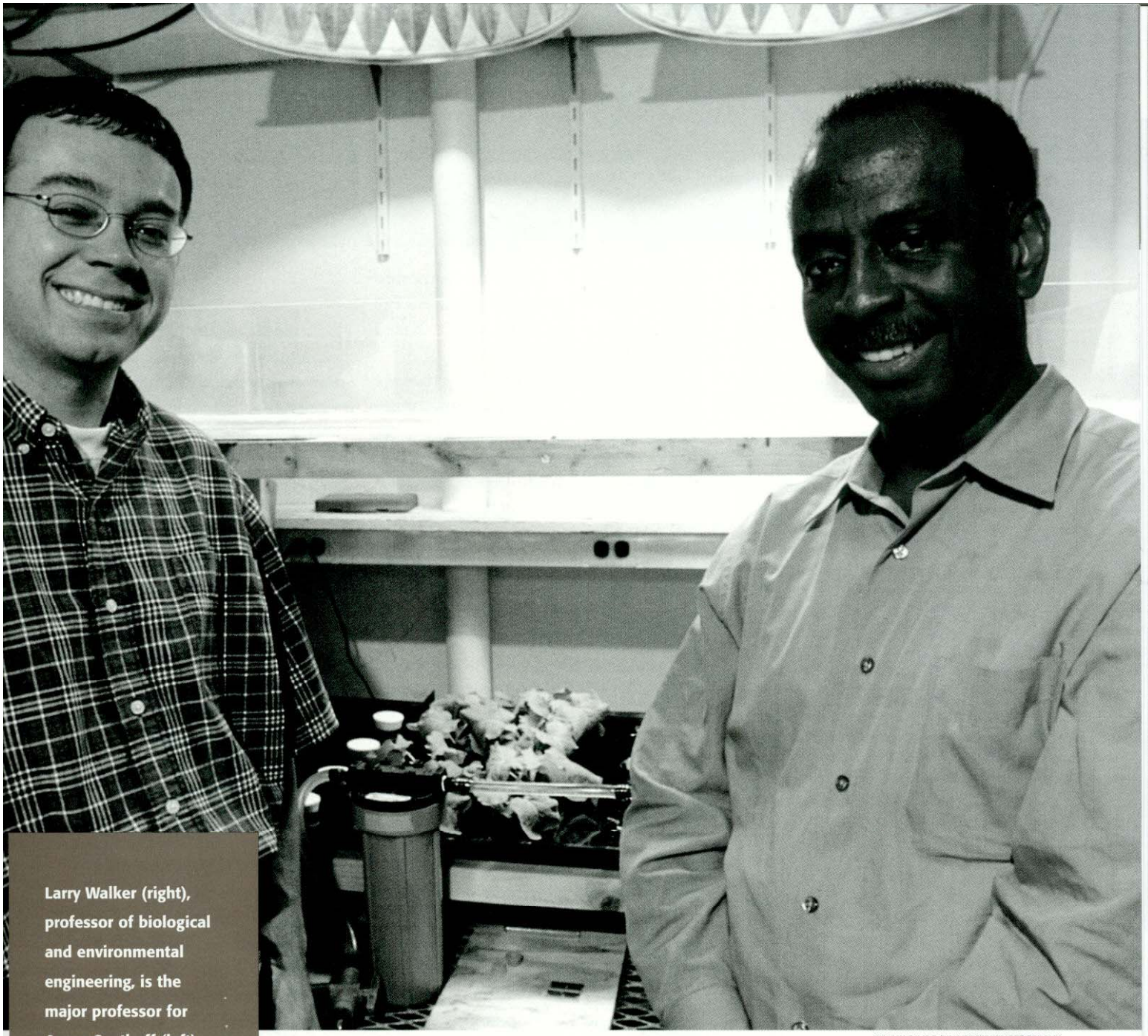
New Energy Sources Have Their Roots and Future in Agriculture

Researchers in the College of Agriculture and Life Sciences are finding ways to generate energy and industrial products from plants to preserve the biosphere, boost economic prosperity, and foster national security.

by Joe Wilensky



Larry Walker (right), professor of biological and environmental engineering, is the major professor for Aaron Saathoff (left), a Ph.D. student who is researching cadmium uptake in plants for environmental clean-up.

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The answers to the world's growing energy needs can be found in our agricultural past but can only be realized with the tools of the future, Larry Walker says.

"If you go back 120 years, most of the industrial products used in this country all came from agriculture," says Walker, a professor of biological and environmental engineering in the College of Agriculture and Life Sciences. "This was before we became an oil- and petroleum-based economy."

Over the next decade or two, the demand for energy and raw materials will increase as concerns continue to mount regarding the depletion of natural resources and climatic changes due to the emission of greenhouse gases. A tremendous challenge is being posed: to generate new material wealth utilizing industrial systems that are carefully linked to the natural material and energy flows of the biosphere and don't jeopardize the health of the planet.

