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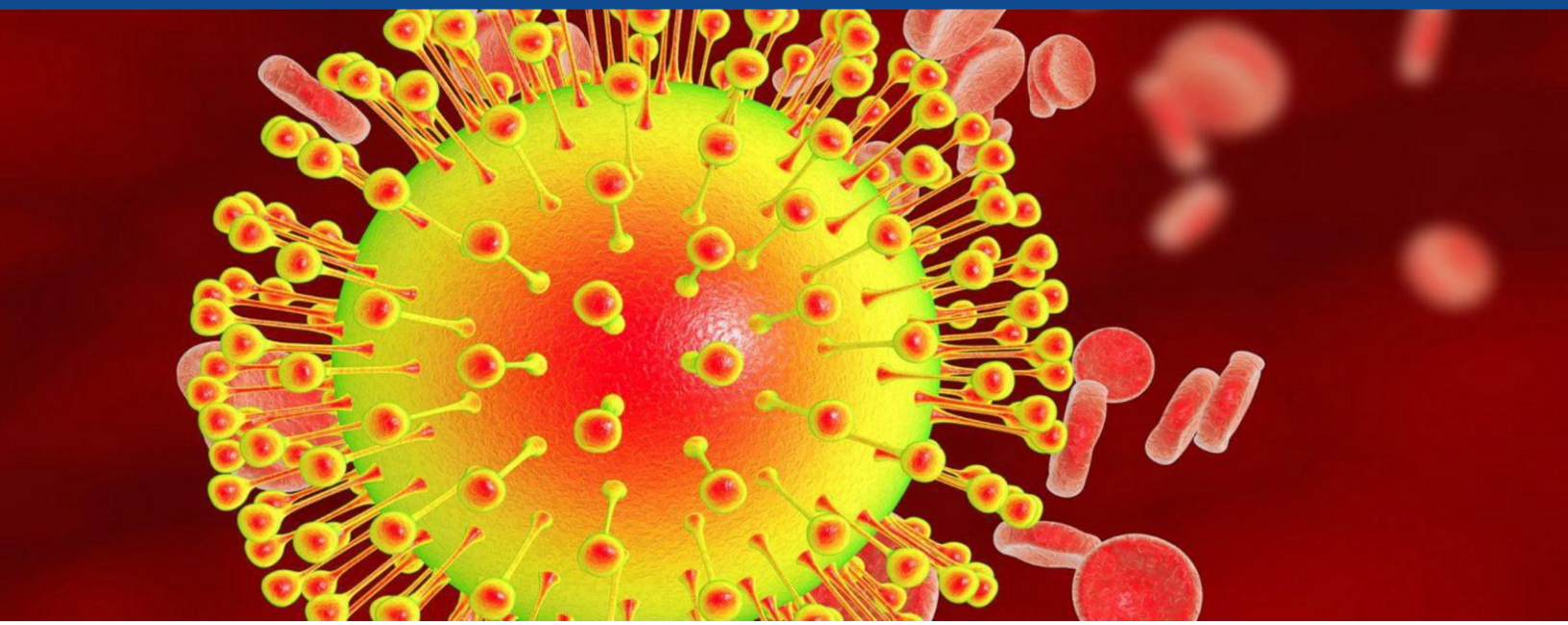
'Science Tikkun':

Repairing the World through the Science of Neglected Diseases, Science Diplomacy, and Public Engagement



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Executive Summary

A review of progress on the recently completed Millennium Development Goals reveals recent successes in reducing the global prevalence of important neglected diseases – AIDS, tuberculosis, malaria, and some neglected tropical diseases (NTDs), including lymphatic filariasis, river blindness, and trachoma - mostly through mass treatment of existing or repurposed medicines. However, wrenching forces linked to a new human-induced geological epoch known as the Anthropocene, including climate change, urbanization and deforestation, human migrations and conflict, are currently promoting the widespread emergence of vector borne NTDs transmitted by insects or snails, as well as Ebola virus infection. The major vector-borne diseases on the sharp increase include dengue, chikungunya, Zika virus infection, leishmaniasis, schistosomiasis, and others. There is also a range of zoonotic respiratory virus infections.

We urgently need new drugs, diagnostics, and vaccines for these new Anthropocene-driven diseases. Our recent finding that these infections now mostly strike people who live in poverty in large and wealthier G20 economies – a concept known as 'blue marble health' – indicates that the problem is not necessarily the lack of financial resources, but instead the inability to mobilize those resources appropriately. Under the auspices of a new *Science Tikkun* framework there is opportunity to create a new movement linking research and development (R&D) with public engagement in order to advocate for this essential support and create new products in a modern geopolitical context. These are necessary steps for eradicating the world's poverty-related neglected diseases.

