beginning with Letters of Intent, rather than full funding proposals, may be a good way to take these chances, if the review panel is properly, and open-mindedly, constituted. Sadly, that doesn’t often happen, and we end up funding more of the same: well-justified extensions of what we already know.

But, we could encourage CIHR or NSERC to take a chance, specifically to put out calls for proposals that are *not* well justified, whose authors are willing to take a leap. Funding agencies could also put out calls for grant panelists to serve as reviewers for these special competitions; people who will allow others to think outside

the box. It may be that these reviewers need to be very junior rather than very senior investigators, the reason being that the junior investigators may not have been completely inculcated in the culture of incremental science.

This could have been a way for Lind to get funding for his scurvy trial; Snow for his cholera work; Goldberger for pellagra; Winkelstein for cervical cancer; a way for us to more easily cross the divide between infectious and chronic diseases; to obtain funding for studies of, say, blood type and social determinants of health.

In a related vein, what about a conversation with journal editors to discuss publication review policies that reward the use of innovative methods and the exploration of new and unusual hypotheses?

Some years ago, colleagues and I developed an approach to examining the intersection of diseases and exposures.⁹ Our initial aim was to find a method for a research agency to identify research priorities, but we found that interesting and as yet unstudied hypotheses could also emerge. Over a matrix of measures of disease impact and estimates of exposure prevalence, we overlaid estimates of statistical power, biological plausibility in the broadest sense, and strength of evidence (the last being a “negative” value.) Some odd and interesting areas for research emerged, including non-Hodgkin’s lymphoma and reproductive factors. In fact, journal articles on this topic post-dated our proposal that this could be a useful area of research.

Increasing interaction

It is clear that greater opportunities to interact – in physical or virtual space – promotes creativity. While there is much to be said against workstations in modern offices, the forced interaction may be valuable. But we could do this in other ways, to provide opportunities for interaction with colleagues from other fields. We could structure our academic departments and society conferences in ways that mingle disciplines, rather than stratifying them by building or month of the year, and we could certainly identify common informal space to which scientists gravitate when taking work breaks.

Why not a workshop at an epidemiology conference in creative and/or lateral thinking? I’ve participated in a few workshops on creativity run by Peter Taylor, a PhD trained scientist from Harvard University, whose professorship is titled Critical and Creative Thinking, at the University of Massachusetts in Boston.¹⁰ Creative skills can be taught and can be learned; but like any other techniques, one has to spend the time and energy doing so.

Much of creative scientific development comes from collaborations across disciplines, and this is especially true in epidemiology. How do we promote this more risky research, going outside the circle of our usual colleagues to find new paths? We can ensure that our students have adequate training in other disciplines, enough to be able to engage scientists in those disciplines. We can provide incentives to faculty who work collaboratively. The usual promotion and tenure criteria, and the criteria for awards, do not strongly support collaborative work; instead they emphasize what “independent” contribution a given epidemiologist has made. The National Academies Press just released a report on “Team Science”, in which the authors reinforced these ideas: developing criteria for allocating credit;

Figure 4. Six components of a thriving ecosystem.

working with funders to develop new collaborative models; and asking funders to require collaborative plans as part of the grant application.¹¹

The Canadian Society for Epidemiology and Biostatistics, the American College of Epidemiology, and other related organizations could lobby for changes in assessment criteria, placing higher value on collaborative research. What better opportunity to begin this work than at the Epidemiology Congress of the Americas in June 2016.

Broadening the funding base

How might we broaden our base of funding? We could lobby government for increased funding, based on evidence of impact or the potential for it, rather than incremental increases in our understanding of health and disease, or evaluation of public health policies.

We can stop assuming that monies from non-governmental sources are somehow of lesser value. A number of years ago a department chair said he wouldn’t believe findings reported in a student’s PhD dissertation because the funding had come from a pharmaceutical company. Clearly it’s unreasonable to assume bias without evidence of it, but this is not an atypical response among academics who pride themselves on being independent thinkers and researchers.

We could develop more effective government–industry co-funding and cost-sharing. This is very possible, and with clear memoranda regarding ownership of the data – equally necessary when we take government contracts as when we take industry funds – there’s little risk of stifling answers that funders don’t like. My colleagues in Montreal and I are beginning the 20th year of follow-up in our national cohort study, the Canadian Multicentre Osteoporosis Study, or CaMos.¹² The work would not have been possible without the joint support of CIHR and a number of pharmaceutical companies.

CONCLUSION

An ecosystem maintains itself through a delicate balance involving all its parts. For the epidemiological ecosystem, those parts include scientists, methods, knowledge, colleagues and collaborators, and even funders and publishers. We need to work with these groups to ensure not just the survival but the health and growth of the system.

