Biotechnology lab opens new doors in agriculture

A new biotechnology laboratory at Disney World's EPCOT Center will show the public the potential for new technologies in agriculture, reports Marsha Freeman.

On Oct. 7, an unusual exhibit opened in the Kraft Company's Land pavilion at Walt Disney World in Florida. It is the first biotechnology research laboratory open to the public, where every day, people will be able to watch scientists doing research that will have a direct effect on the quantity and quality of the food they eat in the future.

To some sections of the radical environmentalist movement, "biotechnology" has become the scare word of the 1980s, the way "nuclear power" and "radiation" were in the 1970s. Conjuring up visions of "biologically engineered" mutants, and experiments that produce "the fly that ate New York," the likes of Jeremy Rifkin have sometimes succeeded in stopping or delaying important research.

The recent conviction and prison sentence of food irradiation pioneer Dr. Martin Welt over minor violations of federal regulations is an example of how ignorance can be organized into an anti-science mob to stop new technologies from feeding the world's hungry. The 30% of the world's food that is harvested but rots before it can be consumed, could largely be saved if the food irradiation technology developed by Dr. Welt were widely applied.

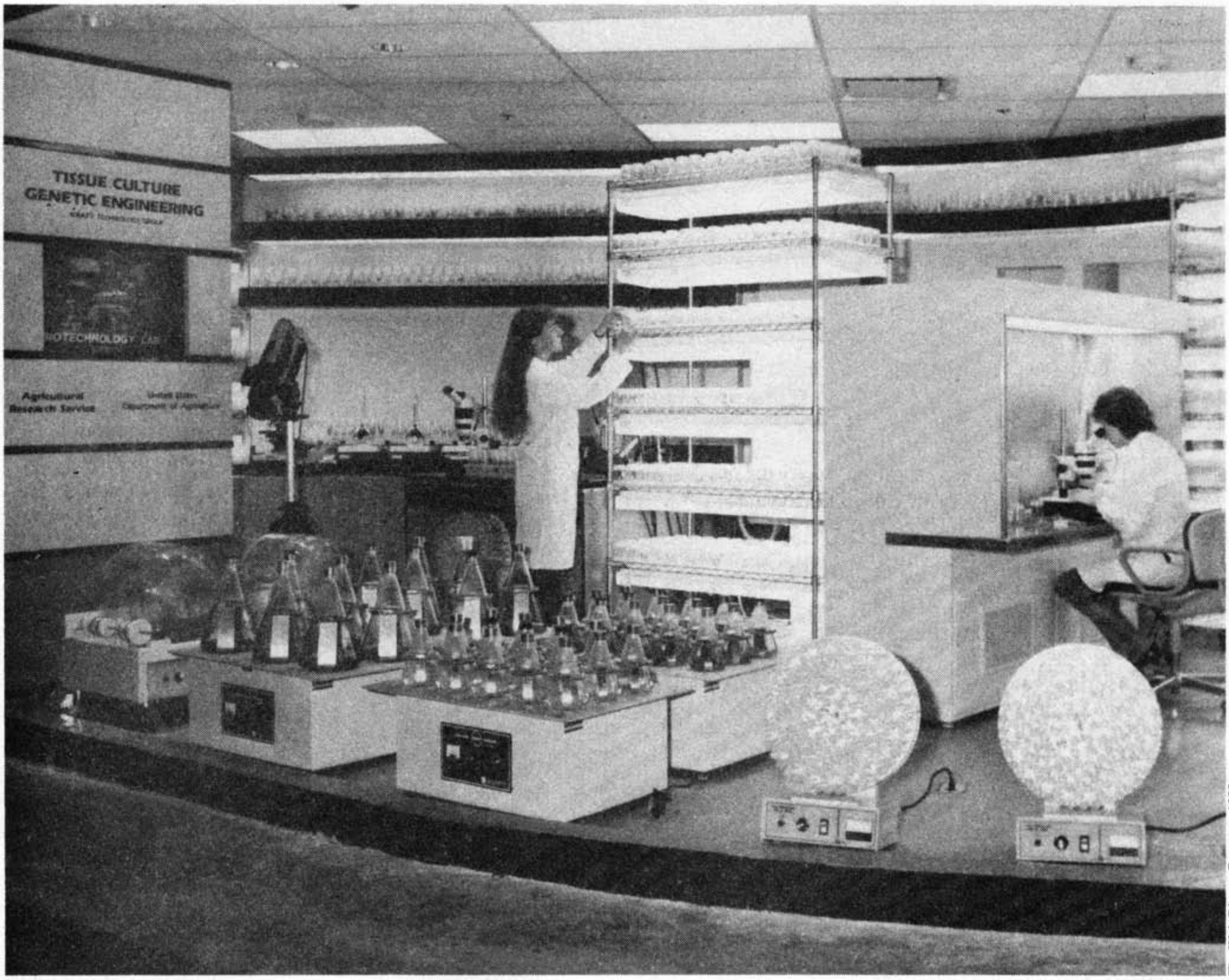
In order to educate the American public, in particular, about the science and promise of biotechnology, the U.S. Department of Agriculture (USDA) has joined with Kraft Foods and Disney to put some of the research on display. Michael A. Miles, the president of Kraft, stated at the laboratory dedication Oct. 7 that the purpose of the exhibit is "to demystify plant biotechnology for the general public."

