MolecularMedicine

Ken Warren and the Rockefeller Foundation's Great Neglected Diseases Network, 1978–1988: The Transformation of Tropical and Global Medicine

Conrad Keating

The Wellcome Unit for the History of Medicine, Oxford, United Kingdom

Online address: http://www.molmed.org
doi: 10.2119/molmed.2014.00221

In 1970, Sir Harold Himsworth, Secretary of the British Medical Research Council, published a book on the theory of scientific knowledge in which he observed how scientists add to the collective corpus of enlightenment (1). He rejected the Baconian picture of natural knowledge as a ramifying tree, which scientists explore by climbing like squirrels up and out along the branches. Instead, he proposed the model of a great sphere into which, more like moles, scientists burrow centripetally from multiple starting points on its surface. At any point, they start with a concrete problem and a practical aim.

A decade earlier, the American medical researcher, Kenneth S Warren identified just such a problem and, more importantly, a scientific program for its alleviation. Warren had developed a personal research formula in immunoparasitology that had established his status as a renowned investigator in schistosomiasis. His work was an early attempt to apply modern biomedical technology in the understanding of the mechanisms of disease prevalent in developing countries. At the time, with over 3 billion people in those countries suffering from infectious diseases, Warren set himself the objective of finding the most cost-effective form of medical intervention to help reduce the sequence of "exposure, disability and death" (2). Warren adopted a numerical view of global health and was firm in the belief that the lives of children in poor countries mattered just as much as those of children in rich countries. Everyone scored the same in terms of the metrics of importance, and the aim was to achieve good health care at low cost. He was particularly interested in diarrheal and respiratory diseases (the biggest killers of children), neonatal death and the delivery of vaccines. The celebrated Australian research biologist Gus Nossal first met Ken Warren in 1976 and was impressed by his ambitious vision: "His passion was to bring the fruits of the new biology, genetics and molecular biology to bear on tropical diseases, which had been the domain of the older generation who had been out in Africa for 20 years, divorced from the new biology" (2014 interview with G Nossal by C Keating; see Acknowledgments). Warren's vision would be to establish a network of labs that would apply this "new biology" to parasitic diseases prevalent in the developing world, particularly malaria and schistosomiasis.

The opportunity for Warren to realize his global ambition came in 1977. He resigned from Case Western Reserve University (Cleveland, OH, USA), where he had taught both in the medical school and in library sciences, to take up the post of Director of Health Sciences at the Rockefeller Foundation (RF). Established in 1913, the Rockefeller charter states a noble ambition: "to promote the well-being of mankind throughout the world." It was at the RF that Warren was to forge his career and make an enduring contribution to the transformation of disease control and world health.

GENESIS AND RECRUITMENT

In December 1977, Warren presented his proposal to the board of trustees of the RF to encourage research on the great neglected diseases of mankind (GND) by

Address correspondence to *Conrad Keating, The Wellcome Unit for the History of Medicine, 45-47 Banbury Road, Oxford OX2 6PE, UK. Phone: +44-1865-274615; Fax: +44-1865-274605; E-mail: conrad.keating@wuhmo.ox.ac.uk.*
Submitted November 3, 2014; Accepted for publication November 4, 2014; Published Online (www.molmed.org) December 16, 2014.

creating "a network of high-quality investigators who would constitute a critical mass in this field, attract the brightest students and conduct research of excellence" (3). The great neglected diseases were described as "great" in terms of prevalence and "neglected" in terms of the involvement of major international scientists and financial support. Warren, now with the financial backing of the RF, was going to roll out his synthesized program, which would include diarrheal and respiratory diseases, malaria, schistosomiasis, African sleeping sickness, hookworm and many other infectious diseases. Integral to the GND network was the establishment of research units in the mainstream of modern biomedical investigation within universities, medical schools and great scientific institutions. Moreover, the program affirmed one of Warren's sacrosanct beliefs, that "a significant part of the investigator's efforts would be spent in applied collaborative research with colleagues in developing countries" (3). In this sense, the project would establish global networks linking "the bench with the bush" (4).

