



**M**odern science is necessarily international, and geographic borders play a dwindling role in defining issues scientists take on: poverty, climate change, shortages of food and water. Here, in the third installment of our Revolutionary Minds series, we profile eight revolutionary thinkers whose global research has the potential to effect worldwide change. They exemplify what it means to work without borders, defying not only geographic barriers but also far more profound ones—those that seem to limit access to vital resources in so many parts of the world.

They are doing so by refusing to be confined to the traditional territory of any one discipline. When we set out to find researchers tackling the problems of water scarcity, climate change, or conflict, what we discovered was that today's leading lights cannot be so easily categorized. They pursue peace by promoting conservation, conservation by improving human health, health by borrowing lessons from business. The most innovative minds we came across were consistently the most interdisciplinary ones. By expanding the boundaries and the reach of traditional scientific research, they are reimagining the world's future. —Emily Anthes



## Saleem Ali

The Siachen Glacier, in the Himalayas, is a frozen battleground. The 20,000-foot-high region of Kashmir has been the source of a longstanding ownership dispute between India and Pakistan, one that has cost the nations more than 15,000 casualties combined. In addition, the decades-long conflict has generated tons of human and military waste, contaminating a glacier that is home to numerous species of threatened flora and fauna and supplies freshwater to hundreds of millions of people.

Now, the **damage to the glacier may provide a way out of the military conflict.** Saleem Ali is lobbying to turn Siachen into a nonpolitical “peace park,” a move that could not only preserve an important ecosystem but also provide a face-saving exit strategy for both nations. In this way, Ali says, the environment, so often a source of conflict, can be used to promote peace.

“Far too often, we consider environmental issues in terms of resource scarcity,” says Ali, who grew up in Pakistan and is now an environmental studies professor at the University of Vermont. “That necessitates some kind of a conflict framework. Whenever you’re trying to divide up the pie, you end up in a conflict.” But, he says, “you can reframe the problem and make environmental quality an issue. Depleting the quality of the environment is going to be something that neither side would want, so you can cooperate over it.”

In collaboration with other scientists, Ali has drawn up plans that call for cleaning up Siachen and turning the glacier into a conservation and research zone. The armed forces would not have to withdraw completely from the re-

gion, but could be trained as rangers responsible for maintaining the park. “We have tried to reach out to the armed forces directly,” says Ali, who has already enlisted the support of former military officials in both India and Pakistan. “In order for this to work, you have to think of some strategic opportunities for the army.”

The peace park proposal has been submitted to both governments, which are planning talks later this year, Ali says, but the road ahead won’t be easy. For instance, when Ali helped organize a scientific meeting, funded by the National Science Foundation, about the proposal, the US delegation ended up having to shuttle back and forth between two different meetings—one in India, one in Pakistan—because neither government would approve visas for the other side’s scientists. A truly bilateral meeting is planned for this fall in Nepal, relatively neutral territory.

As the wheels turn on the Siachen proposal, Ali will press on with other projects. His edited volume on peace parks will be published this fall, and he will continue his involvement with the Pakistani *madrassahs*, or Muslim schools, where he is establishing an environmental science curriculum. He has secured funding from the US Institute of Peace to work with the schools, which are often viewed as incubators of ethnic conflict and sectarian violence. Ali hopes, however, to illustrate the importance of harmony and accord by fostering an appreciation for science. “Science has a certain objective quality,” he says. “In order to really get good science, you have to have some sort of cooperation.” **1**

Photograph by Mark Mahaney



## Josh Ruxin

In 2000, Josh Ruxin, then working for a competitiveness consulting firm, traveled to Addis Ababa, Ethiopia to speak at a pan-African business conference. The day before his speech, he visited some health clinics and was shocked by their condition. At the conference, he decided to ask the audience an impromptu question: How many of you have business strategies governed by health concerns? “Every hand went up,” he recalls today. “That was just stunning to me.”

A few months later, Ruxin resigned from his job, ready to use his business know-how to improve health in some of the world’s poorest places. Along with economist Jeffrey Sachs and entrepreneur/philanthropist Rob Glaser, he helped found the Access Project, which works against the conventional wisdom about how to improve health care in Africa. “The current diagnosis of what’s broken in public health is: ‘It’s all about the money. We just need more money,’” says Ruxin, who has a master’s degree in public health. “But the resources are there, just not leveraged very well.”

Ruxin believes that **what international public health most needs is better management.** “Way before improving the health care in poor nations is about complex interventions, it’s about managing your staff, maintaining patient records, making sure someone orders supplies, all that basic stuff,” says Ruxin, who now lives in Rwanda, where he manages a variety of development projects. In just one of many such stories, Ruxin recalls visiting a clinic that had an expensive array of solar panels but no power because no one had been trained to change the long-dead batteries.

