Concept Note: TRANSFORMATIVE TECHNOLOGIES AND INSTITUTIONS

An Alliance for a Healthier World (AHW) theme focused on Transformative Technologies and Institutions would work to:

1. Develop a policy and research framework for discovering, developing and delivering transformative technologies to improve the health and health care of populations, particularly the disadvantaged;
2. Apply systems thinking to create an enabling environment to support how transformative technologies and institutions might overcome failures of the market and to reduce health inequities; and
3. Position the University through its research and education mission to help harness potentially transformative technologies and institutions to make health systems more equitable.

The overarching goal of this AHW would be to bring together faculty and students from across Johns Hopkins University (JHU), along with our partners around the world, to unleash the full range of scientific, analytic, and creative capabilities to promote global health equity. By health equity, we refer to a multi-dimensional concept concerned not only by the attainment of good health and the equitable distribution of health care, but also by the opportunities and capabilities to achieve this goal and the fairness of the process for doing so. Health equity plays an important part in any theory of social justice or consideration of social arrangements. This will require an inter-disciplinary approach drawing on all Schools, Divisions and disciplines along with partners around the world, where JHU works not only to bridge gaps in knowledge and intervention, but also builds translational links from discovery and development of new technologies and institutions to delivery. The vision of the AHW is to bring together faculty and students from across Johns Hopkins University, along with our partners around the world, to unleash the full range of scientific, analytic, and creative capabilities to promote global health equity. We will collaborate with government, civil society, and other academic partners, and engage the poor in finding “end-to-end” solutions to complex problems.

Background

Transformative technologies and institutions have the potential to improve significantly the health of populations and narrow the disparities between those who have and those who do not have access to health care. These disparities result from modifiable and non-modifiable factors as well as genetic and environmental influences. In leveling these differences, we recognize that health equity is born out of a commitment to equal opportunity and capacity for all people, regardless of the circumstance and context of where they are born or may reside.

Transformative can refer to changes in one or more dimensions of health equity. It is rooted in innovation that advances health equity, measured in milestones of lives saved, disability
averted or improved quality of life. In some cases, the transformation is in how we detect or even prevent disease, and in other cases, in how we treat or cure the disease, but success is also benchmarked in how its intended recipients perceive the change or realize such benefits. The process sometimes matters as much as the product: innovation is not just for those in disease-endemic countries, but importantly, has to involve meaningfully those in disease-endemic countries.

In moving from bench to bedside or community, such technologies and institutions face barriers to therapeutic, financial or structural access. These three hurdles roughly correspond to different parts of the value chain. Therapeutic access focuses on whether research institutions and industry undertake or prioritize the research and development (R&D) to address public health challenges. Financial access relates to the affordability of the product by those in need when it enters the marketplace. And structural access considers how the delivery system brings a technology to those whom it may benefit. For the benefits of a technology to be realized, all three hurdles have to be surmounted.

**Therapeutic access.** By therapeutic access, we refer to the alignment of R&D to public health priorities. Why are some diseases neglected, and others not? In 2002, an analysis revealed that only 1.1% of drugs coming to market over a twenty-five year period were for neglected diseases despite the fact that these diseases comprised 12% of the global health burden (Trouiller et al., 2002). Despite the emergence of public and private initiatives to address this therapeutic gap, a follow-up study reviewing the past twelve years showed a persistent shortfall in R&D for what remain neglected diseases. Only 1% of the new chemical entities approved and 1% of the clinical trials registered over this period were focused on these neglected diseases (Pedrique et al., 2013). Small or non-paying markets make R&D for some diseases not attractive commercial opportunities. As the G-FINDER survey documents, the infectious diseases of AIDS, tuberculosis and malaria still command nearly seventy percent of funding for neglected disease research. In the most recent G-FINDER report, the increase in neglected disease funding in 2014 can be almost entirely attributed to Ebola (Moran et al., 2015). Overcoming this mismatch between where resources are deployed and where they are needed—as well as growing the pie of available resources—is key to confronting health inequity.