The idea of attracting several groups of carefully selected scientists in both developed and developing countries to focus on parasitic diseases was both innovative and controversial. It was innovative in that, while outstanding work had been done in parasitology, by the 1970s, the discipline had fallen behind the revolutionary changes that had been taking place in molecular and cell biology, genetics and immunology. The controversy lay in the tendentious use of the word "neglected," which proved provocative, for, as the Swedish immunologist Hans Wigzell observed, it "in essence claims that errors are made as to where support is channeled. This is of course true, but nevertheless, this is frequently something that [until then had not been] stated in public" (2014 interview with H Wigzell by C Keating; see Acknowledgments). In many ways, the concept of the GND was a departure from tradition, and this was certainly the case with how the project was funded. As a researcher himself, Warren knew only too well the frustrations of writing grant applications, the trepidation of not having a grant renewed and the general impediments to not being able to get on with the work. To avoid these strictures and smooth the progress of research, all of the GND grants were guaranteed for a period of 8 years.

The impetus to get the project off the ground relied almost entirely on Warren's strength of character and his personal evolution as a scientist. He was a "force for good," but he also did not mind ruffling feathers, especially at the World Health Organization (WHO) (2014 interview with R Peto by C Keating; see Acknowledgments). He was critical of the commendable but unobtainable goals for total primary health care for every human being (set out in a declaration at the WHO conference at Alma Ata in 1978) and instead advocated a selective assault on those few diseases that caused the highest mortality among the world's poor. Warren was described by Sir David Weatherall, a leader of one the foundational units, as "a larger than life character" (2014 interview with D Weatherall to C Keating, see Acknowledgments); he was an inherently charismatic man, charming and, according to Allen Cheever, who worked with him at the National Institutes of Health in 1960, "was many things but never unenthusiastic and never modest. Ken saw what he wanted and got it!" (2014 interview with A Cheever by C Keating; see Acknowledgments). He could also be bombastic, eccentric and swashbuckling, but these perceived components of his personality were tempered by the recognition that he had a great vision for tropical medicine and the delivery of health services in the tropics. A more nuanced understanding of Warren's character and *modus operandi* is offered by his wife Sylvia: "He did rub people up the wrong way, but somebody like that is bound to. Enthusiastic was probably the best way to describe him. Very focused, very sure of what he wanted to do, and very adept at finding the best way to do it" (2014 interview with S Warren by C Keating; see Acknowledgments).

That there was a heavy emphasis on basic sciences in the GND program can be seen as a reflection of Warren's own research background. He was probably the only physician in the Laboratory of Tropical Diseases, which later amalgamated with malaria researches to become the Laboratory of Parasitic Diseases in 1960. He was interested in schistosomiasis, which offered an excellent prism through which to understand the science of parasitology. His imagination was captured when he saw *Schistosoma mansoni*–infected mice being studied by his colleague, Bill De Witt, who was interested in the effects of malnutrition on infection. Warren's early laboratory research concentrated on the quantitative aspects of the study of schistosomiasis, particularly worm numbers through perfusion of the portal system, and the counting of hepatic eggs in pepsin-digested liver fragments (2014 interview with A Cheever by C Keating; see Acknowledgments).

With the concept and research focus in place, Warren spent the best part of a year persuading some of the world's leading scientists to bring their chosen specialisms into tropical medicine. In addition to persuading several American colleagues to join the GND, he established collaborations with scientists across the world, in Egypt, Australia, Thailand, Sweden, England and Mexico. It was a truly interdisciplinary group, bound together by Warren's ability to persuade good scientists to work on diseases in which he was interested. He did it with a combination of bonhomie, enthusiasm and the mutual respect of those working with him (2014 interview with Keith McAdam by C Keating; see Acknowledgments). Of course, there was no peer-review committee, no consensus; the entire group was selected singlehandedly by Warren.