Access tasks itself with making sure clinics are getting the most out of their resources, and successes are already measurable. In six months, Access turned one clinic with no patient records, no accounting system, and about five patients a day into one that sees 100 to 150 people a day and actually generates income. In the effort to improve health care for the world’s poorest citizens, Ruxin says, there is “real traction that can be gained from drawing on unconventional skill sets.” <sup>[2]</sup>

Photograph by Rob Hann



## Joseph Adelegan

Joseph Adelegan didn’t set out to provide a new source of cheap, climate-friendly energy for the citizens of Nigeria. All he wanted was to clean up the waste spewing out of a local slaughterhouse. But when his plan to

build a waste treatment plant was rejected because of the greenhouse gas emissions it would create, he devised a solution that addressed both problems: He would **turn toxic waste into renewable energy** that could mitigate global warming.

Adelegan, a civil engineer at Nigeria’s University of Ibadan, created “Cows to Kilowatts,” a partnership of several Nigerian nonprofits and a team of Thai waste management experts. The plant they designed, currently under construction, will use bacteria to digest the waste. The process creates two main products: a biogas, composed mostly of methane, and a slurry, rich in phosphorous and nitrogen.

The biogas, which can be used for cooking, will be distributed to more than 5,000 families and cost only one-quarter of the price of natural gas. It is climate-friendly because it captures methane, burns relatively cleanly, and releases less carbon dioxide than fossil fuels do. The nutrient-rich slurry will become low-cost organic fertilizer for local farmers.

The UNDP is investing \$500,000 in the plant, which will “recoup the cost in only two years,” says Adelegan, who is also executive director of the Global Network for Environment and Economic Development Research. The Nigerian government has shown interest in scaling “Cows to Kilowatts” up to the national level. “We have the high aim of expanding this process,” Adelegan says. “It is a concept that has the potential to be replicated in other places—not only in Africa.” <sup>[3]</sup>

Photograph by Mark Mahaney



## María Valeria Lara

Scientists are beginning to fundamentally rethink agriculture. Today, 40 percent of the world's crops are raised in irrigated soil, and humans use 70 percent of their freshwater for farming. But with climate change and the world's growing population poised to make such a water-intensive approach untenable, biologists are trying to engineer plants that can withstand the stress of severe water shortages.

María Valeria Lara, a plant biochemist at Argentina's National University of Rosario, is taking a different approach. Rather than engineering crops that merely adjust in times of drought, she and her colleagues are **creating plants that make better use of water** throughout their entire lifetimes, not only in dry conditions. "Ultimately, we hope to obtain plants that are able to conserve water more efficiently," she says.

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To do this, she is tinkering with a gene that codes for NADP-malic enzyme. The enzyme is thought to affect the opening and closing of a plant's stomata—pores in the leaf surface through which water evaporates.

"We postulate that if there is more of this enzyme within the plant, the stomata will be closed more often, and will therefore lose less water," Lara explains. That should enable the plants to get more growth from smaller amounts of water, whether or not they're facing drought.

So far, Lara and her team have successfully modified two species of plants, tobacco and a common research plant, to express more of the relevant gene. "We are now beginning the process of characterizing the workings of these plants," she says. From there, she hopes to move on to commonly cultivated food crops, such as wheat and soybeans. Transforming these crucial crops, she says, will represent true success in safeguarding the world's food supply from climatic stress. **4** **Photograph by Rob Hann**



## Arne Bomblies

The connection between malaria and water is indisputable—the mosquitoes that carry the parasite breed and develop in wet environments—but it's not always intuitive. "More precipitation doesn't really mean that there will be more mosquitoes," says Arne Bomblies, an environmental engineering doctoral student at MIT. "If it rains really hard in one location, water might flood through breeding habitats and flush out the mosquito larvae," preventing the larvae from becoming the adult insects that transmit the disease.

And so Bomblies knows that controlling malaria requires an understanding of water. His research involves **creating better predictions of malaria transmission by coupling an entomological model with a hydrological one.**

The hydrology model combines a number of variables—such as precipitation, land cover, runoff patterns, soil moisture, and air temperature—that influence the formation of the shallow,

freshwater pools where mosquitoes like to breed. High temperatures or winds, for example, cause stagnant pools to evaporate more quickly and should cut malaria incidence.

By taking all these factors into account, the model can predict where pools are likely to be located at any given hour. These results are then used in conjunction with behavioral simulations of Africa's dominant species of malaria mosquito to identify when and where malarial disease burden will be high. "Our big picture goals are to predict the effect of climate variability and climate change on malaria burden in Africa," he says.

This summer, Bomblies went to two villages in Niger, where he studied their drastically different patterns of malaria infection. He and his colleagues collected data to validate their model and used it to determine how the villages could reduce malaria transmission. "What happens if we eliminate that pool by filling it in?" Bomblies asks. "What happens if half the people use bed nets? We want to understand what happens at that kind of scale, a village-to-village scale." **5** **Photograph by Mark Mahaney**



## Gladys Kalema-Zikusoka

outbreak among mountain gorillas, one that was causing the apes to lose their hair and develop white, scaly skin. An autopsy of a dead infant identified the disease as scabies—common in Africa's poorest human villages but not in great apes. When Kalema-Zikusoka and her colleagues discovered scabies mites in nearby villages, they demonstrated that the apes had picked up the mites when they came into the human settlements to scavenge for food.