We define *Science Tikkun* broadly as an added role for leading US scientists to elevate the profile of their knowledge and findings, and educate leaders in the areas of government, business, religion, the military, the media and other sectors in order to improve the human condition. Through a process of science diplomacy Science Tikkun also seeks to promote international cooperation and scientific collaboration to improve the human condition. The term derives from the ancient Jewish concept of *tikkun olam* (repairing the world) that gained momentum in the 16th century contemporaneously with Galileo, William Gilbert, and the origins of modern scientific approaches.

There are key historical global health precedents for scientists to directly take on not only the science, but the necessary public advocacy and policy activities. Both the smallpox and polio vaccines were refined or developed and then tested for efficacy through the stalwart actions of Drs. D.A. Henderson and Albert Sabin, respectively. Both scientists led global advocacy efforts for these interventions and then shaped public policies to have these vaccines adopted. Similarly the concept of integrating mass treatment of NTDs through a package of interventions was pioneered by scientists, including this author, who worked with policymakers in the US and UK Governments to ensure mechanisms for appropriating funds,

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delivering the essential medicines, and integrating the package within health systems.

To launch a Science Tikkun movement new programs of public science engagement and diplomacy should be established, beginning with an expanded US Science Envoy program and possibly an office of science diplomacy shared between the US State Department and White House Office of Science and Technology Policy. Also proposed is the establishment of a unique Albert B. Sabin Fellows program for training a new generation of US science ambassadors.

Introducing the Anthropocene and the Rise of Poverty-Related Neglected Tropical Diseases

It has been almost two decades since the United Nations (UN) Millennium Development Goals (MDGs) were launched, and with it a new global awakening about poverty and disease. Under the auspices of the MDGs there has been tremendous progress in implementing existing technologies for mass treatment of neglected diseases such as HIV/AIDS, malaria, and the neglected tropical diseases (NTDs) (BOX 1) [1, 2].

BOX 1: THE NEGLECTED DISEASES. The major 'neglected diseases' affecting people living in poverty include HIV/AIDS, tuberculosis, and malaria, as well as a special category of afflictions known as neglected tropical diseases (NTDs). The NTDs include some emerging virus threats such as dengue, Ebola, and Zika virus infections and chronic parasitic infections such as Chagas disease, hookworm disease, leishmaniasis, and schistosomiasis. Almost everyone living in extreme poverty is affected by one or more of these diseases [5].

As a result there have been dramatic reductions in the global prevalence of AIDS, tuberculosis, and malaria, and some NTDs such as lymphatic filariasis, trachoma, onchcocerciasis, and ascariasis [3-5]. Most of these successes stem from mass treatment approaches that use existing drugs made available for free or produced or sold at low cost [3-5].

At the same time, the pace of building new innovations - new drugs, diagnostics, and vaccines – for the poverty-related diseases has not kept up with the successes of implementing mass treatment of existing medicines. Thus despite decades of progress in reducing the impact of AIDS, tuberculosis, and malaria, as well as a few of the NTDs, many of the most important NTDs and related neglected diseases of poverty continue to worsen in terms of numbers of people who are infected or at risk of acquiring these infections. According to the recent Global Burden of Disease Study (GBD) 2013 (published in 2015), the diseases on the dramatic rise include some of the most important NTDs including Ebola, Chikungunya, and Zika virus infections, as well as Chagas disease, dengue, foodborne trematodiases, leishmaniasis, and schistosomiasis [3]. All of these diseases are considered 'neglected' because they disproportionately affect people living in extreme poverty. Together, these diseases, most of which are transmitted by insects or snails and known as "vector-borne diseases," affect more than one billion people living in poverty, a population that includes most of the world's poor (BOX 2 and Table 1). There is no expectation these diseases will diminish in prevalence or incidence anytime soon without new technologies.

BOX 2: NEGLECTED AND POVERTY-RELATED DISEASES ON THE RISE

- INSECT-TRANSMITTED VIRUS INFECTIONS
  - Chikungunya, Dengue, Zika
- INSECT- OR SNAIL-TRANSMITTED PARASITIC INFECTIONS
  - Chagas Disease, Food-borne trematodiases, Leishmaniasis, Schistosomiasis
- OTHER (ZOONOTIC) NEGLECTED DISEASES
  - Ebola, SARS and MERS Coronavirus infections

Table 1. Emerging Neglected Diseases on the Rise (modified from Ref 3)