Apparently, public "opposition" to biotechnology research exists not only in the United States. The Land agricultural manager, Dr. Henry Robitaille, reported at a seminar held after the laboratory dedication that the Aug. 12 issue of *Science* magazine reported the shutdown of a Soviet biotechnology laboratory "due to the reaction of the public and the press." At the dedication ceremony, Secretary of Agriculture Richard Lyng said, "Over the past week, America's visions of the marvels of science have been dramatically rekindled by the successful flight of the Space Shuttle Discovery, which, incidentally, was launched about 60 miles from here at Cape Canaveral."

"In the same manner," he continued, "this exhibit will help create a deeper understanding of the marvels of science here on Earth, and its importance to the most basic part of our daily lives—the production of food and fiber. Our scientists are on the threshold of many exciting discoveries, that are every bit as important to the future of mankind as the explorations in space.

"Through technologies like tissue culture, which you'll see in this exhibit, I'm convinced that our nation's researchers are capable of unlocking many of the remaining mysteries of plant science, so that no one on this planet will ever need to fear that the world's farmers cannot produce enough food for our survival."

Asked by this reporter if the current food crisis, produced in part by the drought of 1988, would change the Department's lack of support for long-term research, Lyng said that



The Walt Disney Company 1988

New Plant Biotechnology Laboratory at Kraft Food's Land Exhibit at Disney's EPCOT Center

not investing in research is "short-sighted."

Lyng also said that the laboratory will "stimulate young people's interest in science," and perhaps interest them in vocations in technical fields. They will be moving into a world "where population continues to grow and food needs to grow with it," he stated.

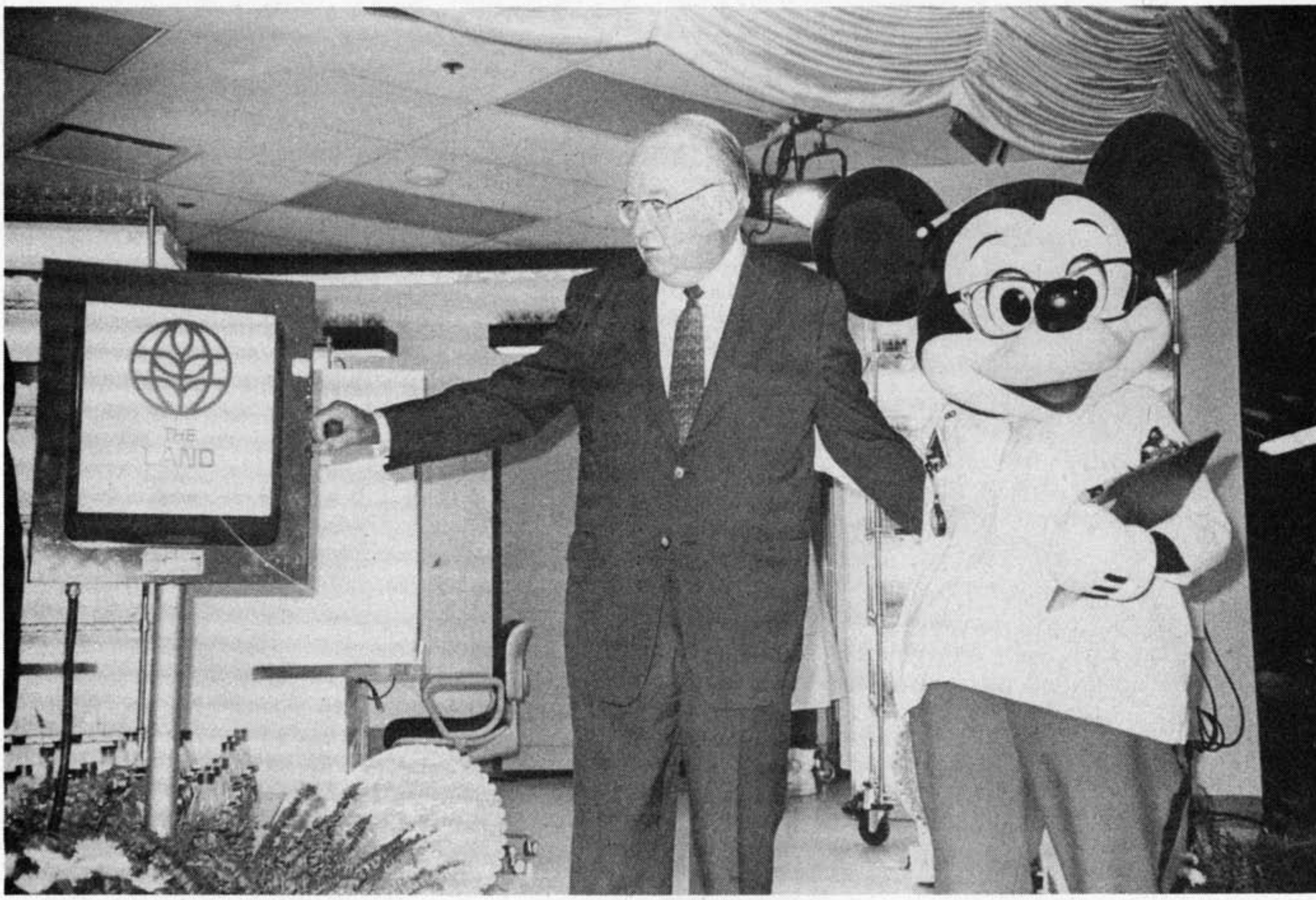
The new laboratory houses over $200,000 in research equipment, donated by the Agricultural Research Service of the USDA, in a 500 square foot facility built by Kraft. It is the last stop in a series of greenhouse and aquaculture facilities toured by visitors, as they go through the exhibits on a boat ride.