A few years ago, Michael Libes published “6 Components of a Thriving Ecosystem”.¹³ The diagram he developed is shown in Figure 4. The analogy between his start-up model and our situation in a more mature epidemiological ecosystem is very strong. Libes’ 6 components are: cross-disciplinary inclusion, the pool of talent, shared ideas, mentorship, an incubator for drawing the other components together, and funding.

We need to be aware of the mechanisms by which we can ensure the security of the ecosystem, since public health depends on epidemiology, its basic science. And we need to try new strategies, to expand our thinking about how to do science and how to reward it. Both researchers and funders would benefit by not following the crowd, and by taking a longer and broader view.

I have one final note of caution to us all, heard on US National Public Radio on 26 May 2015: “If you’re not at the table, you’re on the menu”.

REFERENCES

1. Wikipedia, the Free Encyclopedia. Knowledge Ecosystem. Available at: http://en.wikipedia.org/wiki/knowledge_ecosystem (Accessed August 17, 2015).
2. Commons Rising. What is a Knowledge Ecosystem and the Virtuous Cycle of its Formation. Available at: http://commonsrising.ning.com/group/knowledge_ecosystem/page/what-is-a-knowledge-ecosystem-and-the-virtuous-cycle-of-its-formation (Accessed August 17, 2015).
3. Buck C, Llopis A, Najera E, Terris M (Eds.). *The Challenge of Epidemiology: Issues and Selected Readings*. Washington, DC: Pan American Health Organization Scientific Publication No. 505, 1988.
4. Winkelstein W, Jr. Smoking and cancer of the uterine cervix: Hypothesis. *Am J Epidemiol* 1977;106(4):257–59. PMID: 910793.
5. Barrett-Connor E. Infectious and chronic disease epidemiology: Separate and unequal? *Am J Epidemiol* 1979;109(3):245–49. PMID: 453165.
6. Glasgow RE, Green LW, Taylor MV, Stange KC. An evidence integration triangle for aligning science with policy and practice. *Am J Prev Med* 2012; 42(6):646–54. doi: 10.1016/j.amepre.2012.02.016.
7. Sulsky SI, Kreiger N, Mckeown RE. Not continuing along previous lines: Exploring how new directions emerge in epidemiologic research. *Ann Epidemiol* 2012;22(5):369–71. PMID: 22326693. doi: 10.1016/j.annepidem.2011.12.007.
8. Hiatt RA, Sulsky S, Aldrich MC, Kreiger N, Rothenberg R. Promoting innovation and creativity in epidemiology for the 21st century. *Ann Epidemiol* 2013;23(7):452–54. PMID: 23790350. doi: 10.1016/j.annepidem.2013.05.007.
9. Kreiger N, Sloan M, Lacroix J. Establishing research priorities in etiologic epidemiology. *Ann Epidemiol* 1999;9(1):19–24. doi: 10.1016/S1047-2797(98)00029-5.
10. Taylor P. University of Massachusetts, Boston, Faculty Profile. Available at: http://www.umb.edu/academics/cehd/faculty/peter_taylor (Accessed August 17, 2015).
11. Cooke NJ, Hilton ML (Eds.). *Enhancing the Effectiveness of Team Science*. Washington, DC: National Academies Press on Team Science, 2015. Available at: http://www.nap.edu/catalog.php?record_id=19007 (Accessed May 22, 2016).
12. Kreiger N, Tenenhouse A, Joseph L, Mackenzie T, Poliquin S, Brown JP, et al. The Canadian Multicentre Osteoporosis Study (CaMos): Background, rationale, methods. *Can J Aging* 1999;18:376–87. doi: 10.1017/S0714980800009934.
13. Libes M. 6 Components of a Thriving Startup Ecosystem, 2012. Available at: <http://www.triplepundit.com/2012/08/consciously-creating-startup-ecosystem> (Accessed August 17, 2015).

RÉSUMÉ

Les écosystèmes comprennent toutes les choses vivantes et non vivantes d’une région donnée (p. ex., forêt pluviale, désert) qui sont en interaction et en équilibre. La perte d’équilibre (p. ex., la coupe à blanc d’une forêt pluviale) peut signifier le déclin de l’écosystème, sauf s’il est capable de s’adapter aux nouvelles conditions. L’expression « écosystème de connaissances » désigne une approche de la gestion des connaissances dans un domaine particulier; les éléments de ce système sont des personnes, des compétences et ressources technologiques, ainsi que de l’information ou des données. L’épidémiologie peut être considérée comme un écosystème de connaissances; comme les systèmes écologiques, son existence peut être menacée par des facteurs internes ou externes qui peuvent perturber son équilibre. Nous décrivons ici certaines des menaces à l’écosystème de connaissances de l’épidémiologie, l’origine de ces menaces et les réponses susceptibles de les atténuer.

MOTS CLÉS : écosystème; connaissance; épidémiologie; risque