Disease	Type of Disease	Increase between 1990 & 2013
Dengue	Insect-transmitted virus infection	+610.9%
Chikungunya and Zika	Insect-transmitted virus infection	+>1,000.0%
Chagas disease	Insect-transmitted parasitic infection	+22.4%
Cutaneous Leishmaniasis	Insect-transmitted parasitic infection	+174.2%
Food-borne trematodiases	Snail-transmitted parasitic infection	+51.1%
Schistosomiasis	Snail-transmitted parasitic infection	+30.9%
Ebola	Person-to-person virus infection originally from bats	+>1,000.0%
MERS and SARS Coronavirus infections	Person-to-person virus infection originally from bats	+>1,000.0%

Indeed, instead of diminishing in prevalence or incidence there is a great concern that these tropical diseases can be expected to worsen and increase because of human-influenced activities such as climate change, urbanization, deforestation, conflict, human migrations, and even nuclear proliferation [6]. Such external forces have been bundled in a framework, which is sometimes known as the "Anthropocene".

Good examples include the dramatic appearance and rise of dengue, leishmaniasis, and schistosomiasis in the Middle East, North Africa, and Southern Europe just in the last few years [7], in addition to the emergence of Ebola in West Africa, and chikungunya and Zika virus infections in the Western Hemisphere [6].

Partly in recognition of the role of such forces affecting international development the UN in 2016 put forward a new set of Sustainable Development Goals (SDGs) that replaces the MDGs that ended in 2015. Unlike their predecessor the SDGs heavily emphasize international development in the context of the environment, human movements, conflict, and climate change.

Where are the drugs, diagnostics, and vaccines?

For the NTDs highlighted in Box 2 and Table 1 that continue to rise as a result of Anthropocene-driven forces there is a stunning dearth of new drugs, diagnostics, vaccines, and vector-control technologies needed to control or eliminate these diseases [1, 8]. For instance, we did not have vaccines to prevent Ebola or Zika virus infections in time to prevent their devastating effects in West Africa or Brazil, respectively. Nor do we have vaccines for any of the diseases highlighted in Table 1 [8, 9, 10], with the one exception of dengue. The specific needs for NTD and related neglected disease interventions were reviewed recently [1]. A major finding was that despite the fact that they now represent some of the world's most common poverty-related diseases and ones that potentially

threaten global security, there is so far minimal activity in terms of new product development. The Box 2 NTDs are mostly ignored by the major multinational pharmaceutical companies [8-10]. Such products are sometimes known as 'antipoverty' drugs, diagnostics, and vaccines for their ability to not only improve public health but also to reduce the poverty-promoting effects of NTDs [9-11].

Framing the Issue

Scientists are still in their nascent stages of translating discoveries to address the major poverty-related NTDs. This situation is especially tragic given that most of the world's neglected diseases now mostly strike the poor who live amid wealth. This author's newest analysis indicates that today most of the world's neglected diseases are actually striking the hidden poor living in the group of 20 (G20) nations, together with Nigeria [5]. The concept is referred to as "blue marble health" and reflects a changing dynamic in which the older notions of global health, namely developing versus developed countries, are giving way to a general increase in the global economy, which leaves behind people who live in poverty and suffer from diseases of the poor [5].

Together the G20 and Nigeria blue marble health countries account for enormous economic power with more than $60 trillion in their combined gross domestic products (GDPs). Therefore, the financial resources and instruments to invent new technologies for poverty-related diseases likely already exist [5].

The fact that no new drugs, diagnostics, or vaccine are available to address diseases of poverty that now mostly occur in G20 nations with the financial sources to build such interventions suggests that today we are missing a generation of scientists who can effectively engage the public and global leaders.

To close these gaps and to address the UN SDGs we need a new type of science ambassador trained to work at the laboratory bench and simultaneously engage the public and global leaders in meaningful discourse. Together these public scientists could create a new initiative or movement to repair the world through science and science diplomacy (BOX 3).

BOX 3: FRAMING THE ISSUE. There is urgency to create a new movement linking research and development (R&D) with public engagement to eradicate the world's poverty-related neglected diseases in a modern geopolitical context.

A recent analysis by the heads of leading non-profit product development partnerships (PDPs) together with the World Health Organization (WHO) and two scientists from disease-endemic countries confirms the urgency to develop some key technologies for the NTDs and other poverty-related diseases [1, 12]. They include new small-molecule drugs, next-generation vaccines, point-of-care diagnostics, and transgenic and paratransgenic strategies for vector control [1]. Such products are essential for global elimination efforts. Beyond the actual technologies, Yamey and Morel also highlight the accompanying need for innovations in product delivery, procedure, health policy, and strategies [12]. Simultaneously, this author's observation that most of the NTDs and poverty-related diseases are today found in wealthier G20 nations further indicates that our inability to have these technologies and strategies in-hand reflects at least as much an absence of political will as it does absent financial resources and instruments [5]. We need to close this gap by better engaging decision-makers and the public.

