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# A Kernel of an Idea

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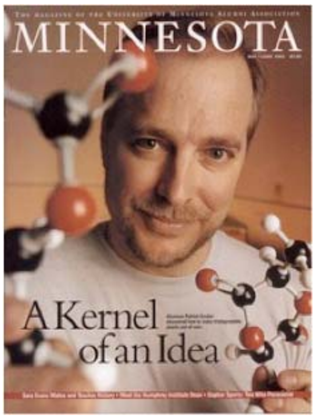


Patrick Gruber, photo by Dan Marshall

*By Chuck Benda*

Foundering in a college chemistry class more than 20 years ago, Patrick Gruber (Ph.D. '89, M.B.A. '94) suddenly felt something click. "The professor was talking about Avogadro's number and all sorts of other stuff that didn't make much sense to me," Gruber recalls. "I remember looking up at him thinking: 'I don't understand a damn thing you're saying.' Then I looked down at my desk and back up, and for some reason it all became very clear. Chemistry became very simple all of a sudden."

It was a defining moment for Gruber and would lead—10 years down the road—to an even bigger click: a breakthrough technology that would present a sustainable alternative to petroleum-based materials. In other words, plastics and fibers conventionally made from nonrenewable petroleum can now be made into an economical, environmentally friendly polymer derived from corn.

"Thirty or 40 years from now, people will look back at the work he has done and be wowed," Randy Howard, CEO of Cargill Dow, says of Gruber's discovery. "I describe it as the second industrial revolution."

Nobody at Cargill, Inc., based in Minnetonka, Minnesota, meant to start a revolution when they hired Gruber in 1988. But the agricultural commodities trader was looking to expand its repertoire into other realms of agribusiness. Former Cargill CEO Ernie Micek, then head of Cargill's corn milling operation, gave Gruber, who was just completing his Ph.D. in chemistry from the University of Minnesota, a simple directive: Find something new to make from corn. That Cargill expected his findings to yield at least $100 million a year in revenues didn't dissuade Gruber from the job offer.

Within six months, Gruber had identified the potential product he could make from corn: a little-known family of polymers (plastics) called polylactide, or PLA. Soon after, he conceived and tested the manufacturing process, successfully cooking up small batches in his kitchen at home. Today, PLA is being used to manufacture everything from carpet to high-performance athletic clothing to food packaging materials. Production for 2003 is expected to exceed 200 million pounds, but Gruber believes PLA could soon replace almost all conventional plastics—of which some 270 billion pounds are manufactured annually. Instead of $100 million annually, he expects sales to reach $2 billion annually in less than 10 years. Eventually, sales could surpass that many times over.

In addition to being able to match or exceed the performance of conventional plastics—including its insulation, wicking, and draping qualities—PLA sports a long list of desirable characteristics. It can be manufactured in a very environmentally friendly, or green, fashion. PLA production results in 30 percent to 50 percent fewer greenhouse gases and consumes 30 percent to 50 percent less fuel than conventional plastics. In most forms, PLA is 100 percent recyclable—and it can be recycled over and over and over. It can be incinerated, if necessary, with very few emissions. And, if composted in specially designed landfills, it breaks down into its basic, non-polluting building blocks in fewer than 60 days (the process takes longer in conventional landfills).

From the front page of the *India Times* to *Newsweek*, Gruber and PLA have become front-page news. Over the past few years, his achievements have earned him an impressive list of accolades, including the Discover Award for Environmental Innovation from the Christopher Columbus Fellowship Foundation, the Technology of the Year Award from the Department of Energy's Office of Industrial Technologies, the Inventor of the Year Award from the state of Minnesota, *Discover* magazine's award for the top environmental innovation of the year, the prestigious Julius Stieglitz Award, and—Gruber's favorite—the Design and Engineering Award from *Popular Mechanics* magazine.