For a program that was to prove a landmark in combating disease in the developing world, it is interesting to recall, almost 4 decades later, how some of the

GND scientists remember meeting Warren for the first time. Anthony Cerami, the world-renowned biomedical scientist, was at Rockefeller University in 1977, and looks upon his first meeting with Warren as career defining. "The first time I met Ken Warren was a memorable and unique experience. Over lunch, Ken painted in broad strokes but very bright colors, his vision of what was to be subsequently known as the GND. The dedication of Ken to the field of parasitology and the poor people of the world is an aspect of the GND that I will never forget. He managed to instill these thoughts in everyone. It was the most important lunch of my life, since it launched me into new unknowns with a group of dedicated people that I am proud to be associated with" (2014 interview with A Cerami by C Keating; see Acknowledgments). Many of the enlisted "high class investigators" echoed this sentiment and recognized that the GND had a profound influence on their careers and personal values.

Warren's approach was to recruit what he considered to be outstanding groups in various disciplines that were not working in tropical medicine and to fire their interests. It was this strategy that he used to persuade Hans Wigzell to join the GND, who at the time was working on the immunology of murine malaria at Uppsala University in Sweden. Just how unorthodox the GND program was seen to be at the time is succinctly and powerfully illustrated by Wigzell. "I remember that Ken came to the Karolinska Institute, and I introduced him to the president at the time, Sune Bergstrom, a very good scientist and a Nobel laureate. I remember talking to him soon afterwards, and he said that he couldn't understand Kenneth; he said, 'this strange American, what is he actually doing, it's strange?' He actually couldn't place it in the simple curriculum or the traditional way of doing it. It was actually a very new approach" (2014 interview with H Wigzell by C Keating; see Acknowledgments). In a similar fashion to Wigzell's recruitment, Warren knew that attracting Oxford-based physician scientist David Weatherall (at that time working on disorders of hemoglobin in the tropics) and his team into the network would provide kudos and the scientific underpinning for the control and management of common diseases in the poorer countries of the world. Indeed, Oxford's reputation in international health for developing long-term North–South partnerships for research and capacity building in tropical medicine can be traced to a seemingly innocuous meeting between Weatherall and Warren in 1977. "When Ken first told me about the GND program, over an excellent dinner at a slightly decadent hotel in London, I was quite skeptical. [But] in the words of the poet Oliver Goldsmith, 'Fools who came to scoff remained to pray.' When he told me that the Rockefeller would offer research support for a minimum of 8 years and that the only stipulation was that we met annually with the other groups to exchange information, I decided to go ahead" (2014 interview with D Weatherall to C Keating, see Acknowledgments).

THE NETWORK IN ACTION

The first meeting of the GND was held at the Abby Aldrich Rockefeller Hall, New York, in 1978. By tempting some the best minds in medical science into the field of tropical medicine, Warren ensured that the first meeting was an unforgettable experience. He invited two giants of British parasitology, George Nelson and Philip Marsden, to the event, to elaborate on the new possibilities of applying modern specialties to the old field of parasitology. The two men were great raconteurs, full of mind-expanding stories gathered over decades working in the tropics, and thrilled the group by signposting the way that the new biomolecular sciences might affect old diseases. With only three scientists from each of the 14 units present, the meeting was characterized by its intimacy and was held in an atmosphere that oscillated between excitement, optimism and relaxed conviviality. It marked the fulfillment of an audacious ambition: to bring new biomolecular scientists to the field of parasitology, create intellectual and personal connections between the different units, and mould them into a strike force that was greater than the sum of its parts.

Each year, the meetings became bigger and more rumbustious. Close friendships were established between many outstanding researchers, and the annual event became rather like a reunion, or perhaps a family gathering. The meetings took place in locations as far afield as Woods Hole, Massachusetts, a game park in Kenya, Israel, and an Oxford college, but all the time, there was a unifying theme: to report on the past year's work, progress and developments; to share knowledge, ideas and doubts; and to create a sense of common goals and of joint destiny. Sylvia Warren was often at the meetings and has no doubt of the contributions made by the foundational units. "They got an enormous amount accomplished at their meetings, and then they got on with their work afterwards because there were no impediments; they had long-term funding, so they didn't need to waste time filling in grant applications. It allowed them to produce, and how!" (2014 interview with S Warren by C Keating; see Acknowledgments).