Based on previous successes linking scientists in the NTD community with government and political leaders of the group of eight (G8 countries) to deliver packages of essential medicines for preventive chemotherapy that have now reached at least than 450 million people [1, 13] has been a useful model; similar efforts could be undertaken for "version 2.0," namely the development of new technologies to complete global elimination efforts [14]. An important first step is to shape mechanisms for having direct engagement between scientists and global leaders from the sectors of government, politics, religion, military, the media, and the public in order to highlight the urgencies for these technologies to improve public health, while also promoting economic development and global security. However, most scientists do not have the skills or tools to assume and maintain this public role. A new generation of science ambassadors is required who are versed in the modern trends of neglected and emerging diseases in the context of rapidly-changing geopolitics.

"Science Tikkun": Inspired by *Tikkun Olam*

As a rallying cry to stimulate biomedical scientists towards greater engagement in international development and blue marble health, Science Tikkun may help to seek an inspirational tone. In multiple articles I have identified provocative links between the world's great religions and their NTDs – for example most of the world's Chagas disease is found in Christian-majority countries, whereas leishmaniasis and schistosomiasis are mostly in Islamic nations, and lymphatic filariasis disproportionately affects the Hindu nations of South Asia [15]. This intersection of disease and religion will be discussed below in the context of engaging religious leaders by scientists. While each of the world's great religions may provide a potential framework for addressing public engagement in science, for me one of the more inspirational ones is the concept of *Tikkun Olam*, "to repair the world" [13]. Some scholars believe the most powerful expression of *Tikkun Olam* comes from the 16h century Jewish mystic Isaac ben Solomon Luria Ashkenazi (Isaac Luria) who was born in 1534 in Jerusalem, but spent most of his life in Ottoman-occupied areas of the Middle East, especially in the Galilee of present day Israel or in Syria (FIG 1) [16].

Luria was a devotee of Jewish mysticism and the Kabbalah, which had its origins in a 13th Century text from Spain known as the Zohar [16]. According to Luria and his version of the Kabbalah (Lurianic Kabbalah), during the creation of the universe, after God created light, either Adam or a primordial human somehow fumbled and failed to capture it, thereby scattering sparks that required reuniting [16]. *Tikkun olam* says the world and cosmos can be repaired and redeemed only when such divine sparks are again joined through kindness, good works, and great accomplishments [16].

Fig. 1. LEFT: Grave of Isaac Luria (1534-1572) in Safed, Israel. Photo by Jonathan Stein, Public Domain. RIGHT: William Gilbert (1544-1603), physician, astronomer, Public Domain [38, 39].

Could repair and redemption manifest through science? Advancing science and mathematics represents one of the highest intellectual achievements of humankind – or as Harvard professor Atul Gawande points out about the

scientific community, "arguably the most powerful collective enterprise in human history" [17]. According to the science historian John Gribbin, the first individuals who fully employed the scientific method, William Gilbert and Galileo Galilei, were (ironically) born just 10 and 20 years after Luria in 1544 and 1564, respectively [18]. Gilbert was both a physician and scientist. Invoking science for bettering the human condition and to pursue humanitarian goals might hold a special place in the Lurianic Kabbalah. However, doing so would require scientists to go beyond the comfort zone of grants and articles in scientific journals through engaging global and political leaders as highlighted above. Here I outline the concepts of 'Science Tikkun' as a framework to repair the world through science, science diplomacy, and public engagement (BOX 4).

BOX 4. SCIENCE TIKKUN. Science Tikkun is broadly defined as an added role for leading US scientists to engage the public in order to elevate the profile of their knowledge and findings, and educate leaders in the areas of government, business, religion, the military, the media and other sectors. Through a process of science diplomacy Science Tikkun also seeks to promote international cooperation and scientific collaboration to improve the human condition. Science Tikkun is also more narrowly defined as working in the area of NTDs and neglected diseases in order for these sectors to commit resources for R&D, and promote international cooperation for developing new tools.

The focus is on biomedical science but it could be extended to the physical sciences. Ultimately, Science Tikkun heralds a potential movement to link R&D with the worlds of diplomacy and foreign affairs, as well as public engagement.

Breaking down the problem

Embarking on a Science Tikkun initiative linking biomedical science for neglected diseases with public engagement, science diplomacy, and advocacy first requires an appreciation of the new forces currently promoting the rise or emergence of NTDs and other neglected diseases in this new era of the SDGs. They include both external factors linked to the Anthropocene and the specific human vulnerabilities associated with poverty and social and geographic restrictions. Indeed most of the diseases listed in Table 1 may have emerged or re-emerged in part from some combination of these two major drivers.

