But is spending on individual subsidies and incentives the best use of typically limited government and international funding for public health? The biggest strides in the history of the reduction of child mortality in the United States came from infrastructural investments—in particular, investments in safe water (*23*). Malaria was eradicated from the southern United States and southern Europe, obviating the need to identify optimal pricing policies for individual malaria prevention and treatment products. Institutional pushes are needed for such infrastructural investments to take place in the two dozen countries that account for three-quarters of today's child mortality burden. Until these investments are made, micro-level subsidies and incentives appear necessary.

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PERSPECTIVE

Models of education in medicine, public health, and engineering

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Discussion on global health in both the academic and the public domain has focused largely on research, capacity building, and service delivery. Although these efforts along with financial commitments from public and private partners have contributed to a broader appreciation and understanding of global health challenges, the reflection of global health in academic training has largely been lacking. However, integrative models are beginning to appear.

The current approach to global health practice has largely been "on-the-job training" that does not provide a fundamental and sound theoretical basis for the challenges faced by global health practitioners. As a result, although practical experiences help, lack of sound foundations affects the ability to make a lasting impact. In general, there is a growing need to integrate the demands and the local perspective into mainstream education for diverse disciplines in both developing and developed countries (*1*).

Disciplinary education in three key areas of global health—namely, medicine, public health, and engineering—are also evolving to reflect the needs for training in an increasingly globalized world (*2*). We believe that our engineers, clinicians, and public health professionals will be better off in solving the great problems of our time by appreciating the challenges of both resource-rich and resource-constrained environments.

New models of medical education are focusing on integrating systems-level understanding of human physiology and also on integrating medical knowledge with that of nursing and public health. Public health education, on the other hand, which historically has been the domain of medical professionals or epidemiologists, is now increasingly accommodating students and scholars who come from a diversity of backgrounds, including anthropology, economics, sociology, and engineering. Similarly, engineering education is also incorporating more real-world challenges that not only focus on the core concepts but the applications of the concepts in complex environments. Using our personal experiences in developing and implementing new models of education, combined with the vision of innovation in disciplinary education from our respective institutions, our goal in this Perspective is to discuss how these emerging models of education may change the way we train global health practitioners and hence meet the technical capacity needs of the rapidly growing discipline.

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New educational models in medical education

Health and health care are about understanding the individual—their biology, their behaviors, and their predisposition to health or disease. Although enormous gains in health care can be attributed to the traditional model of medical education designed by Flexner over 100 years ago, the challenges of the 21st century will not be met if we do not rethink the way in which we train clinicians and expect them to practice.

It can be argued that globally, we are challenged by a similar set of problems seen through different lenses: Resource-poor countries are challenged to design systems that can provide access and quality, whereas resource-rich countries are challenged to design affordable systems that can sustain access and quality. What is the role of a medical student or a clinician in this environment? How can modern medical education train medical professionals to address these challenges comprehensively, while continuing to promote cutting-edge research, innovation, and quality care?

The opportunity to innovate and drive convergence to a common health and health care platform is the challenge for the 21st century. Achieving this requires educational programs that encourage a new type of medical graduate: one who understands systems beyond the individual organ; understands disease and cure in context; and has developed the knowledge, skills, and tools to innovate, seeing the global context as a resource for understanding and ideas rather than as simply "developing countries in need."

The need for rethinking medical education globally has been echoed in several high-level reports, including the 2010 Lancet Commission on Health Professional Training for the 21st Century (*3*). The 2010 report argues for a transformational change in health-professional education that focuses on a global-perspective, systems-thinking, transprofessional education that is competence-based, and close alignment of the

education system with the health care delivery system. This requires a fundamental shift in the way we structure the education of health professionals across disciplines and specialties. An interdisciplinary approach that incorporates key concepts of population health, provides a perspective of multiple specialties, and provides room for technological innovation and field-based experiences is a departure from the existing models of medical education that are tightly packed and leave little flexibility for experiences outside the confines of highly structured curricula.

Existing institutions often create barriers to transformational thinking, and the required shifts can be difficult if not impossible to achieve. Schools of medicine, nursing, and public health are often physically, theoretically, and operationally distant; students and faculty have reduced opportunity to interact and to share common problems from differing perspectives. Team-based training within a global perspective is often absent or limited, and the power and importance of this training is underrecognized.

