Three summers ago, I noticed that one of my brother’s assigned summer reading books had been sitting unread for a couple of weeks. My curiosity finally got to me. When he was otherwise engaged, I sneaked Tracy Kidder’s intriguingly titled *Mountains Beyond Mountains* to my room.

The book tells the story of Dr. Paul Farmer, one of the founders of Partners in Health (PIH), an organization that works with poor communities to combat disease and poverty. *Mountains Beyond Mountains* describes Farmer’s work in Haiti, where PIH first applied its novel community-based healthcare model emphasizing a holistic approach to caring for the indigent. Farmer’s work reveals the true power of medicine: to heal, to feel, and to change the world. The book had a profound effect on me. I knew I wanted someday to use the power of medicine to help poor people suffering from disease and malnutrition.

Until I read that book, my academic interests were firmly rooted in mathematics. I had asked for advanced mathematics textbooks for Christmas since elementary school. I had completed three middle-school science fair projects on applied math. But now, guided by my concerns about the state of global health and my passion for problem-solving, I was about to arrive on the doorstep of a new interest: epidemiology.

**The Accidental Epidemiologist**

I was searching for a topic combining medicine and mathematics for the science project required by my tenth-grade research class when I happened upon the World Health Organization’s description of measles. Some unsettling numbers got my attention: In 2006 alone, measles had caused 242,000 deaths. And nearly every one of them could have been prevented with an injection that has been available for over 40 years and costs less than one U.S. dollar. I grabbed my marble composition notebook and started to write.

In 2002, around 2.5 million children under the age of five died from vaccine-preventable diseases (VPDs). Many people may wonder how VPDs can persist in our modern world. The answer is simple and stark: national wealth and disease burden are inversely proportional, and VPDs, such as measles, primarily affect the poorest and youngest. For these reasons, I narrowed my focus to studying the spread of VPDs and improving VPD outbreak control.

VPDs are not the only health threat facing poor populations: Tuberculosis, HIV/AIDS, and malaria, among other diseases, also inflict tremendous suffering and death upon the poor. I considered these other pressing medical issues as I examined the immunization strategies for VPDs. If I could develop cheaper ways to stop a VPD outbreak, health agencies could redirect their limited funds to these other areas of dire medical need.

**Stopping Outbreaks, with Numbers**

I began to study mathematical epidemiology in greater detail. I scoured the internet and read scientific journals, and during my research I came across a central epidemiological concept: the herd immunity threshold, which is the percentage of the population that must achieve...
immunity in order to guarantee protection to the entire population (or “herd”). The greater the number of people immune to infection, the less likely it is that a susceptible person will come into contact with an infected person. When herd immunity is attained, the disease cannot spread within the population. The herd immunity thresholds for very infectious diseases, such as measles, are around 90 percent.

With this in mind, I set out to develop a mathematical model into which an outbreak control agency could plug readily available survey data, and thus determine in real time the minimum number of vaccines required to stop an outbreak. By using the minimum number of vaccines required, the agency spends the least amount of money possible. My plan was to allow an outbreak control agency, say the Fiji ministry of health, to generate approximations of the immunity threshold that change based on the disease dynamics (inputted as survey data).

I embarked on this quest from the port of my PC, using simple formulations. It was just me, my computer, and the World Wide Web. As my knowledge of epidemiology increased, so did the complexity of my models. But eventually I reached a plateau. I had developed a mathematical model for the herd immunity threshold that appeared viable based upon application to actual measles outbreak data. But this model did not incorporate a critical aspect of disease spread: the effects of immunization on disease dynamics during an outbreak. For months, I was stuck.

Then, late one night, the solution became clear: I could add another equation concerning immunization to a basic model for disease spread, reformulating my basic model to incorporate the effects of immunization into the herd immunity threshold model. I was ecstatic. This addition introduced a new variable into the model: the immunization rate during the outbreak.

I now had a springboard to further advance my model, and I could focus on developing an algorithm for predicting several days in advance how many vaccines would be needed to stop an outbreak. My initial excitement turned to frustration as I could not make headway with my algorithm. Countless hours in front of the computer screen testing various approaches proved fruitless. Then, as I was about to power down one night, a graph lying on my floor demonstrating the relationship between the herd immunity threshold and the immunization coverage in the population caught my eye. I noticed a clear association upon which I based a new algorithm—with success.

I had achieved my goal. An outbreak control agency can use the algorithm to predict several days in advance the minimum number of vaccines needed to stop an outbreak. Raw survey data (such as number of infections or recoveries) can be input into the algorithm, which will produce the threshold prediction.

Over the past two years, my research has undergone several iterations, evolving from a high school science fair project into a published work. Each idea seemed to engender another, as an amorphous jumble of variables and numbers slowly developed into a concrete and applicable equation or algorithm. Looking back, I am pleased with my progress. I am sole author of one paper published in The Internet Journal of Epidemiology, and I have one accepted with minor revision by PLoS ONE, and another currently under review by The Internet Journal of Epidemiology.

Mission: Equity
Dr. Martin Luther King, Jr., once said, “Of all forms of inequality, inequity in healthcare is the most shocking and inhumane.” This inequality inspired me to conduct my research, but there are many more battles to fight. HIV/AIDS is the bubonic plague of our time. Tuberculosis is mutating more rapidly than scientists can develop new antibiotics. Malaria parasites are infecting sleeping children all over the world. And every year VPDs are killing more than 1.4 million children under age five.

It falls to our generation of scientists to fill our chapters of history not with somber statistics and excuses, but with innovation and profound change. The path from here is ours to forge. The story of my research is insignificant in comparison to today’s global health challenges. But if you and other rising mathematicians and scientists will join me, we can meet these challenges. As Paul Farmer says in Mountains Beyond Mountains, “Equity is the only acceptable goal.”

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