The Anthropocene as a major driver. The Anthropocene has been identified as the first geological epoch arising from human influences-- agriculture, conflict, environmental contamination and nuclear proliferation, climate change, urbanization, deforestation, dams, and human migrations (FIG. 2) [6, 19]. This author has reviewed the evidence linking the rise of Anthropocene forces to the emergence of Ebola in West Africa or Zika in the South Pacific and Western Hemisphere, as well as other NTDs, especially vector-borne disease [6].

Fig 2. The major forces arising out of the Anthropocene now promoting the emergence of catastrophic neglected tropical diseases (NTDs). Reproduced from Ref. 6 http://dx.doi.org/10.1371/journal.pntd.0004648.g002

Poverty and other human vulnerabilities. The other major driver of NTDs is poverty, especially extreme poverty. NTDs first and foremost occur among people living in poverty and there is evidence that NTDs cause poverty by adversely affecting the intellectual and cognitive development of children, the ability of people to work in agriculture and other pursuits, and by interfering with positive pregnancy outcomes [13, 20]. As indicated above, new evidence indicates that extreme poverty and NTDs are not restricted to the poorest low-income countries. Instead a new 21st century paradigm, which this author has termed 'blue marble health" to distinguish it from conventional norms of global health, is the finding that most of the world's NTDs and neglected diseases are currently found in wealthy countries, and it is mostly the poor who live amid wealth who suffer [5]. This finding is especially relevant to the G20 nations, which together with Nigeria accounting for most of these diseases. The framework of blue marble health is especially relevant to the concepts of Science Tikkun because it finds that support for poverty-related neglected diseases including R&D is no longer a resource issue. The funds for the G20 nations to assert priorities for NTD R&D exist but the political will to mobilize such funds is sadly missing.

Outside of poverty and blue marble health there are other key human vulnerabilities to consider [21]. As Mechanic and Tanner point out [21], vulnerabilities also include social isolation found among the aged and the mentally disabled; and geographic isolation among the incarcerated, aboriginal societies, and other groups. The socially and geographically isolated are also often impoverished and are frequently also susceptible to NTDs and other neglected diseases. Indeed a recent analysis finds that aboriginal populations exhibit some of the world's most consistently high rates of NTDs [22]. Together the poor and the socially and geographically isolated represent the voiceless populations most susceptible to neglected diseases and NTDs. They are truly forgotten people with forgotten diseases [13].

Approaching the Problem

For my medical and graduate training in 1980 I entered into a combined MD and PhD program offered jointly by Weil Cornell Medical College and Rockefeller University [23]. The universities are adjacent to each other in a medical complex located in the East Side of Manhattan. Prior to becoming a university in 1955 Rockefeller was known as the Rockefeller Institute of Medical Research. I was attracted to that particular program both because of its scientific excellence and motto, *Scientia pro bono humani generis* – science for the benefit of

humanity. Indeed during the 1980s Rockefeller University made a strategic decision to specifically address global health problems, especially tropical infectious diseases [23]. I previously highlighted a life-changing decision I made while in the Rockefeller University library reading a paper by a former Rockefeller Institute parasitologist who branded hookworm infection as the "great disease of mankind" due to its huge global public health and economic impact [23]. I was amazed upon conducting a search of the biomedical literature that almost none of the new discoveries and advances in molecular biology were being applied to the study of hookworm, so that I made this disease the start of my life's calling advocating for the poor and conducting R&D in what became known as the NTDs.

Today, NTDs such as hookworm remain tragically underfunded in terms of R&D for new drugs, diagnostics, and vaccines. During the 1990s the Geneva-based Global Forum on Health Research helped coin the term '10/90 gap' to refer to findings that less than 10% of global financial resources go to supporting the diseases that disproportionately affect people living in extreme poverty in resource poor countries [5, 23]. In some cases the poor account for up to 90% of the global burden of certain diseases. In contrast, non-communicable diseases – cancer, diabetes, heart and lung disease - in North America and Europe receive the vast majority of R&D support, through the activities of multinational pharmaceutical companies, biotech's, and high powered academic biomedical research universities and institutes. Some twenty years later major R&D shortfalls remain and the concept of the 10/90 gap in terms of supporting NTD and related neglected disease research remains valid [5]. For some diseases such as hookworm, schistosomiasis, and other helminth infections, and diarrheal disease pathogens the 10/90 gap may even approach a 1/99 gap or worse.

A major finding from the blue marble health framework is that huge R&D gaps for neglected diseases need to be reconsidered in light of findings that most of the world's NTDs and related neglected infections of poverty are now found in the G20 nations. Blue marble health strongly points to the observation that a fundamental reason why gaps in R&D funding for these neglected diseases remain is not necessarily a lack of resources [5]. Ultimately, the G20 nations, which account for 86 percent of the global economy, have the ability to invest in R&D for the world's neglected diseases now mostly found in their own nations.