Gruber, who holds nearly 50 patents related to his discovery, believes that different permutations of the same basic technology may soon be used to replace fossil fuels almost entirely. The Department of Energy apparently believes Gruber is right; it recently awarded him a $25 million grant to begin

**Turning Last Year's Corn into Plastic**

Carbon is a basic building block of countless compounds—including all of our primary gaseous and liquid fuels. Ethane, methane, and propane, for example, all consist of carbon and hydrogen combined in various ways. Carbon is the critical ingredient in plastics, too, along with numerous other materials. A major problem with relying on oil as the primary source of that carbon is really quite simple: The supply is finite and fast running out. Estimates vary, but experts agree that, at current usage rates, our petroleum reserves will run out in approximately 50 years. With the oil goes ready access to carbon.

In essence, Mother Nature harvested the carbon upon which we now rely some 50 million years ago and stored it in oil. Patrick Gruber's technology enables the harvest of last year's carbon. The basic scientific principles behind it are simple. It all begins with the sun. The sun's energy is what drives photosynthesis. Photosynthesis is the process that enables plants to turn water and carbon dioxide into sugar, which contains carbon. Plants use some of the sugar as their fuel, but the excess is stored in the plant as starch. In corn, most of the excess starch is stored in the individual kernels. Because all plants store starch in their stalks and leaves, too, Gruber believes it will soon be possible to use less valuable plant material—such as corn stalks, grasses, or even wood chips—as the feedstock.

To make plastic from corn requires several steps, figuring out how to do just that.

Not bad for someone who almost dropped out of chemistry.

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Soft-spoken and easygoing, Gruber quickly makes visitors to his office feel at home. Indeed, his office looks and feels more like a den or family room than a lab where a world-renowned scientist makes discoveries.

Gruber doesn't wear a lab coat and has no desk, just a grouping of comfortable brown leather furniture, a couple of tables for a computer and photos of his wife, Sally, and their five children, and a practice putting green and cup. "When people come here to talk to me, they're here to talk about something that's important to them," says Gruber. "Sitting across a desk from each other only adds a barrier that doesn't need to be there." On the walls hang prints of lighthouses and other North Shore scenes—reminders of his passion for boating and diving the wrecks of Lake Superior.

An interest in the natural world steered Gruber toward science in general, and ecology in particular, from the time he was a young boy. The second of three sons, Gruber, 42, grew up near Como Lake in St. Paul. Earth Day activities fed his curiosity about how ecological systems worked: What constitutes water quality and how do you measure it? What's good soil? What's bad soil? And why are these things important?

"I remember Earth Day [1970] was a big deal," says Gruber. "I didn't have a clue about how the real world—jobs and all—worked, but I knew I wanted to do something in science that could make a difference."

After he graduated high school in 1978, Gruber enrolled at the College of St. Thomas where he began studying physics. "At first I wasn't really into school all that much," he recalls. "I never had to study much in high school, so I was pretty overwhelmed that first year at college."

He struggled to keep up, even dropping a class to lighten his load. But then one day in chemistry class, something clicked, and Gruber knew he was in the right place.

He graduated from St. Thomas in 1983 with a bachelor's degree in chemistry and biology and entered the graduate program at the University of Minnesota. He later would earn his M.B.A. from the University as well. His work at the U focused on the study and characterization of carbohydrate molecules, but he also received excellent background training in the fundamentals of biological systems, kinetics, process chemistry, stereochemistry, and more. Although he had no idea at the time, the work he was doing was preparing him to solve a problem no one else had been able to solve—and, in the process, open the door to a promising future for the ecological health of the planet.

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When he took the job at Cargill, Gruber began in a workmanlike fashion, making a list of all the chemicals he would be able to derive from corn. Then he surveyed dozens of executives, asking them to identify some of the parameters they would use to guide them if they were given his assignment of developing a valuable new product line. Would they go for an existing product and try a new approach? Or would they try to come up with an entirely new product for new markets?

