From Lipid Rafts to Vaccine Coolers

Sometimes cell biologists can take strange detours in their careers as they try to make a difference. The journey of one of us—Ken Jacobson—from research in lipid rafts and cell motility to addressing an obstacle to successful immunizations in Africa is just one example. This story suggests how scientists can follow new paths to make the world a better place. It also shows how cell biology training can be critical to addressing obstacles to improved public health.

The Problem

Recognizing the crucial role of vaccines in preventing childhood illness and death from infectious diseases, public agencies and private organizations are investing hundreds of millions of dollars to develop new vaccines. However, the full value of those investments, and their optimal impact on health, cannot be realized until vaccines can be delivered to consumers reliably and cost-effectively. One major reason for vaccine wastage is damage from heat or cold. To prevent this, a series of storage and transport links between vaccine manufacture and administration must be maintained. This keeps the vaccine within the World Health Organization (WHO) standard temperature range and is called the cold chain (see Figure 1). Vaccines that require temperature control to protect them against overheating or freezing in transit include those against measles, Diphtheria-Tetanus-Pertussis, yellow fever, Bacillus Calmette-Guérin (for tuberculosis), *Haemophilus influenzae* type b, Tetanus Toxoid, Hepatitis B, and oral polio vaccine.

In the less developed regions of the world, cold chain failure is a major problem. Vaccine wastage rates average up to 50% worldwide; in some countries cold chain failure results in vaccine wastage rates exceeding 75%, according to the WHO. That means that only 25 of every 100 doses shipped by the manufacturer will be safely and effectively administered to children who need them.

The economic impact of wasted vaccines, combined with the administration of subpotent, ineffective vaccines, is nearly incalculable. Using subpotent vaccines puts recipients at risk of developing disease even after vaccination because they don't develop the necessary protective antibody levels. In such cases not only is health negatively affected, but public confidence and trust are undermined. It is difficult to convince individuals to travel long distances when they see vaccinations prove ineffective. Indeed, Bill and Melinda Gates, whose foundation funds malaria eradication efforts, mentioned the need for an efficient cold chain in a recent interview on National Public Radio in the U.S.

Currently, most vaccine transport at the end stage of the cold chain uses an insulated box with a tight lid. Ice packs are used to maintain the temperature between 2–8°C (see Figure 2). The boxes must be used for transport within one working day; and they can store small quantities of vaccine in emergency situations when, for example, power fails. This is the most vulnerable part of the cold chain, and sadly, this technology has gone unchanged for nearly 50 years.

Focusing on a Solution

How did we become involved in a potential solution? Almost two decades ago, one of us (Ken Jacobson) became interested in solar home power for the developing world. Together with individuals at North Carolina State University (NCSU), Jacobson formed the Solar Development Initiative as part of the North Carolina Solar Center. The then Director of the Center, Larry Shirley, suggested that we point our efforts toward global health. We thus contacted Jim Lea, who was developing

Figure 1. The vaccine cold chain. The last step, from local health center to the recipient, is the most vulnerable (adapted from WHO/PATH documents).

Figure 2. Most vaccine is transported in ice packs. Adapted from WHO/PATH brochure "Optimizing Immunization Systems and Technologies for Tomorrow" (2009)

the Center for Global Health at the University of North Carolina at Chapel Hill (UNC). Shortly thereafter, we discovered that Rama Venkatasubramanian at RTI International was leading an effort in semiconductor thermoelectrics and had recently published some of his work in *Nature.* The two of us (Jacobson and Lea) realized that this could provide an innovative technical solution for the pernicious problem of cold chain failure. We contacted Rama, who became quite interested in the project, especially as it met the mission of RTI to improve the human condition.

Improved semiconductor technology provides the basis of an economically viable portable vaccine carrier in which ice packs are replaced by a solid-state thermoelectric (TE) temperature regulator. In practical terms, a TE device is a heat pump that transfers heat with electrons instead of a fluid. Thermoelectrics have constant efficiency and a lifetime limited only by the life of the power source. Advances in semiconductor thin films now permit fabrication of very efficient TE elements that are durable and lightweight. The cooler/carrier envisaged is compact, has no moving parts, and provides constant, reliable temperature control. Internal temperature of 2–8°C is maintained in an ambient environment of 43°C. We envision adding photovoltaic cells on the outside of the carrier, providing an onboard source of power and thereby allowing for a smaller rechargeable battery pack. This will also help keep ambient heat out.

Facing Obstacles

However, developing an efficient, field trial–ready vaccine cooler, beyond an initial prototype constructed at RTI using limited resources, has required much greater than expected persistence. The major obstacle is funding. Although this concept appears to be a viable, cost-effective solution to the problem of cold chain vulnerability, we have thus far failed to attract support from major foundations and government agencies. This is despite an R&D team that includes a world leader in semiconductor TE cooling at the RTI and a NCSU engineering group with highly respected expertise in heat transfer measurement and simulation and insulation technology. The appeal to the idealism of university students interested in using appropriate technology to provide better access to healthcare around the world also should build momentum in furthering this approach. Drawing on their intellectual energy would surely aid the development process.

We have not given up. We still believe that by reducing vaccine wastage, this application of TE cooling technology to a global public health need will help significantly increase immunization coverage and decrease the incidence of vaccine-preventable diseases worldwide. ■

—Ken Jacobson and James Lea, University of North Carolina at Chapel Hill

Cell Biology Textbooks for Africa

U.S. Embassy Deputy Public Affairs Officer Karen Grissette (right) presented science textbooks to Academic Learning Project Marketing Officer Mercy M. Masuki (center) and Deputy Vice Chancellor David Ngassapa (left) of Muhimbili University of Health and Allied Sciences (MUHAS) in Dar es Salaam. The textbooks were provided by the ASCB on behalf of scientific textbook publishers to support the joint MUHAS-UCSF Academic Learning Project. (Photo courtesy of the American Embassy).