Using Very Small Chips to Meet Very Big Goals

Harvard University

Of all the initiatives targeted at improving the health of the world's neediest citizens, a small nonprofit company called Diagnostics-For-All (DFA) has some of the biggest goals.

"Our success as a company," says Executive Director James J. Barber, Ph.D., "will be measured in how broadly we can make a difference in how health care is delivered in the developing world...in how many lives we can touch with our capabilities."

But improving health care in, for example, Africa, where 60 percent of the population lives in rural areas underserved by hospitals, is a colossal challenge that begs the question: Where, exactly, do you begin to make a difference?

For DFA co-founder George Whitesides, Ph.D., the answer is simple: with a diagnosis.

Introducing the Paper Lab-on-a-Chip

As a result of his groundbreaking work in microfluidics—which involves the manipulation of fluids that are geometrically constrained within a small space—Whitesides realized that he could create "simple" solutions for point-of-care diagnostics for use in resource-poor settings.

His invention, created in his Harvard University lab called The Whitesides Group, is a paper-based microfluidic chip the size of a fingernail. It works like a miniature, portable laboratory capable of testing a tiny sample of bodily fluid such as blood or urine for proteins or other enzymes that indicate health or disease.

Using a patent-pending technology, The Whitesides Group patterns the paper with water-averse polymers, forming a series of channels that guide a fluid sample to a specific location on the chip that is pre-treated with a reagent. When the reagent is exposed to the fluid sample, it results in a color change that can be read and translated into a diagnosis.

By using paper instead of glass, plastic or silicone commonly used in microfluidic devices, Whitesides and his team have created the perfect portable lab-on-a-chip. Inexpensive to produce—manufacturing costs could be as low as one cent per chip—and easy to transport, the paper-based testing device requires no equipment or power sources and once used, it can be incinerated. What's more, its user-friendly design will require minimal training for public health workers in the field.

First Application: Health Monitoring for AIDS and TB Patients

DFA's first paper diagnostic chip will test for liver function, a simple test that could save thousands, if not millions of lives in the developing world.

The high incidence of AIDS in places like Africa has brought about another epidemic: tuberculosis (TB). According to the World Health Organization, the rate of TB has quadrupled in many countries since 1990. In Africa, where those weakened by HIV/AIDS are susceptible to the infection, more than 500,000 succumb to TB each year.

Although the infectious disease can be cured with proper treatment within six months, the antiretroviral drugs prescribed for both TB and AIDS can have serious side affects. According to DFA, about five percent of patients in the developing world receiving treatment for TB or AIDS—nearly one million people—die of drug-related liver complications due to lack of access to the necessary health monitoring.

"These drugs are very toxic and put patients at high risk of developing liver failure," says Hayat Sindi, Ph.D., DFA co-founder. "In the U.S., patients undergoing similar treatment would be tested for liver failure once or twice a week. In countries like Africa, if patients are lucky enough to live near a lab, it can take weeks for a result. By then, it may be too late to stop or alter the course of treatment to recover damage done to the liver."

Inventor and Co-founder George Whitesides

Microfluidics is just one of the many frontiers explored by Whitesides and his highly technical team of scientists working in the The Whitesides Group laboratory.

In his nearly 50-year career, the Harvard chemistry professor has contributed groundbreaking research in such diverse areas as nuclear magnetic resonance spectroscopy, materials and surface science, and nanotechnology. He has also explored biophysics, the origin of life, cell-surface biochemistry and science for developing economies. A highly accomplished and award-winning scientist, he has received both the National Medial of Science and the American Chemical Society's Priestly Medal.

"Maybe every 50 or 100 years or so, someone comes along who can not only dabble in a broad range of sciences, but who can make significant contributions in those fields," Barber says. "George is one of those people, a completely remarkable man in terms of influence."

He is also, colleagues say, blessed with practicality and a burning desire to help. He strategically structured DFA as a not-for-profit entity in order to maintain a focus on serving the developing world first.

"Dr. Whitesides' work developing the diagnostic-on-a-chip was driven by a desire to produce diagnostic devices that could reach people in need," says Barber.

Citing its commitment to acting with flexibility and speed to improve global health, Harvard University, through its Office of Technology Development, agreed to give DFA the option to exclusively license the diagnostic technology royalty-free for not-for-profit purposes.

A Laboratory Full of Rising Stars

As an educator at the Massachusetts Institute of Technology (MIT) and now at Harvard, Whitesides has mentored countless up-and-coming scientists, researchers and entrepreneurs. Two of those students, Hayat Sindi and Jim Barber, are central players in the formation of DFA (other principals include Carmichael Roberts, Ph.D., co-founder and board member, and Isaac T. Kohlberg, Harvard's Senior Associate Provost and Chief Technology Development Officer).

Hayat Sindi

Sindi, of Saudi Arabia, came to Harvard as a visiting scholar specifically to work with Whitesides. She found in him both a mentor and a kindred spirit.

"From the time I was a young girl, I knew I wanted to make a difference in the universe," Sindi says. "I really admired scientists, and I knew I wanted to dedicate my time and education to helping others."

Whitesides encouraged Sindi, the first woman in the Persian Gulf area to hold a doctorate in biotechnology, to enroll in a Harvard Business School course on commercializing science. She formed a multidisciplinary team that not only wrote a business plan for DFA, but also worked tirelessly to compete in both the 2008 MIT $100,000 Entrepreneurship Competition and Harvard Business School's 12th Annual Business Plan Contest. In an unprecedented sweep, DFA took top honors at both competitions, marking the first time MIT would award its grand prize to a not-for-profit team.

"By formulating a business plan for a nonprofit company, the group was pushing to change the opinion in the marketplace that it isn't all about making money...it's also about saving people's lives," says Sindi.

In addition to helping to capitalize the new company, the MIT prize is also a harbinger of success: in its 19 years, the competition has helped create nearly 100 companies with an aggregate market capitalization of $10 billion.

Jim Barber

DFA executive director Jim Barber knows a thing or two about building value in emerging markets. After completing a doctorate in organic chemistry under Whitesides in 1980, he went on to a successful career in specialty chemicals and materials, most recently as president and CEO of Metabolix Inc., which he shepherded from a research boutique to a leader in biodegradable plastics. When that company went public in 2007, Barber seized the opportunity to once again work with his mentor.

"I had become very interested in public health and wanted to put my time and energy into that realm," he says. "DFA is the perfect marriage of a broadly applicable technology with great social need."

"Our success as a company will be measured in how broadly we can make a difference in how health care is delivered in the developing world…in how many lives we can touch with our capabilities."

— James J. Barber, Ph.D., Diagnostics-For-All

The Future of Diagnostics-For-All

While its fundraising efforts are ongoing, Barber says DFA hopes to have a working prototype of the liver function test by the end of 2009 and to be conducting field studies with the paper diagnostic by 2011. In the meantime, the company is connecting with public health groups and other organizations to establish distribution networks across the developing world, from Africa to Asia and Latin America.

From there, say DFA's co-founders, the sky is the limit on the type of tests that can be embedded on the paper chip.

"We are developing a test that is broadly useful in different settings, in different geographies, in different social contexts," says Barber.

The list of possibilities includes tests for kidney function, electrolyte levels and malaria as well as specialized applications for emergency responders, pediatric care and environmental testing.

Straightforward and simple, each assay meets DFA's central criteria: to make a difference by providing a much-needed on-the-spot diagnosis.

"Diagnosis is critical," says Barber. "It allows care to be delivered."