The Aga Khan University and the University of Toronto are testing new models for courses that bring together students from various disciplines across geographic boundaries using blended learning strategies. The goal is to create a new capacity of scholars who are on one hand rigorously trained, and on the other aware of the tools of other disciplines, so that they are able to provide the right care at the right time.

The current trial links 4th-year undergraduate science and arts students at the University of Toronto with advanced nursing and medical students in Tanzania and Uganda and education students in Pakistan in a common course that relies on case-based problems built around a shared resource (Science of Early Child Development, www.scienceofecd.com). Such "global" models of courses focus around areas of common importance, such as child development, pediatric disorders, and health systems design.

Nearly all specialties are engaged, in some form, in dealing with global health issues. Yet, this engagement often seems disconnected from learning opportunities for residents or fellows. Elective opportunities do exist within many programs, but these tend to be based on individual needs or desires, are typically underresourced, and do not focus on core global-health learning objectives. There is great potential to be gained by more formalized course content during residency and linkage, where possible, to bilateral exchange. These exchange opportunities are often highly valued by residents but are frequently more ad hoc in their organization and experience. Although "clinical medicine" is often the focus of this exchange, there are equally important learning opportunities related to the health systems within which clinical medicine is delivered.

Resource-poor countries that are beginning to invest more heavily in medical education have the opportunity to "skip" the past century's models and to explore innovative and potentially transformational models that can be built from scratch and have impact within their country but also add new knowledge to the global challenge (*4*). Greater community-based emphasis that better aligns training to needs, the building of educational and health systems that integrate public and population health and health care, and education and models for training that use and leverage the existing public health system are all areas of important potential innovation. Use of mobile technologies has allowed materials to be archived in an affordable way, increased access to new information, and provided students with an opportunity to understand current mobile and e-health paradigms and challenges. If properly designed, implemented, and evaluated, these models can and will affect thinking globally.

The Aga Khan Development Network (AKDN; www.akdn.org) is working to achieve such an integrated model of medical education in East Africa. As a private not-for-profit development organization, the AKDN is building an integrated health system in East Africa and linking this to a Faculty of Health Sciences that is committed to a transformational education model. A unified Faculty of Health Sciences across disciplines will focus on competence-based and transprofessional training. In the first 2 years, medicine (6-year program) and nursing (4-year program) students will start with a general arts and sciences core curriculum focused on establishing a common language of understanding and critical thinking. Subsequent professional training years build on principles of population health, human development, ethics, professional practice, and health systems function. From the first year, students will have interdisciplinary learning opportunities within community settings that will integrate these concepts through direct care, program development, and research projects. Building international relationships that promote global learning will be an important strategy within the curriculum.

"The opportunity to innovate and drive convergence to a common health and health care platform is the challenge for the 21st century."

Models in global public health education

Global public health is a relatively new discipline, dealing with entire populations and aiming to promote health and interventions that could improve the quality of life of society as a whole. Historically, global public health professionals were largely trained as clinicians with expertise in infectious diseases. In addition, in many countries health professionals are trained within a disease and curative approach, which leads to poor adaptation in the face of new and complex challenges that may be rooted in a complex web of medical, socioeconomic, religious, and cultural issues. This has been true in such diverse global problems as AIDS and obesity. The recognition of the existence of social determinants of health are often beyond the scope of current training provided to clinicians. Public health training for clinicians also comes at a cost, both to the trainee and the system. The current models of training adds additional years, which takes the clinicians away from their ability to practice. However, emergence of new challenges has provided us with the realization of our collective interdependence and the need for multidisciplinary approaches.

The emergence and intensity of global health concerns have increased at a rapid pace. In this new context, it is necessary that professionals be capable and trained to work in evidence-based policy development and ready to take prevention actions and interventions adapted to the concrete local realities. We envision future global public health professionals as agents of change, capable of understanding social, geographic, economic, and cultural determinants of health with a vision not of individuals but of populations.

The Universidad Peruana Cayetano Heredia is the first in the Latin American region to acknowledge the gap in training and has created a new 5-year, integrated bachelor degree in Public Health and Global Health (Fig. 1). The development of this program has been guided by the recommendations of the Lancet Commission on Health Professional Training for the 21st Century (*3*) but has been adapted to local realities and public health challenges specific to the region. The integrated curriculum includes (i) a competence-based curriculum; (ii) three integrated levels of learning: informational (acquiring knowledge and skills), formative (promotion of values and professional ethics), and transformative (development of leadership skills); (iii) local realities as well as global knowledge components, including new research developments in medicine and public health; (iv) technologies to enhance learning; and (v) an evaluation component, so that the program can be assessed and learning outcomes can be shared with other regional and global partners. The learning outcomes are a list of metrics to evaluate short-, mid-, and long-term outcomes of the training (such as scholarly activity, academic performance, jobs, entrepreneurship, and impact on policy) via quantitative and qualitative assessment tools.