THE YEARS OF TRANSFORMATION

The main focus of the GND was to look at the mechanisms of disease—how things worked. In that field, the network was prodigious, but not necessarily in the practical production of vaccines to immunize against infection. Perhaps the most enduring legacies of the GND can be found in the transformations brought about in the financial modeling of such projects and its capacity to incubate new talent and collaborative work. A remarkable feature of the RF's program was its actuarial model that facilitated a way of achieving a great purpose with modest resources. Over the 8-year period of its existence, 161 scientists and clinicians were involved; there were 360 trainees, 150 (42%) from the developing world; and 180 papers were published. This step

was accomplished at the cost to the RF of approximately 15 million dollars; rarely had so much been achieved for so many by such a small capital outlay. Of course while funding was critical, other elements were equally indispensable. In the mind of Keith McAdam, "the important thing to remember is that it wasn't about the money. There was an excitement about the science, and the links between the people who were below the leaders was tremendous. So instantly you had collaborations going across continents and suddenly each of these units was working together, and meeting together and playing tennis together. Although the atmosphere was competitive, and you couldn't get away with second rate work" (2014 interview with K McAdam by C Keating; see Acknowledgments). To get funding, everyone had to go to the annual meeting, which helped to forge the GND into a major force that identified with the subject of parasitology, with Ken Warren and with the RF. A symbiotic relationship was built up within the GND; Warren gave unwavering commitment to his units, and in return they did not want to let him down.

The program also played a role in expanding the horizons of parasitology by funding a talented group of young researchers who reinvigorated the status of tropical medicine in the United States. A brilliant cohort of scientists, including John David, Adel Mahmoud, Anthony Cerami, James Kazura and Gerald Keusch, were seduced by Warren to work on tropical diseases and otherwise may not have done so. All of these investigators have made a lasting contribution to disease control and human health, both as part of the GND program and in subsequent years. For Warren, an important part of working in tropical medicine was to study in the field, and this became an important component of the GND program. Seeing first hand the disease burden in indigenous countries proved to be a career-defining experience for many of the network's scientists. Anthony Cerami spent time in Kenya observing the presence of cachexia in animals and people infected with parasites. Thus, a search began for the mechanism of this common occurrence in chronic disease, which is now known to be a macrophage protein produced in response to infection. Cerami's work is a vindication of Warren and Himworth's concept of the scientific endeavor—choose good people, fund them and let them rip. Cerami readily acknowledges that the GND years were the most important in his life in science. His reflections capture the subtle equipoise between sacrifice and achievement that many biomedical scientists will recognize: "The annual meeting of the GND offered to each of us an opportunity to recharge our batteries to continue the hard, lonely work associated with science. The GND became a family dedicated to improving the well-being of mankind. The family aspects of belonging to a group had unique sociological effects. Every group wanted to show that they had been working hard over the past year and had established new and important scientific findings. Everyone wanted to look their best" (2014 interview with A Cerami by C Keating; see Acknowledgments).

Of course there were occasions when things did not run smoothly. In 1979, the second meeting of the GND program was held at University College, Oxford. David Weatherall hosted the meeting and had gone to great lengths to provide an exciting scientific program for the delegates and to make their stay in the city memorable. However, after spending only one night in the historic but spartan undergraduate accommodation, many of the American delegates were so disgruntled that they checked out en masse and decamped to the refined comfort of the Randolph Hotel! Sir David was not unduly offended, and besides, perhaps as much as any of the foundational leaders, through a combination of serendipity and sound planning, his influence on tropical medicine had greatly expanded during the GND decade. First, he recognized that the RF's financial lifeline came at a time when support for science in general, and for work in the developing world in particular, was at a low ebb in the UK. The subsequent funding enabled Oxford medicine to develop permanent links with a number of centers in the developing world. Second, the inaugural GND meeting in New York in 1978 also had a profound, if tangential, influence on the long-term development of medicine in the tropics. The then director of the Wellcome Trust, Peter Williams, had also been invited to attend the meeting by Ken Warren. On the first evening in New York, Williams and Weatherall met and, "over a good bottle of scotch," discussed how they could form partnerships between British universities and centers in the tropics (2014 interview with D Weatherall by C Keating; see Acknowledgments). This meeting led to the establishment of the Oxford-Wellcome Trust unit in Thailand in 1979 and began a program that altered the concept of tropical medicine to medicine in the tropics. This template was subsequently expanded to encompass partnerships in India, Indonesia, Vietnam, Sri Lanka, Laos and Jamaica. Besides producing international leaders in tropical medicine research, these connections have led to important developments in the management of common diseases such as malaria. Weatherall's contribution to understanding the cause of thalassemia, and his lifelong contribution to the control of tropical diseases in poor countries, was recognized in 2010, when he was awarded the Lasker Prize.