Since the Kraft Land pavilion and EPCOT Center itself opened in 1982, more than 50 million people have been through the exhibit. Approximately 300 people per day choose to learn more about tomorrow's food technology by taking an added walking tour through the greenhouses, with a staff member of the Land as a guide. Since the opening of the Land, Kraft has had biotechnology research under way, although until now it has not been open to public view.

About one year ago, Kraft opened a new part of an exhibit at the Land. It is a joint project with the National Aeronautics and Space Administration's Kennedy Space Center, using soil that is a simulant of lunar soil, to do experiments that will determine how best to grow food on the Moon.

In the Land's Desert House, visitors see drought-tolerant crops under cultivation. These are not now being widely used in many of the arid parts of the world. Salt-tolerant plants, called halophytes, are also grown in the Desert House, and their development could lead to the reclamation of salinated soils, and could reverse the spread of deserts.

The Kraft exhibit shows extensive use of non-soil-based agriculture in closed greenhouse environments. These include hydroponic systems, where the plants are grown in a liquid nutrient medium, and aeroponics, where the plant roots are in the open air and periodically sprayed with a nutrient



Marsha Freeman, 21st Century Science & Technology

Left, Richard Lyng, U.S. Secretary of Agriculture, speaking at the dedication for the biotechnology laboratory

solution.

In the Tropics House, the visitor sees little-known crops under cultivation, easily adapted to tropical climates, which could increase food production in developing nations. This includes varieties such as the winged bean, whose seed contains up to 37% protein, which, some scientists feel, has the potential to become the "soybean of the tropics."

In closed-environment agriculture, pest management is difficult because the elements of weather, such as wind and rain, that act upon agricultural chemicals in open fields, do not exist. Therefore, it was very important for the new plants being cultivated to be as disease-free as possible from the start.

Rather than planting crops from seed, many of the thousands of plantlets that are needed in the greenhouse exhibits at the Land are started using a tissue culture—a piece of an existing plant from which an entire new plant can be cloned. In addition to decreasing the time needed to start the next generation of plants, the identical clone will have essentially the same characteristics as the original, including possible resistance to disease.

As agriculture manager Dr. Henry Robitaille explained at the opening of the laboratory, "Biotechnology isn't new to the Land; it simply moved from backstage to 'on stage.' "

The sponsors of the exhibit hope this laboratory, presented in both an educational and entertaining way, will dispel people's fear and ignorance about some of the tools that will help eliminate hunger from the world's peoples.

The promise of biotechnology

For many years, farmers and agricultural specialists have worked to improve the stock of crop plants on which the world depends for its sustenance. Previous successes in cross-breeding to produce hybrid strains of corn, for example, significantly lessened the drought damage to that crop this past summer.

