# Profile of Rebecca Richards-Kortum

**Jennifer Viegas,** *Science Writer*

Rice University bioengineer Rebecca Richards-Kortum returned from a 2005 trip to Malawi with a transformed view on the interplay between technology and cultural, economic, and social realities. While in a newborn intensive care unit, Kortum, now a mother of six children, witnessed premature infants struggling to breathe because the unit lacked technologies widely available elsewhere. She found an "equipment graveyard" full of assorted donated machines designed for high-resource hospitals. Richards-Kortum also met African children with AIDS who received antiretroviral drugs that required refrigeration, yet the children lived in villages without electricity.

Impelled by such adversity, Richards-Kortum decided to go beyond geographic and disciplinary boundaries to solve challenges in global health. She and her team integrate advances in nanotechnology and molecular imaging with microfabrication technologies to develop inexpensive, portable medical devices that can be used in a variety of settings. In 2005 Richards-Kortum established the educational initiative Beyond Traditional Borders and two years later founded the Rice 360°: Institute for Global Health. The efforts have resulted in student-designed technologies that solve healthcare problems in the developing world. Elected to the National Academy of Sciences in 2015, Richards-Kortum recently led the development of a new form of fiber optic endoscopy, described in her Inaugural Article (1). Its application to a low-cost, portable, and high-resolution endoscope can help improve early detection of cancer and precancerous lesions.

## Early Mentors

Richards-Kortum grew up in Grand Island, Nebraska. She loved math and science in elementary school, but was unsure of her career plans. "There weren't a lot of role models for scientists and engineers, especially for women," she says. "I went to college planning to major in education and thinking that I would teach high school math and science." She entered the University of Nebraska, Lincoln, in 1981, where she was inspired by her freshman physics class professor, Paul Burrow. "He is one of the best teachers I've ever met and showed me what good teaching meant," Richards-Kortum says. During her sophomore year, the physics department chair, David Sellmyer, offered her a research position in his laboratory. At the university she also met her future husband, Philip Kortum, who is now an assistant professor of psychology at Rice University.

After graduating with highest distinction in physics and mathematics in 1985, Richards-Kortum considered attending medical school. "I discovered PhD programs in bioengineering and knew that was the perfect blend of science and medicine for me," she says. She decided on the Massachusetts Institute of Technology (MIT), where she earned a Master's degree in physics in 1987 and a doctorate in medical physics in 1990. Her doctoral advisor was Michael Feld. "He introduced me to translational research," she says, "and helped me develop the scientific confidence to be a principal investigator." Upon graduation Richards-Kortum began her academic career at The University of Texas in the electrical and computer engineering department, becoming an assistant professor in 1990, an associate professor in 1995, and a professor in 1999. In 2005, she joined the faculty of bioengineering at Rice University, where she became the first woman and youngest individual at Rice to earn the rank of University Professor (2015). The title enables her to teach in any academic department and share her knowledge across disciplines.

Rebecca Richards-Kortum. Image courtesy of Tommy LaVergne (Rice University, Houston).

## Low-Cost Sensors for Infectious Diseases

Richards-Kortum's research group has integrated advances in nanotechnology and microfabrication to develop low-cost sensors to detect pathogens and infectious diseases, such as HIV (2), cryptosporidium (3), malaria (4), and tuberculosis (5). Exemplifying her group's use of readily available materials, the HIV

This is a Profile of a recently elected member of the National Academy of Sciences to accompany the member's Inaugural Article on page 10769 in issue 39 of volume 113.

device is made of paper and plastic, and enables diagnosis of the virus in infants in low-resource settings.

Richards-Kortum's team also developed a low-cost sensor to detect hemoglobin concentration (6) in patients with anemia, which affects a quarter of the world's population. The researchers impregnated paper with chemicals to break open red blood cells, and then created an inexpensive, handheld reader to analyze hemoglobin on the paper. The device reduced per-test cost more than 100-fold, compared with standard care.