There is little doubt that in the decade of the GND program, parasitology had been transformed from a low technical endeavor to one that was at the forefront of the biotechnology revolution. And yet the GND was viewed by some as being peopled by "Johnny-come-latelies," with Warren evaluated alternatively as an "upstart," or a "new kid on the block" (2014 interview with K McAdam by C Keating; see Acknowledgments). These views may have evolved in response to the fact that the GND *was* indeed an exclusive club and was recognized as such by those both inside and outside its

sphere of influence. Hans Wigzell was conscious of this antagonistic situation and believed that it emanated from a "romantic, post-colonial attitude" held by people who possibly felt threatened by microbiology and the new technologies that were being applied to the field (2014 interview with H Wigzell by C Keating; see Acknowledgments). The rumblings from the establishment were subdued rather than overt, but they were felt unambiguously by Wigzell: "It was somehow that unless you had contracted malaria, or any other parasitic diseases yourself, or that you had been swinging in the jungle or been getting infected, you were not really a true person to be working in tropical diseases. I wouldn't call it a vehement one, but it was a kind of an *uppish* kind of treatment, and Ken was treated like an underdog and doing things that were, in quotation marks, 'not completely proper'" (2014 interview with H Wigzell by C Keating; see Acknowledgments; italics added to indicate H Wigzell's inflection of the word).

This disparaging view was far from being held by all of those outside the network. One of the most distinguished figures in parasitology, Dame Bridget Ogilvie, while not being a part of the GND program, recognizes its achievements and Warren's contribution to medical science. Ogilvie herself earned a PhD at the University of Cambridge for her work on *Nippostrongylus brasiliensis*, and in 1963 joined the British Medical Research Council's National Institute for Medical Research, spending her academic career studying immune responses to intestinal worms. For more than a decade as the Director of the Wellcome Trust, Ogilvie was one the most influential figures in the world of tropical medicine. She had first met Ken Warren at a parasitology conference in Washington, DC, in the late 1960s and greatly respected his scientific work, viewing him as being in the vanguard of American parasitology. In fact, she looked upon Warren "as a breath of fresh air," and eschewed belligerence for a more balanced evaluation of Warren's contribution to neglected diseases. "The GND network really began to get the Americans to start doing serious science. Exactly as he did himself in the 1960s, with really beautiful work on the immunological basis of what happens to the schistosome egg in tissue. So Ken was the first American I met who was doing serious science, and he transformed things." While Ogilvie objected to the program taking too fulsome praise for advances made, and funded by, other institutions in the field, she nonetheless attended many of the GND meetings as an external observer and recognized the contributions made to the greater understanding of tropical diseases: "As far as the US was concerned, I greatly respected and admired what Ken did; he really changed things" (2014 interview with B Ogilvie by C Keating; see Acknowledgments).

THE GND IN RETROSPECT

The GND program forms an important chapter in the anthropology of tropical diseases. The interdisciplinary approach led to a great leap forward in understanding pathogenesis and represented the first attempt to apply modern biomedical technology in the elucidation of the mechanisms of disease prevalent in developing countries. It also gave renewed vitality to parasitology and elevated the status of tropical medicine by the accretion of knowledge and new tools developed for the control of what were the great neglected diseases. Far from being ephemeral, much of the seed funding given by the RF continues to have a long-term impact today. For instance, the creation of the Chair of Parasitology at the Karolinska Institute was a direct consequence of Warren's GND program. Looking at parasitic research in his own country and across the other foundational units led Hans Wigzell to write, "seldom before has such relatively little money had such an impact on the course of research in tropical medicine" (5). The nexus of the relationship between the RF and the groups in the field was trust and respect, which allowed the GND program to make enduring advances in the field of parasitology. With collaborations that transcended both national borders and biomedical disciplines, within a very short time, the GND network was making a major impact on the international scientific scene. This collective endeavor brings to mind Lewis Thomas's depiction of the life scientific, seen at times as a lonely activity, and yet communal and interdependent. If the objective is to find a single piece of truth about nature, the "whole scientific enterprise must be arranged so that the separate imaginations in different human minds can be pooled, and this is more a kind of game than a systematic business. It is in the abrupt, unaccountable aggregation of random notions, intuitions, known in science as good ideas, that the high points are made" (6).