In the end, Gruber decided to do it all: find something that could be used to manufacture multiple products that could be sold to multiple markets. He hadn't forgotten the values he had begun to claim as his own since Earth Day 1970 and decided that the "greener" the product, the better. As he narrowed his focus, one item on his list stood out: PLA. "PLA had been known for a long time—since the early 1930s," Gruber says. "It had been manufactured in small quantities for use in the medical device industry."

The old PLA—which had been used to manufacture things such as bone pins and screws and other surgical implants—wasn't made from corn. It was made from lactic acid using a harsh solvent and a recrystallization process. It was a very dense form with a high molecular weight. It couldn't be melted or extruded like many of the common forms of plastic manufactured from petroleum. The only way to work with it was to machine it like metal. Plus, it cost anywhere from a few hundred to a few thousand dollars per pound to produce—a cost that made it entirely impractical as a replacement for conventional plastics.

Gruber knew that PLA, like all polymers, consisted of long chains of molecules that could potentially be manipulated into new combinations and produce a large family of products with very different properties. Simply stated, individual PLA molecules are either "right-handed" or "left-handed" and thus can be combined in an almost infinite array. The trick was to figure out how to manipulate those molecules to combine in ways that produced products with more desirable qualities. It was a "trick" that other scientists had tried to master and failed.

works something like this:

1. Through various milling processes, the starch is turned back into sugar.

2. The sugar is fermented and broken down into smaller pieces, which then form lactic acid.

3. Through distillation, the lactic acid molecules are further broken down to form lactide monomers.

4. The molecules of lactide monomers (which are in a ring form) are then broken apart and recombined into long chains of molecules (the PLA polymer). By manipulating this process, the producer can control the way the molecules combine and thus create a family of PLA polymers, each with different characteristics suited to different applications.

5. The final PLA polymer—the plastic—is then formed into beads, or pellets, for shipping to manufacturers where it will be melted, spun, or molded.

*—C.B.*

But for Gruber, the insight appeared seemingly out of thin air, just as it had in his chemistry class many years earlier.

“Once I had decided on PLA as the product, the basic process came to me in a matter of seconds,” says Gruber. “Others had tried distillation, but they couldn’t figure out how to characterize the molecules they produced. My work with carbohydrates in graduate school had taught me to characterize complex molecules and it was a relatively straightforward process to transfer that to PLA.”

Within a matter of days, Gruber began cooking up batches of PLA in his kitchen at home. The need for more product quickly outgrew the capacity of his home kitchen—and the patience of his wife. Gruber wasted no time in expanding his production capacity. He and his colleagues installed the new equipment themselves on a weekend, knocking out a few walls in the process.

As efforts to grow the fledgling business progressed, Gruber and others at Cargill realized that other walls would have to come down too.

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Gruber credits Cargill for its vision in allowing him to pursue the development of PLA, but it soon became apparent that the company wasn’t particularly well-suited for developing and bringing to market a product like PLA.

“Much of what we were trying to do was very unusual for Cargill,” Gruber recalls. “They weren’t used to spending so much money up front—and they weren’t used to waiting so long for results.”

According to Gruber, developing a new class of polymers typically takes about 20 years. Although Gruber and his colleagues were able get that job done in about half that time, by the mid 1990s Cargill’s investment had already grown into the hundreds of millions of dollars and the company still wasn’t seeing any returns. Cargill had neither the experience nor the infrastructure to compete efficiently in the plastics industry, so it began shopping for a partner. At first the reception was tepid. “One company offered to ‘take it off our hands,’” Gruber recalls. But after a closer look, Dow Chemical understood PLA’s potential and decided to join the effort.

In 1997, Cargill and Dow formed a 50-50 joint venture, Cargill Dow LLC, to focus solely on PLA and related products that could be developed using Gruber’s technology. Cargill’s access to and expertise in processing corn and other agricultural products mixed well with Dow’s expertise in producing and marketing plastics and other chemicals. (Dow was a pioneer in the plastics industry, developing such products as Styrofoam and Saran Wrap.) Operating as Cargill Dow, of which Gruber is now vice president, the new organization moved things along more quickly. Soon, manufacturers as diverse as Sony, Mitsubishi, IPER (a European chain of grocery stores), Woolmark, and Pacific Coast Feather Company began developing and testing products made from PLA. In April 2000, Cargill Dow opened a PLA plant in Blair, Nebraska, that is capable of producing 300 million pounds of PLA annually.