Research is a core foundation of the program, with experiential rotations in the public and private sectors within and outside the country. These rotations include internships in local municipality, local hospitals, regional health policy think tanks and directorates, international agencies such

as the United Nations Children's Fund (UNICEF) and World Health Organization (WHO), as well as private health insurance companies. Through a thesis and additional 9 months of training, students are also able to achieve a master's degree in Public Health and Global Health.

New models in engineering education

Historically, engineering education—particularly, biomedical engineering education in the United States and the developed world—has focused on integrating the medical challenges of the developed world in the curriculum. Over the past two decades, this has been a highly successful model, with the creation of new technologies, new private ventures, and overall improvement in the functioning of medical facilities. However, with the exception of just a handful of select curricula (for example, the Beyond Traditional Borders program at Rice University, http://rice360.rice.edu/btb) (*5*), the biomedical engineering curriculum nationally and internationally reflects a focus on core engineering principles and their applications in societies that are not resource-constrained. Students graduating from these programs are therefore not only unequipped to fully comprehend challenges in the developing world, they are also not cognizant of ethical and policy challenges of the resource-constrained environments.

The ability of the engineering curriculum to adapt will have major implications for the intellectual capacity of engineering graduates. First, it will allow students, regardless of their future pursuits, to develop an appreciation for new paradigms of design and implementation in environments beyond the developed world. Second, these models of curriculum will have a better chance of scaling and reflection in engineering institutions of the developing world, which currently suffer from curricula that do not address their local challenges. Third, the curricula will also enable more engineers to engage with their public health colleagues, just as in the past two decades engineers have worked closely with clinicians. This would create a new class of entrepreneurs who will be able to develop solutions optimized for large populations in the developing countries with growing economies. Additionally, more engineers and quantitative scientists will enter the domain of global health and allow for a richer understanding of our current global challenges.

Success of any rigorous program, in the short and the long term, will need three key ingredients: (i) early exposure to complex challenges; (ii) incorporation throughout the curriculum of hands-on design for resource-limited situations; and (iii) application of the knowledge and tools from traditional courses to specific, real-world problems. For example, a course in which biomechanics is traditionally studied through understanding stresses on beams and rods can instead use the same principles applied to the design of a crutch for a disabled youth in Zambia, using the resources available in country. Current engineering programs that focus on global health typically incorporate one of the three ingredients but do not focus on all or are unable to integrate them over the entire duration of the program. A more integrated curriculum that introduces and reinforces the key concepts at multiple points and then enables students to apply their core knowledge to address real-world challenges through traditional approaches of problem sets, projects, and papers can have a substantial impact in developing knowledge and making discoveries to solve high-impact global health problems.

These new models of education in engineering, public health, and medicine are not without their critics. Two major criticisms are often brought to the debate. First, it is argued that focusing on interdisciplinary topics leads to better breadth but poor fundamental depth. This criticism is inherent in most interdisciplinary studies, and some of it is fair. However, the rigor of any curriculum should not depend on the examples or the sociocultural context that are used to illustrate the fundamentals. The quality of instruction, the depth of the material, and the appreciation of real-world applications all need to be integrated into the curriculum. The second criticism reflects reluctance based on possible career paths and opportunities. However, our argument is not about exclusivity but instead about inclusion of newer problems and realistic scenarios. In many ways, the career paths for those who are keenly aware of socioeconomic realities of the world are brighter than those who are trained in silos.

In the end, we as practitioners of global health in our respective domains believe that new models of education are needed to recognize the evolution of both the society and its medical challenges. As with any academic discipline that is growing in popularity and intellectual depth and breadth, interdisciplinarity and social realities need to be incorporated in the global health curricula in order to maintain relevance and the ability of the graduates to perform the tasks they are trained for in dynamic and complex environments.

Fig. 1. Practical experiences. Fieldwork conducted by public health students from Universidad Peruana Cayetano Heredia at a slum in Lima, Peru, for their course "Basic Concepts in Global Health." The students are from multiple disciplines, including public health, veterinary medicine, sciences, and psychology. [Credit: Patricia Garcia]

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