In a recent article in *The Lancet* that looked back at over a century of the RF's existence, the GND program was listed as an example of its "excellent philanthropic work" (7). To some degree, Warren was a more influential figure than has generally been appreciated. His ideas were ahead of their time, for he defined a new field of study and its lingua franca. Christopher Murray met Warren in the mid-1980s and recognizes that his concepts still have a resonance today: "I think the GND program had a great effect. He coined the term and it has stuck, and now people compete to call their disease '*neglected*'; there is a bit of a war about what the borders are, what is in and what is not. Is leprosy neglected? Is rabies? There are a lot of different definitions of what is neglected, and I think that the concept can reasonably be traced back to Ken" (2014 interview with C Murray by C Keating; see Acknowledgments; italics added [emphasis by C Keating]). Aside from terminology, Warren used his position of high influence at the RF to give valuable seed funding to ideas and individuals that he thought might be of future value to setting priorities in international health. Although perhaps not the most influential monograph that Warren coauthored,

Good Health Care at Low Cost did have a catalytic effect on the young Christopher Murray, who read the paper while a DPhil student at Oxford (8). "I needed some money to carry out my own study of comparing countries with the same level of health spending and had either good or bad levels of health provision. I wanted to do a good-health-care-at-low-cost study, a bit more rigorously [C Murray trailed off]. So I wrote to Ken, he said 'yes' and the Rockefeller paid for my DPhil fieldwork" (2014 interview with C Murray by C Keating; see Acknowledgments). Thus, a distinctive line of historical continuity is discernible between Warren and Murray, with the latter still working on long-term infant mortality and the global burden of disease.

Warren was interested in metaanalysis, epidemiology, large-scale randomized evidence, large-scale implementation and taking a numerical view of world health. The influence of his work continues today and, according to his former colleague Julia Walsh, has "saved millions of children's lives" (2014 interview with J Walsh by C Keating; see Acknowledgments). His enduring influence, according to Walsh, stems from their controversial study, "Selective Primary Health Care: An Interim Strategy for Disease Control in Developing Countries" (9). The paper advocated, contrary to the WHO view of total primary health care, a new turn toward selective and achievable goals via targeted assaults on specific diseases, as implemented at the GND network. This approach had an enormous impact on health policy. For the first time, the study listed the diseases people died of to establish what the biggest killers were. It established a metric that could be used by donors, governments and bilateral agencies for measuring impact. It asked the fundamental question, "Is the program that you plan to implement going to improve health in any way?" The program's influence has been so far-reaching that it led Julia Walsh to write that "it massively changed the investment and resource allocation at UNICEF, at the WHO, USAID, [and] the World Bank" (2014 interview with J Walsh by C Keating; see Acknowledgments). The views expressed in this original paper are now widely accepted as the appropriate strategy, and its numerically underpinned philosophy led directly to Dean Jamison's *World Development Report: Investing in Health* and to Christopher Murray's *Global Burden of Disease* initiative. Yet conversely, while it is more widely and broadly accepted that the Warren approach was correct, many people working in the field today will never have heard his name.

Ken Warren's first degree was in history and library sciences at Harvard, and it was there that he developed a love of literature, poetry and the works of William Shakespeare. In 1996, in the final stages of metastatic disease, Warren wrote to his friend, the British epidemiologist Sir Richard Peto. Among his positive ruminations on life, the letter contained the final two lines from Shakespeare's "Sonnet 12":

> And nothing 'gainst Time's scythe
> can make defence
> Save breed, to brave him when he
> takes thee hence.

