Fueled by

Sara Volz and the Powerful Potential of Pond Scum

IT WAS IN THE SPACE UNDER THE HIGH BUNK BED IN HER ROOM THAT SARA VOLZ CONDUCTED HER RESEARCH ON CREATING BIOFUELS FROM ALGAE. THERE, BENEATH HER BOX SPRING, ON SHELVES SHE CONSTRUCTED, IN FLASKS SHE GOT FOR CHRISTMAS, AND WITH A 24-CULTURE PHOTOBIOREACTOR SHE BUILT HERSELF, SARA DEVISED A LOW-COST WAY TO FORCE ALGAE TO PRODUCE ENOUGH OIL TO POWER A DIESEL ENGINE.

THE WORK SHE DID IN HER HOMEMADE LABORATORY IN COLORADO SPRINGS—LEARNING, AS SHE PUTS IT, "TO PRODUCE PETROL FROM POND SCUM"—EARNED SARA MANY ACCOLADES AND AWARDS, AS WELL AS THE MONIKER ALGAE GIRL. HER DISCOVERY WAS AN ACHIEVEMENT THAT SHE SAYS CAME DOWN TO PERSISTENCE MORE THAN ANYTHING ELSE.

The Natural Choice

Sara got serious about science in sixth grade, when she went to her first regional science fair with a project examining the effect of certain antibiotics on bacteria. "Blown away" by the work of students just a few years older than she, Sara knew instantly she wanted to do that level of work, too—and that science was an interest that would last past high school. "After that first science fair experience, someone asked me what I wanted to be when I grew up," she remembers. "I said I wanted to be a science researcher. That hasn't changed."

But her focus did. When Sara heard that a neighbor was running his car on recycled vegetable oil, she started reading up on fuels made from renewable biological sources. Biofuels were the perfect merging of her two growing interests, biochemistry and alternative energy. They were also tantalizing: "I read online that with some old vegetable oil, a few chemicals, and a bit of patience, I could make biodiesel in my kitchen." With her parents' permission, she did.

Then, in ninth grade, Sara heard about the potential for biofuels derived from algae. Algae can produce the oil needed for biofuel without using up farmland needed to grow crops for food, as do other biological sources such as corn and soybeans. The problem? Harvesting enough oil from algae is difficult and expensive, making it not economically feasible. Sara wanted to change that.

She started by reading everything she could about biofuels and algae in science journals, in the news, and online. She visited Solix BioSystems, an algal research facility in Colorado, where she talked to researchers. And she started emailing people—researchers, profes-

Algae

by Kristi Birch

sors, people in the energy industry—for advice. Many people ignored her inquiries, but others were helpful, answering her questions and even lending her glassware.

On the recommendation of some of the scientists she contacted, Sara ordered online *Nannochloropsis oculata*, a hardy, easy-to-grow strain of algae with high oil content. In her bedroom laboratory, Sara began trying to grow her algae under different conditions to increase the oil yield. She ran experiments to determine the effect of nitrogen depletion and increased carbon dioxide (CO_2), both known to increase algae's oil production.

She built a photobioreactor—four tubes positioned around four aquarium lights—and prepared nitrogen-limited and CO_2-infused media in which she cultured the algae. With help from a researcher at Colorado College, Sara then analyzed her results and determined the overall lipid production.

The CO_2-infused samples died after a week of culturing. After two weeks of culturing, the nitrogen-limited samples, though they grew fewer algae, did indeed have higher lipid content and overall oil yields. Her work earned her a Fourth Award in the Energy and Transportation category at the 2010 Intel International Science and Engineering Fair (ISEF). More importantly, she had learned a lot about algae and doing basic biology.

Under the Hood

After the competition, Sara wanted to understand the mechanics behind her results: Why did growing algae under conditions of nutrient deprivation increase oil production? To answer that, she would have to look under the hood of the cell to see what was happening to the enzymes in the oil synthetic pathways. Sara decided to focus on ACCase, an enzyme important in oil synthesis, and try to quantify changes in its level under stressed and non-stressed growing conditions.

By this point, Sara was absorbed in her research. She had acquired a clunky old centrifuge from her father's veterinary office to help analyze the algae's lipid content. She even slept on the same light cycle as her algae; when the lights went off for the flasks under her bed, it was bedtime.

Meanwhile, one of her emails landed in the inbox of Stephen Chisholm, Ph.D., then an assistant professor in the Department of Bioagricultural Sciences and Pest Management at Colorado State University. After speaking with Sara—and finding her "knowledgeable, attentive, friendly, curious, obviously highly motivated and making real progress with her project"—he began helping her plan her experiments and guided her with sample collection and storage. When Sara needed to do analytical work that required special equipment, she and her mother made the three-hour drive to his lab in Fort Collins. Sara also began working at the nearby Air Force Academy's Life Sciences Research Center, where researchers helped her with the chemical analyses to measure lipid production and oil content.

Sara developed molecular biology tools to monitor the expression of the ACCase enzyme. She extracted RNA (levels of which indicated levels of ACCase) and lipids from two or three dozen sets of her algae samples and compared the enzyme's expression in the stressed versus non-stressed algae. "Nobody at the time had managed to extract RNA from this strain of algae," says Chisholm.

Sara won a First Award at the 2011 Intel ISEF as well as the Grand Award at the Hong Kong International Science Fair and was featured in a *Popular Science* article about high school inventors. Still, she wanted to dig deeper. "Stress-based oil overproduction was a known effect in the literature," she says. "I wanted to move past that into something that was new and that would take an active role in modifying the algae oil metabolism—changing it, rather than learning more about it."

In the Weeds

Instead of increasing algal oil production through nutrient starvation, Sara decided to try to select for algae that produce a lot of oil. She had heard of a commercially available herbicide, sethoxydim, which is marketed as an ACCase inhibitor. She wondered if, in the same way that some weeds can acquire resistance to an herbicide, so could algae. If so, the resistance would be useful for biofuel production. And she could make it happen: with the herbicide, she could kill off all the algae except those with increased ACCase activity and higher oil production. It would be survival of the fittest: eventually, only the high oil-producing cells would be left to reproduce.

It worked. The young researcher now known on the science fair circuit as Algae Girl had found an inexpensive way to hijack nature's evolutionary processes and increase the algae's production of oil by 300 percent! In addition to another first in category at the 2012 Intel ISEF, Sara won the grand prize at the 2013 Intel Science Talent Search, which she is using to pay for college.

Now a sophomore at MIT majoring in chemistry and physics, Sara plans to study biochemistry in graduate school and become a professor. She's also working in a lab at the Broad Institute, researching a genomic engineering technique that enables gene editing. Its applications are largely medical, but she notes that it can also be applied to creating biofuels. She no longer works with algae, but hasn't quite let go of it, either: "It's still under the bed at home. I held onto it for nostalgia's sake." ■