Given that the resources to close the 10/90 gap are already present in the G20 nations, the gap may be explained on the basis that major political leaders of these countries are largely unaware of the benefits of research, and the impact that new drugs, diagnostics, and vaccines might have on improving global public health but also improving the economic development of the G20 nations. Because the NTDs and neglected diseases represent major reasons why the poorest people remain trapped in poverty, it is possible that new interventions are unto themselves potent antipoverty measures [9-11].

Unfortunately the absence of R&D investments in neglected diseases may reflect the absence of awareness by political leaders, in turn a result of the scientific community being unable or unwilling to engage in public discussions about the benefits of innovation. This gap could be addressed through Science Tikkun.

Identifying and engaging stakeholders

Science Tikkun to address R&D investments for neglected diseases will require engaging key stakeholders from numerous sectors including the military, business community, religious leaders, university administrators, and ultimately the leaders of the G20 nations.

Military. To no one's surprise the G20 nations vastly outspend on defense compared to neglected diseases R&D, but the numbers remain striking. According to the Stockholm International Peace Research Institute (SIPRI) in terms of their annual analysis of military spending, 13 of the leading G20 nations have approximately $1.3 trillion in military expenditures in 2015 [24], approximately 600 times the estimated $2.165 billion spent on neglected disease R&D by the G20 [5]. Of particular concern are the large military expenditures by the highly disease-endemic BRICS countries including China ($215 billion), India ($51.3 billion), and Brazil ($24.6 billion) [24], which easily dwarf neglected disease R&D spending by several thousand to one [5]. In addition, SIPRI estimates that in 2015 the Latin American and Caribbean nations spent $67 billion, Africa $37 billion, and Asia and Oceania $436 billion on military expenditures [24], vastly more than any spending on neglected disease R&D. Further analysis indicates that expenditures on nuclear weapons technologies in some nations represent a 10,000 to one gap relative to neglected disease [25]. There is a clear need to reduce such vast gaps between military-related science-funding versus neglected disease R&D.

Religion. A second sector that requires engagement is national and international religious leaders. Recent findings include the observation that most of the Christian-majority nations currently occur in the "Global South" and that over the last one hundred years the world's Christian populations are found increasingly in Latin American and Sub-Saharan African (e.g., Angola, Democratic Republic of Congo, Ethiopia, and South Sudan) countries, while at least two Asian nations – Papua New Guinea and Philippines – represent Christian majority nations [26]. Today Christian-majority countries account for a high percentage of the world's worm (helminth) infections and almost all of the Chagas disease and human African trypanosomiasis [26]. Similarly, the world's Muslim countries in Africa and Asia (including Bangladesh and Indonesia) comprising the Organization of Islamic Cooperation (OIC) also account for much of the world's helminthic disease burden including approximately one-half of the schistosomiasis cases, in addition to more than two-thirds of the global cases of cutaneous leishmaniasis [27]. Altogether, Christian-majority countries, OIC countries, and the Hindu-majority nations of India, Nepal, and Mauritius account for up to 90 percent of the world's helminth infections and possibly other NTDs [15]. Therefore, Science Tikkun activities should promote strong ties between the neglected disease scientists and religious leaders from Christianity, Islam, and Hinduism.

G20 leaders. Given the major tenets of blue marble health that most of the world's NTDs and related neglected infections of poverty are found in G20 nations (together with Nigeria) [13, 14, 28, 29] and that together these nations spend only 0.003% of the their gross domestic product on NTD R&D [5], there is room to greatly expand the commitments of these nations. Of particular concern are the highest disease-endemic G20 countries now spending less than 0.001% of their GDPs [5]. There is a tremendous need to educate G20 government leaders and parliamentarians about the opportunity to develop and test new

technologies for neglected diseases, as well as to expand current programs for disease control. As highlighted above, the G20 nations and Nigeria account for most of the global economy, and yet most of the world's neglected diseases occur in these very nations [5]. There is a vast global "disconnect" between economic strength and simultaneously, poverty-related diseases.

Other sectors. Additional sectors that will need to be tapped for effective public engagement must include the print and electronic media that reaches hundreds of millions of people on a daily basis [30]. According to the Financial Times of London, the economic consulting firm EPG determined that US and UK Fortune Global 500 companies spend approximately $15 billion annually on corporate social responsibility (CSR) activities [31]. The percentage of CSR spent on R&D is not known but given the long time horizons of this endeavor it is doubtful that it currently exceeds anything beyond a few percent. Finally, while much of the essential R&D for NTDs is conducted by leading research universities, very little of total university research expenditures is devoted specifically towards these diseases. A university score card of neglected disease R&D by the organization Universities Allied for Essential Medicines (UAEM) indicates with a few exceptions most research universities can be considered underachievers in conducting global health research on neglected diseases [32].