Over the past couple decades, a range of financing mechanisms have emerged to address these therapeutic failures. Some of these pay for inputs of R&D. Known as push mechanisms, these include grants, tax credits, investments in product development partnerships, and precompetitive inputs to bring new products through discovery and development. Other incentives pay for outputs of R&D, or in other words, when a product has successfully reached the market. Known as pull mechanisms, these include how we structure reimbursement for products that come to market, prizes and advance market commitments, and monopoly rights awarded through patents or various forms of market exclusivity. Though the WHO’s Consultative Expert Working Group on R&D has reviewed these approaches to innovative financing (CEWG, 2012), our knowledge gap is not only over the evaluation of these ongoing efforts, but also conceptualizing and piloting novel arrangements. The need to respond to Ebola and now Zika as well as to mobilize efforts to tackle antimicrobial resistance has given more
impetus to exploring new policy options. From “pay or play” to social impact bonds, there is a
dearth of innovation demonstration projects to test such approaches, but no shortage of
problems against which to apply these ideas.

Creating an enabling environment for innovation begins with how knowledge is owned and
shared (So and Sachs, 2012). The remarkable success story of bringing MenAfriVac
(meningococcal A vaccine) to more than 235 million people in 15 countries at a cost less than a
tenth of a typical new vaccine underscores the importance of how we harness knowledge and
structure public-private partnerships to do so. Its development was spurred by a meningitis
outbreak in sub-Saharan Africa that afflicted 700,000, cost 100,000 lives and left a quarter of
the survivors with long-term disabilities. But the opportunity costs for manufacturers of existing
meningitis vaccine products were too great to draw them into adapting this vaccine platform to
strains endemic in Africa. Setting a target product profile with a low price point, transferring
conjugate vaccine technology from the U.S. FDA to India’s Serum Institute, and striking
collaborations as a virtual pharmaceutical company—the Meningitis Vaccine Project teaches
how an alternative value chain can bring a life-saving product to market (Jódar et al., 2003).

Moving beyond incentives that reward company by company and drug by drug, innovative
financing might also be more attentive to transforming the innovation ecosystem for an entire
field of investigators and companies. For example, making available certain research tools, from
compound libraries to platform technologies, could equip or lower the barrier of entry to an
entire community of researchers to undertake investigations into an otherwise neglected area
of research. Making transparent and sharing research findings and the underlying data could
help speed innovation. Creating institutions to pool the building blocks of knowledge could
lower the transaction costs for researchers or companies doing so separately in order to pursue
a line of investigation.

Financial access. By financial access, we refer typically to end-products brought to market that
may not be affordable to those in need. Lowering drug prices proved to be a tipping point in
enabling the global development community to commit to the treatment of HIV/AIDS patients
in resource-limited settings. In the late 1990s, triple drug therapy for HIV/AIDS cost $10,000-
$15,000 per patient per year, well beyond the means of most of the twenty-five million patients
so afflicted in low- and middle-income countries at the time. Who would seek voluntary
counseling and testing if all they would be promised was just a lifetime of stigma and no
treatment? The Consumer Project on Technology, now known as Knowledge Ecology
International, would go onto negotiate a deal with Cipla, an Indian generic company, to bring
the first generic, triple-drug treatment regimen to market, at a price of $350/year. At less than
a dollar a day, global development aid agencies could no longer turn a blind eye to the problem.
Only when the price of treatment came down did it become possible to consider the launch of a
Global Fund.

Without financial access, the transformative impact of life-saving treatments cannot be
realized. Despite success in lowering the price of patented AIDS drug treatments, the challenge
of financial access has not gone away. Approaches to ensure financial access have ranged
widely, from discounts with economies of scale and guaranteed purchase volumes and generic competition to dual markets with tiered pricing, humanitarian access licensing, and public subsidy of the R&D costs with close-to-marginal cost pricing. These issues in financial access are not just ones faced by healthcare systems in low- and middle-income countries. When Turing Pharmaceuticals hiked the price of Daraprim, an anti-parasitic drug, from $13.50 to $750 per tablet on the U.S. market, this highlighted an industry-wide trend. The U.S. market price of doxycycline—a drug long off patent, but without multiple suppliers—had increased from $20 for 500 tablets to $1,849, a ninety-fold hike between October 2013 and April 2014. The prices of specialty drugs under patent have also soared. In 2012, eleven of the 12 cancer drugs approved were priced over $100,000 a year. Among the top 100 drugs in the United States, the median revenue per patient has risen seven fold, from $1,258 to $9,396 over a five-year period (EvaluatePharma, 2014). Such findings have recently drawn increasing policymaker attention.