Agriculture can provide the raw materials that can be converted into industrial chemicals and energy to create agriculturally based bioindustries.

We're returning to the idea that we can rely on a plant- and microbial-based infrastructure for producing many of the goods we need, Walker explains. This has already begun—companies are producing soy-based ink, plant-based pharmaceuticals, and biodegradable polymers. "We're taking an agricultural role in a nonfood area and expanding it," he says. This new role has become possible only recently because of engineering and scientific breakthroughs in genomics, metabolic engineering, advanced screening, fractionation, and separation systems.

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Walker has had the opportunity to help set the parameters and goals for this rapidly expanding frontier. He is a member of the National Biomass Research and Development Technical Advisory Committee, which was established by the U.S. Biomass Research and Development Act of 2000. The committee, a group of 26 people from industry, academia, nonprofits, and the agricultural and forestry sectors who are considered experts in their fields, established a collective vision of far-reaching goals to increase the role of bio-based energy and products in our nation's economy.

Currently, less than 5 percent of U.S. energy consumption and less than 10 percent of specialty chemicals, intermediate chemicals, and commodities are produced from plants. The Biomass Research and Development Technical Advisory Committee drafted a vision statement and a road map, setting goals for a projected transition to plant-based materials: by 2020, at least 25 percent of the 1994 levels of organic carbon-based industrial feedstock chemicals and 10 percent of liquid fuels will be produced by bioindustries; and by 2050, up to 90 percent of the U.S. organic chemical consumption and up to 50 percent of the liquid fuel consumption will come from bio-based industries. Also required for this ongoing transition is incorporating "green" thinking—the smart design of products, processes, and systems—into the development of new industries.

Big companies like Cargill, DuPont, and Dow Chemical are already producing products like biodegradable polymers in crops such as corn. These large companies, ones that historically produced the bulk of their materials from petroleum, are now running their own research centers for plant biotechnology and expect to get more and more of their industrial chemicals and energy from plant sources. "Petroleum products won't be available cheaply forever," says Beth Ahner, assistant professor of biological and environmental engineering in the College of Agriculture and Life Sciences.

"This whole concept that we're going to use renewable resources to provide energy, industrial raw materials, and more material products for consumers also provides another outlet for rural communities to be part of the economy," Walker says. This is

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reflected in the philosophy of the U.S. Biomass Research and Development Act of 2000, which also stresses that from the standpoints of national security, economic development, and rural development, alternatives to oil must be found, and this should happen from a sustainable and green perspective.

"Many of us see this as an agricultural/biotechnology initiative," says Walker. "Others see this as an environmental initiative to promote better stewardship of our agricultural resources. Others see it as a renewable energy initiative, and still others as an economic development initiative."

By integrating science and engineering concepts across the scale from nanobiotechnology to industrial ecology, a new generation of engineers, scientists, and researchers can be poised to fulfill the goals of all these initiatives.

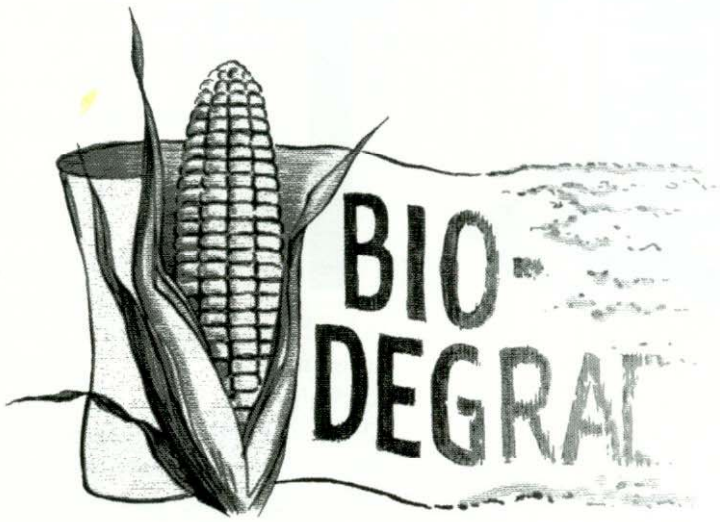
One way to prepare this next generation is through a Cornell program headed by Walker, titled "Educating Young Researchers for Sustainable Agriculturally Based Bioindustries," which received four years of funding from the U.S. Department of Agriculture in 2001. The core of this program is the Multidisciplinary Graduate Education Traineeships (MGET), in which Ph.D. and M.S./Ph.D. students receive fellowships.

The program's goals stretch much further, though, to engaging the broader student community, intellectually, in designing and developing these innovative bio-based industries. By integrating research graduate students, professional students, and undergraduates, the MGET program aims to provide students with fundamental training in science and engineering; to train students to work effectively in multidisciplinary teams of both basic and applied researchers; to provide students with a global perspective on the opportunities and challenges for developing sustainable bio-based industries; to create a multilevel graduate education program that integrates professional degree students, research students, and undergraduate students; and to increase the participation of women and minorities in what is a strategic national priority.