With dozens of products currently on the market and dozens more on the way, Cargill Dow expects to build at least three more plants similar to the one in Nebraska—one every three or four years—to keep up with the growing demand for PLA. Eventually, if Gruber and his colleagues can continue to refine the technology—the way Gruber thinks they can—they will be able to develop versions of PLA that can replace just about every kind of plastic on the market. They’ll be able to do so from less valuable feedstock, and they’ll use the same basic technology to begin to develop fuels to replace petroleum-based liquid and gaseous fuels. It sounds fantastic to some, but those who have seen Gruber in action think it is not only possible but also highly probable.

Cargill Dow CEO Randy Howard is among the believers. “As far as I can tell, Gruber never seems to consider what to do if he fails,” says Howard. “He seems to start with an unshakable belief that it’s going to work; we just have to figure out how. That’s a very uncommon attitude.

“He is as driven a person as I have ever seen,” Howard continues. “I’ve never seen anyone who dedicates everything he has the way that Gruber does to reach the vision he wants to create. And, the truly amazing thing is, he continues to enlarge and grow that vision every day that he comes to work.”

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It is Gruber’s vision that caught Robert Elde’s attention. “Pat sees the big picture when it comes to understanding our current agricultural and industrial practices —and our dependence on petroleum and how these things are seriously damaging our ecosystems,” says Elde, dean of the College of Biological Sciences at the University of Minnesota. Elde, who among his many duties promotes University partnerships with industry, has gotten to know Gruber as he has explored the potential for developing collaborative efforts with Cargill Dow. “The work he’s doing is moving us in a direction that will one day help us solve these problems.

“Instead of relying on crude oil—on photosynthesis that occurred 50 million years ago in the Middle East—the work that Pat is doing is allowing us to tap last summer’s round of photosynthesis,” Elde continues. “Now we can grab the materials and the energy we need from annually renewable resources—and do so in a way that is much less damaging to our ecosystems. What was once only a pipedream [eliminating our dependence on oil] is now a possibility. Imagine, for a second, how that will reshape the current economic and political climate.”

Gruber has surprised even himself by how his work has evolved. “When I started on this journey, I was simply looking to identify some chemicals or new products that could be derived from corn,” says Gruber. “My vision of where this can lead has grown enormously since then. As the technology advances, I believe we will be able to use it to replace almost all the liquid fuels we currently derive from petroleum. And if it’s done right, it can help solve our problems of excess carbon dioxide in the atmosphere. This is going to make a very real difference in the world.”

The Department of Energy grant to explore the use of Gruber’s technologies in developing alternative fuels was awarded within the last few months, and that work is only beginning. But Gruber is convinced it isn’t a matter of whether or not it will work, but how long it will take to get it right: “We’re trying to develop the ground rules, so to speak, to understand and develop the technologies and the infrastructure that will be needed to make this work on a large scale.”

Along with the scientific work, Gruber does a fair amount of proselytizing on the concept of sustainability. He is regularly invited to give presentations around the world to corporate, academic, and government groups. Always the reception is warm, but always, his audiences’ level of skepticism surprises Gruber.

“Most people automatically assume that if you’re going to do something that is environmentally sound and sustainable over the long term, it’s going to cost more money or diminish the quality of our lives,” says Gruber. “That’s simply not true. You can make these technologies economical, you can do it with a smaller environmental footprint, and you can make money doing it. That’s the fun part.”

That’s why Gruber is so attuned to when complex concepts suddenly click. “This is about what the world’s going to look like for my kids,” he says, “and to me, that’s as important as it gets.”

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