Structural access. By structural access, we refer to the last-mile challenges of delivering these technologies to those in need. These obstacles can be considerable. Availability of the products might be limited by stockouts; access, by limits to local infrastructure, from the lack of laboratory facilities to shortages of human resources; and quality, by substandard or counterfeit drugs or thermal instability of the product.

Technologies may only be transformative if we can ensure structural access to them, and the gulf can be great. A UNICEF report notes that if we could lift the level of care for pneumonia and diarrhea across the 75 countries with the highest mortality such that the bottom 80% were treated as well as the top 20% of households in each country, we could save 2 million children from dying of pneumonia and diarrhea (UNICEF, 2012). The UN Commission on Life-Saving Commodities for Women and Children concluded that scaling up 13 life-saving commodities over five years could save the lives of over six million women and children. These commodities include oxytocin for post-partum hemorrhage, injectable antibiotics for newborn sepsis, chlorhexidine for newborn cord care, contraceptive implants for family planning, and oral rehydration salts and zinc for diarrhea. The Commission identified various barriers preventing access, including “severely under-resourced regulatory agencies in low-income countries, leading to delayed registration of commodities; lack of oversight of product quality and general inefficiencies; market failures, where return on investment is too low to encourage manufacturers to enter the market or produce sufficient quantities; and user supply and demand challenges such as limited demand for the product by end-users, local delivery problems and incorrect prescription and use” (UN Commission, 2012). The breadth of these barriers speak to the complexity of structural access challenges.

Technologies themselves can also transform access to life-saving treatment. Ready-to-use therapeutic foods (RUTF) have played such a role in the treatment of severely malnourished children. RUTF such as Plumpy’Nut provide nutritional treatment that is portable and shelf-stable and that can be prescribed and taken as single-serving foods by children with severe acute malnutrition. This represented a shift from treating severely malnourished children in hospitals to community-based settings. Children given RUTF were over fifty percent more likely to recover than those provided standard care (Lenters et al., 2013). Whereas standard
treatment entailed hospitalization and therefore was limited by the number of beds available, RUTF allowed mothers to be discharged with this portable, prescribed treatment for their children. This lifted a significant constraint on the number of patients that could be treated.

Collectively, all three hurdles to access—therapeutic, financial and structural—must be surmounted if transformative technologies are to make their way from bench to bedside or community. The challenges in bringing novel antibiotics to market reveal how these three hurdles to access are deeply entwined and how importantly an interdisciplinary approach is needed. Few new classes of systemic antibiotics have been discovered and brought to market in over three decades. The barrier to therapeutic access stems, in large part, from the scientific challenge in discovering novel classes of antibiotics. The more an antibiotic is used, the greater the drug resistance and thereby the shorter the effective market lifecycle and eventual returns on the investment. In a market system where revenues come from selling more of a drug, conserving life-saving antibiotics till they are absolutely necessary to use is not a winning business proposition. Charging a higher unit price for antibiotics might ration its use, but not likely to those in need of the drug. The barrier to structural access is not only one of effective distribution throughout the healthcare system where it might be needed, but also one of rational use. Absent an effective diagnostic, the antibiotic may be used empirically—that is, presumptively without documented evidence of the disease—in case a life-threatening infection might be present or require the drug’s use. The challenges of bringing a novel antibiotic to market are not geographically limited, but shared by North and South. It is an example of how transformative technologies and institutions may be of significant value to all of society, just some parts more than others.

Framework

To overcome these barriers of therapeutic, financial and structural access, this Initiative will focus on transformative technologies and institutions. Some of these interventions will unlock bottlenecks in the R&D pipeline, shape how innovative financing might work, or shift how we deliver care to patients in need. Applying a strategic lens of systems thinking, where we intervene will be context-specific, but we can offer a framework of what these interventions might focus upon.