Much of Warren's professional life was dedicated to helminthology and the science of epidemiology, which he described unsentimentally as being "compassion with the tears wiped away" (2014 interview with R Peto by C Keating; see Acknowledgments). Characteristically, even in the last months of his life, he was encouraging of Peto's idea of a randomized trial to help assess the effects of regular deworming on mortality among 1 million children in India. In the study by Peto *et al.*, which was published in 2013, it seemed only fitting that Warren's memory was celebrated with a quote from Shakespeare. "This report is dedicated to its onlie begetter, Kenneth S Warren (1919–1996)" (10).

The GND program reinvigorated American medicine's interest in neglected tropical diseases and changed the philosophy underpinning health policy and resource allocation. The implications for global health continue to be felt. One indisputable outcome is that Warren's vision to attach the new biomedical and molecular sciences to tropical diseases brought a stellar cohort into the field of parasitology, and their contributions to understanding the mechanisms of disease, improving human health and transforming health outcomes are still relevant today.

It would be an interesting exercise to imagine if the GND were to be reconstituted, what diseases might be selected as being "neglected" in the same geographies. Would attention turn from the communicable diseases targeted by the GND that were a burden on the world's poor, to the noncommunicable diseases that now seem destined to become more commonplace? What can be said is that both Warren and Himsworth sought to expand scientific knowledge, by advocating a model whereby in the metaphorical sense, scientists burrow down into the surface of a problem from several starting points. Of course nothing in science is certain, but the GND started with a concrete problem and a practical aim. Ultimately, Warren and his network were outliers, hugely influential in modern biomedical science, and form an important episode in the emergent transformation of medicine into a truly global, collaborative practice.

ACKNOWLEDGMENTS

I would like to express my appreciation to all the individuals who gave me so much help, advice and encouragement, while researching and writing this article. They include David Bradley, Tony Cerami, Allen Cheever, Keith McAdam, Christopher Murray, Sir Gustav Nossal, Dame Bridget Ogilvie, Sir Richard Peto, Julia Walsh, Sir David Weatherall and Hans Wigzell.

DISCLOSURE

C Keating is curently working on a biographical project of Kenneth S Warren and the GND network.

REFERENCES

1. Himsworth H. (1970) *The Development and Organization of Scientific Knowledge*. London: Heinemann. 180 pp.
2. Walsh JA, Kenneth S. (1979) Warren selective primary health care: an interim strategy for disease control in developing countries. *N. Engl. J. Med.* 301:967–74.
3. Warren KS, Jimenez CC (Eds.) (1988) *The Great Neglected Diseases of Mankind Biomedical Research Network: 1978–1988*. New York: The Rockefeller Foundation. p. 1.
4. Warren KS, Jimenez CC (Eds.) (1988) *The Great Neglected Diseases of Mankind Biomedical Research Network: 1978–1988*. New York: The Rockefeller Foundation. p. 49
5. Warren KS, Jimenez CC (Eds.) (1988) *The Great Neglected Diseases of Mankind Biomedical Research Network: 1978–1988*. New York: The Rockefeller Foundation. p. 37.
6. Thomas L. (1974) Natural Science. In: *The Lives of a Cell; Notes of a Biology Watcher*. New York: Viking Press. pp. 100–103.
7. Chen LC. (2014) China Medical Board: a century of Rockefeller health philanthropy. *Lancet*. 384:717–9.
8. Halstead SB, Walsh JA, Warren KS (eds.). (1985) *Good Health at Low Cost: Proceedings of a Conference at the Bellagio Conference Centre, Italy, 29 April-3 May 1985*. New York: Rockefeller Foundation. 248 pp.
9. Walsh JA, Warren KS. (1979) Selective primary health care: an interim strategy for disease control in developing countries. *N. Engl. J. Med.* 301:967–74.
10. Awasthi S, *et al*. (2013) Population deworming every 6 months with albendazole in 1 million pre-school children in north India: DEVTA, a cluster-randomised trial. *Lancet*. 381:1478–86.