A new cadre of science ambassadors

We are missing a generation of new technologies that are now urgently required for the world's vector-borne neglected diseases emerging in this new era of the Anthropocene and blue marble health. Together the G20 nations constitute 86 percent of the global economy with a total GDP of $67 trillion [5]. Yet on average only about 0.003 percent of that economic horsepower is currently spent on neglected disease R&D [5]. For comparison it is estimated that 2.3 percent of the total GDP of the top 15 G20 countries is spent on military expenditures [24], a figure representing a several hundred-fold difference in support between the two activities. Beyond the government and military expenditures, there is an additional gap for supporting neglected disease activities by global religious leaders despite the observation that these diseases are decimating the adherents of the world's three largest religions – Christianity, Islam, and Hinduism. Similarly minimal attention to neglected diseases is provided through major media outlets, CSR, and even some of our most important and prestigious research universities.

In essence all of our major government, political, military, religious, media, corporate, financial, and educational institutions have largely turned their back on NTDs and related neglected diseases. We therefore require a new approach to advocate for these diseases, especially when the global funds are present in both public and private sectors.

Here I suggest that through Science Tikkun the scientists themselves take on this public advocacy and policy activity.

There several important historical global health precedents for scientists to directly take on not only the science, but the necessary public advocacy and policy activities. For instance, both the smallpox and polio vaccines were refined or developed and then tested for efficacy through the stalwart actions of Drs. D.A. Henderson and Albert B. Sabin, respectively. Both scientists led global advocacy efforts for these interventions and then shaped public policies to have these vaccines adopted [33]. Indeed it has been noted that we owe each of our major vaccines and their widespread use to

specific champions who were often the inventors themselves. Similarly the concept of integrating mass treatment of NTDs through a package of interventions was pioneered by a group of committed scientists, including this author, who then worked closely with policymakers in the US and UK Governments to ensure an appropriate mechanism for appropriating funds and delivering the essential medicines, while integrating the package within health systems [34-36].

Such scientists could be considered also as 'science ambassadors' with a deep understanding of both the science and the geopolitical landscape in order to serve as effective advocates and influencers of public policy. Critical to the skill set of becoming a science ambassador committed to the concept of Science Tikkun is an in-depth understanding of the geopolitical landscape of disease and disease politics. Central to this task is an understanding of the major social sciences – geography, economics, sociology, anthropology, and political science; religion and the humanities; and current events. Given that disease is being shaped by Anthropocene forces there would need to be an appreciation of the forces that promote climate change, urbanization, deforestation, human migrations, and conflict. The concepts of blue marble health and learning the basis of economic and health disparities among the poor living in each of the G20 countries would be critical. Finally, a science ambassador committed to Science Tikkun has to understand modern modes of communication through print and electronic media, including various forms of social media.

Such science ambassadors would need to have fluidity and flexibility to move between academic and university settings where they might interact with experts in the social sciences and humanities as well as their own and other scientific disciplines, and government at the center of international diplomacy. A modern day example of such a Science Tikkun scenario was recently played out through the US Science Envoy Program where an initiative to develop new neglected disease vaccines was initiated jointly between US scientists and those in OIC countries.

The United States Science Envoy Program

The US Science Envoy Program created by US President Obama and Secretary of State Clinton in 2009 may also represent the start of Science Tikkun. Indeed the program, now run out of the US State Department and White House Office of Science and Technology Policy (OSTP), was first announced through President Obama's now famous 'New Beginnings' speech he made in Cairo during his first year in office. The President spoke about how we need to reach out to the Islamic world through scientific cooperation. In this author's role as US Science Envoy we recognized the threat of new neglected diseases emerging out of the conflict zones in the Daesh-occupied territories in Syria, Iraq, and Libya, as well as well as in Yemen [27, 37]. Not surprisingly they included the major vector-borne diseases such as dengue, leishmaniasis, and schistosomiasis, as well as MERS coronavirus infection and other emerging viral diseases.

The US Science Envoy program attempted to address our findings that there are essentially no capabilities of developing new vaccines in the entire Middle East and North African region [27, 37]. Similarly, overall there is minimal capacity for vaccine development in the Muslim world in OIC countries. In a partnership between the US Government, and our Sabin Vaccine Institute (Sabin) we worked with King Saud University (KSU) and the Government of the Kingdom of Saudi Arabia to build infrastructure for new

vaccines. Specifically, Sabin and KSU are collaborating to span the spectrum from discovery through process development, manufacture and first-in-humans clinical trials in order to launch new neglected diseases for the emerging neglected diseases in the Middle East and North Africa [27, 37].