An AHW on transformative technologies and institutions has particular centrality in a major research institution like Johns Hopkins. For thirty-six years straight, the University has consistently led the country in total research expenditures, ever since the National Science Foundation’s methodology began capturing these data to include the Applied Physics Laboratory in the University’s total in 1979. Johns Hopkins also receives the most federal research dollars as well. In fiscal year 2014, that came to $2.242 billion, of which $1.95 billion came from federal government sources. With that public funding comes also significant responsibility to provide returns to benefit humanity.

Giving shape to such strategic interventions, the Global Health Signature Initiative (GHSI) could enhance the impact and reach of University-based research, policy work and education. By
focusing on opportunities where there is transformative potential, the GHSI can help identify priorities for research, position existing research for more rapid translation, or show how solutions might cross-apply from one context to another. By serving as a convener, the GHSI could recruit multi-disciplinary talents to a research project, set the stage for meaningful dialogue among stakeholders key to overcoming an access barrier, or incubate new partnerships or business models. By training the next generation of researchers and policymakers, the GHSI can share a vision of systems thinking across disciplines, inspire social entrepreneurs and researchers alike to tackle big societal problems, and create platforms for engaging larger communities of practice in this work.

**Gaps in Knowledge and Interventions**

Traditional funding streams typically do not integrate the work on technologies and institutions with more expansive societal issues. For example, adapting a technology for a resource-limited setting might inherently be addressing health equity from one vantage point, but the same grant may not cover studies of user acceptability, the economics of manufacture and scale-up, or the licensing of intellectual property in target markets. Yet the full transformative potential of that technology will not be realized without taking into account these factors in an integrated manner.

Gaps in knowledge can occur in the interstices between such research projects and disciplines. In the real world, such problems are solved, in part, by emerging institutions like public-private partnerships. The value added that universities bring is a deeper well of knowledge, broader access and capacity to bridge interdisciplinary expertise, and less anchoring to the assumptions of traditional business models or incentives. In recent years, universities have begun to address these gaps through translational science initiatives, the study of systems thinking and value chain analysis, and the research on the innovation process itself. University technology transfer offices also have become increasingly experienced in shaping licensing arrangements and encouraging entrepreneurial spin-offs. Value added comes to universities not only from amplifying the transformative potential and reach of technologies and institutions, but also in training differently students who will enter this workforce. The growth of campus programs in social entrepreneurship, internship placements and client-based practicums, and prize competitions that crowdsource student ideas represent ways in which real world challenges are entering the classroom. Still such activities do not add up to the change that a GHSI on transformative technologies and institutions might systematically seed.

Gaps in interventions can result when the technology or institution is not yet ready for piloting or when such innovations require an enabling environment to reach transformative potential. Across the pharmaceutical value chain, there are key points of intervention where nurturing transformative technologies or institutions could make a leveraged difference in enhancing impact on the lives and livelihoods of populations. Some of these occur before market entry, and others, afterwards in the healthcare delivery system.
Several examples of where a GHSI might contribute gap-filling research, convene key stakeholders, or map out an intervention include:

1. **Establishing target product profiles.** Defining the optimal features for a technology product can align its development, such that the end-product is delivered at a price point affordable in resource-limited settings or is adapted for use without a cold chain. The process not only takes feedback from potential users, but also can gauge its value. PATH, a product development partnership, carries out a scoping exercise to evaluate potential opportunities for technology development. PATH calls it RAVE, or Rapid Assessment of Value Exercise, in which they evaluate:

   - **Public Health Impact:** Are we solving the most critical health problems?
   - **Technical Feasibility:** Does the technology have overwhelming advantages and the possibility of meeting target specs?
   - **Economic Rationale:** Does the technology have value for money?
   - **Market Sustainability:** Can a functional market eventually exist in the absence of PATH? Who are the users, choosers, and payers?
   - **Policy Environment:** Is the technology likely to be supported by policy makers?