## Educational Programs in Global Health Technologies

Richards-Kortum's interest in addressing global health issues, both through her teaching and her research, began in 2004 when she was preparing an engineering course for nonscience majors. She suspected that global health would pique the interest of her students, and she became immersed in such issues. A year later Mark Kline, who is now the physician-in-chief at Texas Children's Hospital, invited her to visit one of his clinics in Malawi: Queen Elizabeth Central Hospital, where approximately one in five infants is born prematurely. Years later, when Richards-Kortum and colleague Maria Oden won the 2013 $100,000 Lemelson-MIT Award for Global Innovation in honor of their inventions and teaching efforts, they donated the prize money toward the construction of a new neonatal ward at the Queen Elizabeth Central Hospital.

The life-changing trip, after which Richards-Kortum was named a Howard Hughes Medical Institute Professor in 2006, contributed to her founding the undergraduate education program Beyond Traditional Borders and Rice 360°: Institute for Global Health Technologies, which is a research and education institute that promotes the design and dissemination of low-cost solutions to global healthcare needs. Richards-Kortum has outlined how engineering can help meet such needs in several articles (7–9). She and Oden mention that current funding mechanisms often favor technological innovation over simplicity, resulting in technologies that are too costly and difficult to maintain at scale. Instead, Richards-Kortum and her team advocate for "frugal design" that reflects the unique needs and constraints of low-resource settings. Examples of the many technologies created by her students include a "lab-in-a-backpack" full of diagnostic tools, a small clip that pharmacists can attach to a syringe to enable proper dosage of medicine, a hand-powered centrifuge constructed for $35 using a salad spinner, and a portable, battery-operated microscope that costs $240 to manufacture.

## Cancer-Detection Innovations

Richards-Kortum's research has led to 31 patents so far, including several for technologies that improve the early detection of cancer, especially in impoverished settings. In 2012, for example, she and her colleagues created a multimodal optical imaging system to noninvasively identify oral cancers and premalignant lesions (10). Three years later her group developed a low-cost, high-resolution microendoscope, and showed that it improves early detection of cancer and precancerous lesions in a variety of organ systems (10). In some cases, however, the microendoscope did not yield images with sufficient contrast to enable diagnosis of precancerous lesions.

The researchers solved the problem through a new form of fiber-optic endoscopy called differential structured illumination microendoscopy (DSIMe), which is described in Richards-Kortum's Inaugural Article (1). The system, without any bulky optical components attached to the distal tip of the fiber bundle, can perform structured illumination in real time for optical sectioning, while eliminating out-of-focus light and maintaining imaging speed. When tested on patients undergoing surgery for cervical cancer, images acquired using DSIMe showed greater contrast than standard microendoscopy, thereby improving the ability to detect atypical cells.

## Nursery of the Future

Working closely with partners in sub-Saharan Africa, Richards-Kortum's team is currently developing the "Nursery of the Future." She says, "The Nursery of the Future is a comprehensive set of affordable, highly effective technologies designed to support the well-known principles of newborn care." It is directed toward preventing Africa's close to one million annual neonatal deaths, many of which are a result of breathing problems associated with premature birth and infections. In the developed world, infants who struggle to breathe are treated using bubble CPAP (continuous positive airway pressure) machines that cost thousands of dollars, making them too expensive for district hospitals in Africa.

To address the problem, Richards-Kortum's group developed the Pumani bubble CPAP system that delivers the same therapeutic flow and pressure as systems used in high-resource settings, but is offered commercially at $800. "A trial of the Pumani CPAP showed that its use nearly tripled rates of survival for premature babies suffering from respiratory distress syndrome," Richards-Kortum says. The device is now in use at all government hospitals in Malawi, where it is part of the standard newborn care package. Training programs for nurses, clinicians, and biomedical technicians are offered by the Ministry of Health to ensure sustained use.

The project is a personal one for Richards-Kortum, who this year became the first woman to win the American Institute for Medical and Biomedical Engineering's highest honor, the 2016 Pierre Galletti Award. Her family of three sons and three daughters includes two adopted children from Ethiopia. Using the Pumani CPAP and other low-cost technologies, she aims to deploy the project at key medical facilities across Africa. "Our goal is to fully equip the Nursery of the Future at a district hospital for a total cost of $10,000, less than the cost of one Western-style ventilator," she says.

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