A first step: Albert B. Sabin Fellows

Although an office of global health diplomacy was established in the Department of State during the second term of the Obama Administration, its focus is primarily on leveraging our nation's existing foreign investments in global health treatment and prevention programs for AIDS, tuberculosis, malaria, and NTDs, with an emphasis on health systems and health care delivery. So far, US global health diplomacy has not emphasized biomedical science or true science diplomacy.

In order to cultivate a new generation of science ambassadors, a program of Science Tikkun is proposed where PhD and MD-PhD trained scientists receive specific training in subjects needed to grasp the greater geopolitical landscape of neglected and emerging diseases. Specifically, trainees would receive intensive instruction on the major socioeconomic, planetary, and environmental issues linked to the Anthropocene and covered under the UN SDGs. It would address health disparity issues around blue marble health and the GBD. The initial focus might be for US scientists, and many of the proposed topics could also be of interest to non-scientists in the US Foreign Service.

Another major area of emphasis would be educating doctoral level scientists about engaging the essential sectors for advocacy and policy. As highlighted above, they would include leaders in the G20 governments, religious leaders, and representatives from the corporate sector. It would involve full-on media training and engagement with leading science and medicine journalists.

To launch this initiative the creation of a new Albert B. Sabin (ABS) Fellowship is proposed to honor the legacy of Dr. Sabin, who pioneered vaccine diplomacy in the USSR at the height of the Cold War in his quest to develop the oral polio vaccine now being used to eradicate polio globally [33]. The ABS Fellowship could be based at a major university or embedded in the US Department of State. Depending on resources, the period of training would last anywhere from one to 12 months, and possibly lead to new certificate or master's degrees. There are elements of these programs in the current AAAS Science & Technology Policy Fellowship (https://www.aaas.org/program/science-technology-policy-fellowships) and the US State Department's Jefferson Science Fellowship (http://sites.nationalacademies.org/PGA/Jefferson/), but the ABS Fellowship would uniquely emphasize public engagement with individuals and groups from the diverse sectors highlighted above.

In parallel the current US Science Envoy program could be expanded to include the appointment of a permanent envoy, and increase the number of American scientists who serve for 1-2 years in their capacity as science ambassadors. This initiative could be a part of a larger effort to determine how science diplomacy might be better incorporated into US State Department activities and US foreign policy (BOX 5).

BOX 5. NEXT STEPS. Two concrete action items in the pursuit of Science Tikkun could include the establishment of a permanent US Science Envoy and expansion of the current US State Department – White House OSTP US Science Envoy program and the creation of an Albert B. Sabin Fellows initiative.

Concluding comments

From the perspective of global health the planet is undergoing significant and wrenching changes. New Anthropocene forces are promoting the widespread emergence of vector borne neglected diseases, as well as Ebola and possibly others. There is also a range of zoonotic respiratory virus infections that need to be considered. We urgently need new drugs, diagnostics, and vaccines for these new Anthropocene-driven diseases, and the findings of blue marble health indicate that the problem is not necessarily the lack of financial resources, but the need to mobilize those resources appropriately.

Under the auspices of a new Science Tikkun framework there is urgency to create a new movement linking research and development (R&D) with public engagement to eradicate the world's poverty-related neglected diseases in a modern geopolitical context (BOX 6).

BOX 6. There is urgency to create a new movement linking R&D with public engagement to eradicate the world's poverty-related neglected diseases in a modern geopolitical context.

Accordingly, new programs of science diplomacy need to be established, beginning with an expanded US Science Envoy program and possibly office of science diplomacy between the US State Department and White House OSTP, and the establishment of a unique ABS Fellows program for training a new generation of US science ambassadors.

The views expressed in this report are those of the author, and do not necessarily reflect the positions of any of the institutions to which he is affiliated, the Scowcroft Institute of International Affairs, the Bush School of Government and Public Service, or Texas A&M University.

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Mark Welsh, Dean and Holder of the Edward & Howard Kruse Endowed Chair

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The School is ranked in the top 12 percent of graduate public affairs schools in the nation, according to rankings published in U.S. News & World Report. The School now ranks thirty-third among both public and private public affairs graduate programs and twenty-first among public universities.

The School's philosophy is based on the belief of its founder, George H.W. Bush, that public service is a noble calling—a belief that continues to shape all aspects of the curriculum, research, and student experience. In addition to the Master of Public Service and Administration degree and the Master of International Affairs degree, the School has an expanding online and extended education program that includes Certificates in Advanced International Affairs, Homeland Security, and Nonprofit Management.

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Andrew S. Natsios, Director and E. Richard Schendel Distinguished Professor of the Practice

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