In looking at the comparative value of one technology alongside others, PATH considers several dimensions:

   - **Desirability:** What is the need, and is it something stakeholders will prioritize/pay for compared to alternatives?
   - **Feasibility:** What is technically possible, and compared to the alternatives, what is its relative advantage?
   - **Viability:** Can a sustainable business model be envisioned? Why would someone buy this over alternatives?

Like a business or a product development partnership, a landscape analysis conducted by JHU’s GHSI could ask many of these questions, but also apply a wider lens in systems thinking. Such an undertaking could better position an ongoing technology under development at JHU or one considered strategic for advancing a public health goal. Instead of asking whether a single technology or firm might be a worthwhile investment, we could step back and ask larger questions. For example, would the market be better off with multiple suppliers as opposed to backing one (Carey Business School, Economics Department)? If we enabled the underlying platform to be open source, could we stimulate a more vibrant innovation ecosystem for advancing the technology’s development (School of Medicine, Bloomberg School or Engineering)? To enhance user uptake, could a strategic plan to develop a nudge approach to dissemination be created as the technology reached market (Johns Hopkins Center for Communication Programs)?
2. Creating innovation platforms. In the process of developing inventions and interventions, universities generate knowledge. Peer-reviewed publications, NIH’s public access policy, clinical trials data, and funder requirements for data release help build a research commons upon which follow-on innovation might be fostered. A scientific landscape analysis can serve as a starting point for creating a technology trust, which could pool together key building blocks of knowledge, or an innovation platform for targeted research.

Over the past decade, various pooling arrangements, from clearinghouses to patent pools, have begun to emerge, and this has provided valuable experience in how to assemble such repositories. Released by the U.S. NIH, PubChem is a set of linked databases that make publicly available information on small molecule compounds and their biological activity. On the European side, ChEMBL shares annotated data on compounds that have drug-like properties. These databases sometime become places where others upload specialized collections. For example, GSK working with the Medicines for Malaria Venture screened 2 million compounds in its proprietary database and made freely available on ChEMBL and PubChem the data on 13,500 compounds that showed activity against Plasmodium falciparum, the most virulent form of malaria. WIPO Re: Search offers a database of intellectual property shared by pharmaceutical companies and research institutions for those pursuing innovation for new products related to neglected tropical diseases, tuberculosis and malaria. However, such contributions are often ad hoc, not strategically assembled.

Going a step further, once proprietary compound libraries have opened their doors to screening for promising targets, crowdsourced from a larger community of researchers and pharmaceutical firms. These arrangements involve typically some assurances of confidentiality, the option of first refusal, and access to proprietary data. Lilly Open Innovation Drug Discovery (OIDD) offers a platform of in silico design tools and in vitro screening modules that outside investigators can access and to which they can submit potential molecules confidentially. Based on the results obtained, these outside investigators decide whether they would like to participate in the company’s Compound Acquisition program. Taking a variation on this approach, the Drugs for Neglected Diseases Initiative (DNDi) created the Drug Discovery Booster program. DNDi, a product development partnership focused on kinetoplastid diseases, submits a “seed” compound with promising activity against Leishmania or Trypanosoma cruzi to a group of pharmaceutical companies. Each of these companies searches its own proprietary compound database for similar or better compounds and shares these with DNDi. The best “hits” undergo further testing, and the process repeats three times, each time with an improved “seed” compound. Similarly, the Medicines Patent Pool has targeted the generic licensing of specific HIV/AIDS drugs, so that new combinations for adult and pediatric patients might be brought to market. So there are a spectrum of institutional arrangements to pool key building blocks of knowledge. Lifting these efforts from mere repositories to platforms for innovation remains a significant challenge and opportunity.