The MGET program was funded through the USDA's Initiative for Future Agriculture and Food Systems (IFAFS) program as an effort by the USDA to attract some of the nation's top students to agriculture and related sciences. The USDA recognizes that the problems confronting agriculture and rural economies require a multidisciplinary approach in generating solution alternatives.

The USDA awarded four of these grants in MGET's area, and Walker's program was the only one dedicated to developing bio-based industry.

Recent and ongoing research projects include the prospecting of plant cell walls for novel industrial enzymes; fermentation parameters to increase production of a biocontrol agent; environmental technologies such as optimizing biofilms for removing pollutants from air streams; biosensors for operation of these industries; and industrial ecology for efficiently utilizing lignocellulose materials for energy and industrial chemicals.



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Eight graduate students were initially enrolled in the MGET program, with up to four additional students expected to join this fall. The students are being funded for up to two years each. The students in the program work together and take some core courses together, such as Challenges of Developing Sustainable Bio-Based Industries, and they work on multidisciplinary teams with others who seek to integrate concepts across the scale from molecular biology to industrial ecology, Walker explains.

The student teams are made up of plant pathologists, plant biologists, microbiologists, biological engineers, and environmental engineers. The students come from two colleges and six departments.

A key focus of the MGET fellowship program is the diversity of the faculty involved. "It's about getting basic and applied researchers to come together and make an impact in a very important area—for national security, for economic development," Walker says. "It ties into the New Life Sciences Initiative, it ties into environmental initiatives, and it ties into one of the four priority areas for the college."

The MGET program isn't the only area where Walker is working toward strengthening the college's faculty, students, and research in bio-based industries. He is also the program leader for the Sustainable Agriculturally Based Bioindustries Cluster (SABBIC), a multidisciplinary group of biological and physical scientists, engineers, economists, management specialists, and humanists dedicated to developing opportunities to use agriculturally based resources to produce energy, industrial chemicals, and novel natural products through the application of fundamental research, advanced engineering research, and industrial development concepts.

The activities of this faculty cluster rely heavily on recent breakthroughs of molecular biology, genetics, and advanced engineering research. At the other end of the process, they attempt to bring the scientific and technological revolution to rural communities and thus create a strong bio-industry sector in New York State. This would make rural communities more economically diverse and profitable and could even help return abandoned farmland to commercial use.

The spirit of the SABBIC group is perfectly captured by its multidisciplinary makeup, Walker says. Its members include Ahner, an environmental engineer; Jocelyn Rose, a plant biologist; and Rosemary Loria, a plant pathologist, among others.

Cornell University is also part of the Sun Grant Initiative, a federal initiative dedicated to solving America's energy needs and, at the same time, to revitalizing rural communities (its slogan is "Rural-based industries provide energy security"). The initiative is a national network of land grant universities and U.S. Department of Energy Laboratories that have partnered to build a bio-based economy.

Cornell is one of five leading land grant universities in this bioenergy and bioproduct initiative. By broadening their responsibilities beyond traditional agricultural issues, these

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universities are emphasizing research, higher education, and extension programs on renewable energy and bio-based industries.

Walker is also involved in numerous ongoing conferences, workshops, and economic development efforts in New York and the Northeast. He is part of a group based in Buffalo, N.Y., that is working to form a bio-based industry hub in western New York and he will be a key player in creating a bio-based industry "road map" for the Northeast.

Walker hopes these ongoing efforts will create opportunities for young entrepreneurs to start small businesses in bio-based industries. Last fall, a group of faculty and MGET students met with economic development leaders in western New York, and this spring Walker, Professor Roger Spanswick of the Department of Biological and Environmental Engineering, and students traveled to Ottawa, Canada, to meet with the leaders of the first company in North America to build a pilot plant that makes ethanol from grasses and hay.

Ahner works closely with Walker within this "umbrella group" and says that their work facilitates their connections to the outside world. "Sometimes faculty remain somewhat isolated from industrial development and from economic development efforts like those of the Buffalo group. This linkage facilitates the whole transfer of research and technology to the field and to the people who need it. It's helpful, in the long run, to the development of these industries."

Ahner adds that her involvement with Walker's group has even shifted the emphasis of her own research toward a more applied science. "The interdisciplinary nature of bringing the faculty together has certainly molded how I think about things," she says. "I've been primarily looking at some basic science questions, and as an engineer, I wanted to work on applied problems," she says. "I've found some projects that really connect what I'm interested in—trace metal chemistry and trace metal pollutants—to bio-based industry development where I can make a difference."

All these efforts to create and sustain agriculture-based bioindustries have a natural home at Cornell and within the College of Agriculture and Life Sciences. "I see this as an opportunity for Cornell, as a land grant university, to fulfill its education, research, and outreach mission," Walker says. "It's matching the ability to do great basic and applied science with the goal of a more secure energy future and to provide better and more opportunities for economic development in rural communities."

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Illustrations by Jim Houghton