The relationship between Africa's animal sanctuaries and the villages they abut is a delicate one. Eco- and ape tourism can be a financial lifeline for poor parishes, and humans have a vested interest in keeping the wildlife healthy and thriving. But the close proximity can be risky for both animals and humans. Genetic similarities allow diseases to travel easily between humans and apes, giving humans scourges like Ebola and infecting apes with

In 1996, Gladys Kalema-Zikusoka, a veterinarian for Uganda's national wildlife service, was called to intervene in an unusual disease

human pathogens that cause measles, tuberculosis, and more. Such transfers can ravage a community of chimps or gorillas, which have no natural immunity to these afflictions.

In 2002, Kalema-Zikusoka founded Conservation Through Public Health, a grassroots nonprofit dedicated to **saving Africa's wildlife by improving the health of humans.** Its multifaceted approach begins with comprehensive health monitoring; currently, for example, scientists and park rangers collect and analyze more than 1,500 weekly biological samples from Uganda's gorillas. Important data is shared with clinics and doctors that serve and monitor nearby human populations. CTPH also runs human health programs, such as an initiative to make sure TB patients complete their courses of antibiotics, and sends volunteers into villages to educate people about the link between human and animal health.

People have been "very receptive to what we had to say about hygiene, not only for themselves, but also to protect a source of income," says Kalema-Zikusoka. "They're the very people who are likely to make the wildlife sick, and once the wildlife dies they suffer the most." <sup>6</sup>

Photograph by Stuart Price



## Pallaor Sundareshwar

Over the last 10 years, climate monitoring stations have sprouted up all over the globe. But as scientists scramble to keep tabs on

global warming, India, with a population of more than one billion but no official network for tracking climate change, remains an unknown.

Atmospheric scientist Pallaor Sundareshwar plans to change that. The lack of climate data coming from tropical and subtropical locales in general, and India in particular, "is undermining our ability to do something profound and concrete" about climate change, he says. "Global environmental changes usually occur at a very slow rate. They have a tendency to sneak up on us. Unless you're monitoring it very effectively, you're going to miss it."

Sundareshwar is now leading an **initiative to establish an Indian climate monitoring network**, called IndoFlux. Though IndoFlux is modeled on terrestrial networks overseeing other regions of the globe, such as AmeriFlux and CarboEurope, it will expand on them to monitor the land, the coast, and the ocean under a single integrated network. This broad approach means IndoFlux will measure everything from sea surface temperature and marine dissolved oxygen levels to greenhouse gas emissions and soil respiration, allowing scientists to trace the full effects of microscale changes in any part of the environment. The data collected will ultimately inform climate change policy.

Sundareshwar toured Indian laboratories and government offices to drum up support for IndoFlux, and the government eventually earmarked \$50 million over five years for the project. For India, the network should have benefits beyond data collection, such as providing new job opportunities in climate science and promoting interest in the field, says Sundareshwar, who also teaches at the South Dakota School of Mines and Technology. "It has a lot of economic implications and social implications beyond generating very good data." **[7]**

Photograph by Rob Hann



## Tobias Siegfried

Global analysts predict that the wars of the future will be fought over

water. More than one billion people already lack adequate access to it, and governance of the increasingly valuable commodity is often characterized, the UNDP says, by policies that "exacerbate scarcity."

"There are examples of successful management, but they are the exception rather than the rule," says Tobias Siegfried, an environmental and political scientist at Columbia University's Earth Institute. "In the quite complex world we live in now, the environmental issues of water are just one side of the coin. The other side is the political and economic and social conditions in which decisions about water allocation are made."

So Siegfried is rethinking what it means to cooperate over a shared natural resource. Using quantitative modeling and optimization techniques, he studies **how socioeconomic dynamics influence water management** and how they can be harnessed to improve it.

For instance, Siegfried studied aquifers in the Northern Sahara, where Algeria, Libya, and Tunisia compete for the same groundwater. "They steal each other's water," Siegfried says. In doing so, they lower the water table, increasing the cost of retrieving water, and induce hydrodynamic change in the ground, which can cause boreholes to become polluted with saltwater. "All this calls for really careful management, coordinated management," he says. And that's not easy to implement. "Water resources are considered a resource that you do not talk about in the open, especially with your neighbor, who you think is stealing your water."

Siegfried's models determined how much water could be drawn from each aquifer at certain times without wreaking havoc on the shared groundwater supply. If all three nations agree to these recommendations, they could prevent costly hydrodynamic changes and see their water allocation costs drop by a factor of seven in the next 50 years. "That is a strong incentive to cooperate," Siegfried says. In this way, the models can identify water management approaches that generate tangible returns and might persuade nations that sound water policies are not just in the world's best interest, but also in their own. **[8]**

Photograph by Mark Mahaney