Consider the potential from scaling up a technology like the iChip, a device that enabled Northeastern University to discover the first novel class of antibiotics—teixobactin—in years, as an innovation platform for drug discovery from natural products. Under an NIH grant, university
investigators found a work-around that allowed for growing the 99% of soil bacteria that cannot be cultivated under normal laboratory conditions. The iChip captures a bacterial sample between diffusion membranes, and the chamber is returned to a larger sample from its original natural environment (Ling et al., 2015). Governed under a fair benefit sharing arrangement, such an innovation platform—if made available to low- and middle-income countries with biodiverse collections—could jumpstart the global search for natural products that could be the next new class of antibiotics. Such undertakings might engage a network of labs working off a specific technology platform (School of Medicine, Bloomberg School), public health, legal and policy experts steeped in issues of traditional knowledge, benefit sharing and intellectual property (Bloomberg School, Berman Institute, Political Science, Sociology), and those who could help shape the business plan for such an institutional arrangement (Carey School, JHU Technology Ventures).

3. Designing innovative financing mechanisms. Innovative financing mechanisms can offset market failures, realign economic incentives, or share risks differently. Universities can play various roles, from licensor of key technologies to architect of new financing arrangements for institutions.

Through humanitarian access licensing, universities can shape downstream access to inventions made on campus. Push mechanisms, for example, derisk the R&D pipeline by paying for inputs into the R&D process, and in so doing, such funding can be strategically deployed to advance public health goals. Under an NIH grant, a lab at UC Berkeley carried out the microbial synthesis of artemisinin. Typically grown on farms, the synthesis of artemisinin held promise as a way of smoothing out the ups-and-downs in the farmed supply of this key antimalarial drug. The University issued a royalty-free, co-exclusive license to both OneWorld Health and a spin-off firm, Amyris Biotechnologies, for the production of malaria treatments in the developing world (Mimura et al., 2011). In return, Amyris Biotechnologies committed to taking no profit from these sales. The Gates Foundation provided the innovative financing that cinched this arrangement. A $42.6 million grant got divided among these partners, $8 million for the University, $12 million in non-diluted cash in Amyris, and the balance to OneWorld Health to assist with the R&D process. Subsequently, an additional Gates Foundation grant would enable Sanofi-Aventis to help bring this synthetic process for artemisinin the last mile to market. Amyris Biotechnologies not only benefited from the grant to develop proof-of-concept for its microbial synthesis process, but also saw dual market potential in applying the same technique for synthesizing biofuels. Negotiating such a licensing arrangement, UC Berkeley played a key role in stabilizing the sourcing of this key antimalarial drug globally.

Universities can also serve as architects for designing, piloting or evaluating new financing mechanisms for institutions. Pay for performance approaches or pull mechanisms pay for outcomes, thereby helping to ensure returns on investment. As an example, the social impact bond mobilizes private sector funding through an intermediary, which takes the risk upfront, for the operating costs of an intervention (Liebman JB, 2011). The intervention typically is one with a proven track record, but one that the government does not have the funding to scale up. The intermediary issues bonds and raises monies from private investors. Government
repayment of the intermediary depends on achieving certain performance targets, and any savings from making the intervention work accrue to the private investors and intermediary. Such an arrangement might scale interventions more quickly. This alternative means of financing has promise in healthcare as well. Such arrangements tap a broad range of expertise, from the substantive focus of the financing arrangement and the economics behind the financing mechanism to the piloting of these interventions and evaluation of its outcomes.

4. **Reengineering the value chain.** Life-saving goods and services too often fail to reach those in need. By mapping the inputs and outputs along the value chain, these shortfalls can generally be traced to the flows of products, finances or information. For both technologies and institutions, there can be transformative potential in reengineering the value chain along one of these dimensions.

Product innovation can lead sometimes to significant improvements in access. Schistosomiasis—a parasitic disease that afflicts over 240 million people in 78 countries—is treated with praziquantel. The drug—even with discounts for African countries—came to $4 per treatment course, a price point still prohibitive for many (Frost and Reich, 2008). The entry of Shin Poong, a South Korean drug firm, changed the market landscape. With a small government grant, the company developed an alternative process of production that enabled a price half that of the originator companies. As the example of microbial synthesis of artemisinin illustrates, universities also have sought to reengineer the value chain of product R&D. It is not always an easy or successful road. A few years back, researchers at Imperial College and the London School of Pharmacy developed an alternative to pegylated interferon, at that time a key treatment for hepatitis C infection. Licensing this invention to a university spin-off, they sought to have Shantha Biotechnics, an Indian firm, develop the drug at a more affordable price point for use in the developing world. The effort faltered when Shantha Biotechnics was acquired by a multinational drug firm.

For health care at the base of the pyramid, *jugaad* innovation plays an important role. Described as an “improvised solution born from ingenuity and cleverness,” *jugaad* innovation occurs under a resource constraint—doing more with less (Radjou et al., 2012). This can be seen in examples such as of Aravind Eye Care system, a case study often written about and taught in university classrooms. Aravind Eye Care system seeks to provide low-cost cataract surgery services to the millions of Indian patients, for whom this operation would restore their sight. Tiered pricing, high volume, rigorous quality control and standard operating procedures, and assembly-line execution have enabled the Aravind Eye Care system to perform as many eye surgeries as 60% of what the UK National Health Service completes, but at a thousandth of the cost and with half the surgical complication rate (Rosenberg, Tina, 2013). A key input cost, however, was intraocular lenses. By manufacturing these in its own, non-profit plant, Aravind Eye Care system dropped the cost of these from $200 to $10 (Aman et al., 2008). Twenty-five years after the Rockefeller Foundation published the seminal 1985 report, *Good health at low cost*, the London School of Hygiene & Tropical Medicine captured lessons in health system improvements through a new set of case studies. For the GHSI on Transformative Technologies
and Institutions, carrying out similar case studies would contribute both to important scholarship and in-classroom education.

5. **Developing citizen science projects and accountability technologies.** The use of integrated datasets and visualizing such data are not new. Overlaying the data of cholera deaths and the location of water pumps in central London onto a dot map (Tufte, 1983), the physician John Snow convinced local authorities to remove the handle of the Broad Street Pump and thereby stopped the disease outbreak in 1854. What is new though is the amount of data we can collect and how we do so.

With the broad availability of mobile phones globally, the advent of mHealth applications affords new opportunities to collect and crowdsourcedata. The mobile phone has become both a means of collecting data and also a way of receiving expert information. In Uganda, mobile phone users are already registering new births and enabling healthcare workers to file reports on disease outbreaks and medicine stockouts. Engaging ordinary citizens and particularly youth in Uganda, UNICEF has tapped into such a network, called U-report. Reaching its network of U-reporters via SMS text, UNICEF and partner organizations were able to identify cases of nodding syndrome—an epileptic disorder afflicting children in the country (UNICEF, 2012). Using the same network, the World Bank partnered with UNICEF Uganda to launch a five-day campaign to “visualize the BBW [Banana Bacterial Wilt (BBW) disease, which threatened to wipe out this staple crop] and disseminate information to affected communities.” The first SMS text went to 190,000 U-reporters on the network, and within 24 hours, over 35,000 responses flooded back. Follow-up texts gave information about BBW and how to stem its spread (UNICEF, 2014). Using a mobile phone app platform, China’s Ministry of the Environment has embarked on a campaign to have the public to photo-document and report “foul and filthy” waterways. The Ministry promises citizens an official response within 7 days (Tyson and Logan, 2016). Enlisting the participation of ordinary people, crowdsourcing such data has become part of a new wave of citizen science projects.

Some have suggested that these tools afford us the opportunity to build accountability technologies (Ed. Offenhuber and Schechtner, 2013). These involve three steps, the 3Cs: 1) collect; 2) comprehend; and 3) compel. Applicable to a broad range of health equity problems, we could envision how the GHSI could construct and deploy such accountability technologies. Imagine if we could develop a new diagnostic—simple enough to be placed into the hands of ordinary citizens—that could give us a readout on whether the run-off from a factory farm carried drug-resistant pathogens or whether the grocery shelves have retail meat contaminated by these bacteria. The diagnostic itself could potentially be a disruptive technology. Disruptive innovation refers to a process whereby a new product targets a marginalized segment of the market, gains a foothold, and eventually displaces market incumbents (Christensen et al., 2008). Initially the product might be more affordable, easier to operate, or more convenient, but over time, its performance catches up to those already on the marketplace.

We could pinpoint drug-resistant pathogens along the food supply chain, thereby making a latent problem into a signal visible to policymakers and the public. Such data could be
crowdsourced, shared in the cloud as part of a citizen science project, where we could discern patterns that might warrant follow-up. By making the data collected actionable and visualizing the results, such crowdsourced data might identify hotspots of drug-resistant pathogens, from factory farms to food shipments being traded across borders. Such data could feed into a scorecard, a map or even a certification scheme that compels policymaker action.

Complementing such an effort, JHU investigators are working with technology that could shorten the identification of new drug-resistant pathogens from days to a few hours, if not minutes. Instead of culturing the bacteria, genomic sequencing is now possible using an Oxford Nanopore device that could be brought into the field, powered off a battery charger or USB port. Applied to food system issues, tracing the genetic fingerprint of a drug-resistant pathogen from farm to local communities or the food supply becomes more doable. A GHSI on Transformative Technologies and Institutions could examine the landscape of opportunities to demonstrate the powerful potential of this technology. Extending these efforts to drug-resistant tuberculosis, there may be game-changing applications.

Opportunities at Johns Hopkins

As these examples suggest, there are a broad range of ways in which the GHSI on Transformative Technologies and Institutions might work across the University on improving global health equity.

An exploratory phase would help identify many targets of opportunities to pursue. To give this work strategic direction, the Initiative will have to assess the policy as well as the technology landscape. By focusing on a portfolio of projects, the Initiative could grow organically around clusters of JHU researchers and external partners, where success would have transformative potential.

To offer an example, we might consider an initial focus on antimicrobial resistance. Following the World Health Assembly’s passage of a Global Action Plan in May 2015, Member States have committed to develop national action plans in two years. Policymaker interest in this issue will also reach the UN General Assembly, where a High-Level Meeting on Antimicrobial Resistance will take place in September 2016. If unchecked, the UK Review on Antimicrobial Resistance projects that antimicrobial resistance will cost up to $100 trillion dollars by 2050 and cost up to 10 million lives a year by that time. A GHSI on Transformative Technologies and Institutions could undertake a broad range of interventions to address this global health challenge. Taking a snapshot of what these activities might look like, we can lay out some examples of activities aligned with the earlier discussed framework. There are, of course, many approaches not falling neatly into this framework, but this should help illustrate the transformative potential of bringing JHU’s talents to bear on this problem.
<table>
<thead>
<tr>
<th>Potential Strategic Entry Points</th>
<th>Exemplar from Antimicrobial Resistance</th>
<th>Potential University Engagement and External Partnerships</th>
</tr>
</thead>
<tbody>
<tr>
<td>Establishing target product profiles</td>
<td>Developing a depot formulation for benzathine penicillin G for treatment of rheumatic heart disease</td>
<td>ReAct Strategic Policy Program (Bloomberg SPH), JHU School of Medicine, RhEACH, World Heart Federation, UNICEF</td>
</tr>
<tr>
<td>Creating innovation platforms</td>
<td>Scaling the iChip platform to source novel classes of antibiotics from natural products</td>
<td>Krieger School of Arts and Sciences, Bloomberg SPH, Northeastern University, WHO/DNDi Global Antibiotic R&amp;D (GARD) Facility</td>
</tr>
<tr>
<td>Designing innovative financing mechanisms</td>
<td>Modeling a delinkage approach to push and pull financing of novel antibiotics</td>
<td>RWJF Investigator Award project (Bloomberg SPH), Carey School of Business, ReAct</td>
</tr>
<tr>
<td>Reengineering the value chain</td>
<td>Laying out the business plan for a rapid POC diagnostic serving the base of the pyramid in clinical care and for detecting pathogens in the food supply chain</td>
<td>Carey School of Business, CLF (Bloomberg School), School of Medicine, Engineering School, FIND/PATH, WHO, ReAct</td>
</tr>
<tr>
<td>Developing accountability technologies</td>
<td>Forging a consensus for antibiotic certification in salmon aquaculture operations globally</td>
<td>Norwegian Institute of Public Health, CERMAQ, CLF, Antibiotic Resistance Coalition, ReAct</td>
</tr>
</tbody>
</table>
REFERENCES