The promise of one area of application of biotechnology is to more precisely and scientifically alter nature to optimize the productivity of agriculture. The tools include genetic engineering, made possible by the breakthroughs in understanding how genetic codes for specific characteristics are passed on to succeeding generations. A gene that controls the expression of a desired trait, for example, can be introduced into one plant species from another, in cases where the plants would not cross-breed.

This is being directly done in the Kraft biotechnology laboratory, where a graduate student is experimenting with combining positive traits of a newly developed peanut strain, with the wild peanut farmers now grow. The two varieties are sexually incompatible. Through genetic engineering, this can be bypassed, to allow for the direct transfer of desirable genes from one variety to the other, creating a new hybrid variety.

According to Dr. Robitaille, tissue culture technology allows the generation of a new plant from some tissue of an existing one. This can be used to very rapidly multiply the important and improved disease-free new peanut plants in large quantity, without waiting for each plant to complete an entire growing cycle and produce seeds. Large numbers of these quickly grown new plants can then be used to produce large numbers of seeds for farmers.

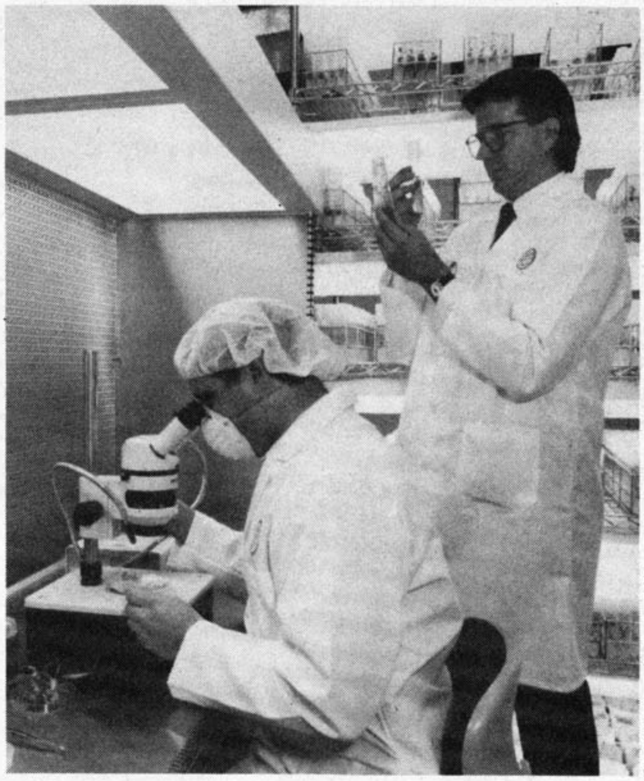
During the first half of this year, the Department of Agriculture sponsored a series of four regional information conferences titled, "Agricultural Biotechnology and the Public." These were held in Raleigh, North Carolina; Reno, Nevada; New Brunswick, New Jersey; and Minneapolis, Minnesota. Scientists presented material on the promise and achievements of biotechnology in an informative and largely nontechnical format.

Dr. Ken Farrell, vice president for agriculture and natural resources at the University of California, described the possibility of making plants immune to disease. Viruses invading a cell do not reproduce themselves, but instead send out a genetic "message" to the host cells of the plant, to reproduce the virus. By changing one of the virus gene messages, the live virus can be made incapable of commanding the host to reproduce it. When a genetically engineered virus which will not reproduce invades a plant, the cell recognizes it as a foreign body and builds up an immunity to future encounters with the natural, disease-producing virus. The plant becomes immune.

Biotechnology has already spun off other technologies which will effect the diagnosis and treatment of *human* diseases. For example, Dr. Charles Sterling of the University of Arizona reported to a regional conference on rapid tests for diagnosing three diseases caused by parasites, which have been developed through biotechnology.

Dr. Sterling developed monoclonal antibodies that recognize the antigens produced from Cryptosporidium, which is a diarrhea-causing protozoan transmitted in polluted water. It frequently attacks small children, and has been found in one-fourth of all AIDS victims. The parasite is a serious threat to very young or malnourished children, and the organism cannot be killed by conventional water treatment. Quick diagnosis is key.

Dr. Sterling bound the antibodies he produced with a chemical that produces a fluorescent glow. Within 20 minutes, the resulting reagent reacts with a smear sample from a patient, showing whether the person is infected with the parasite. Other parasites have been shown to react to Dr. Sterling's tests. If doctors are able to identify the specific parasite early, they can avoid the use of drugs that may worsen the disease, and can try to treat the patient as well as possible.



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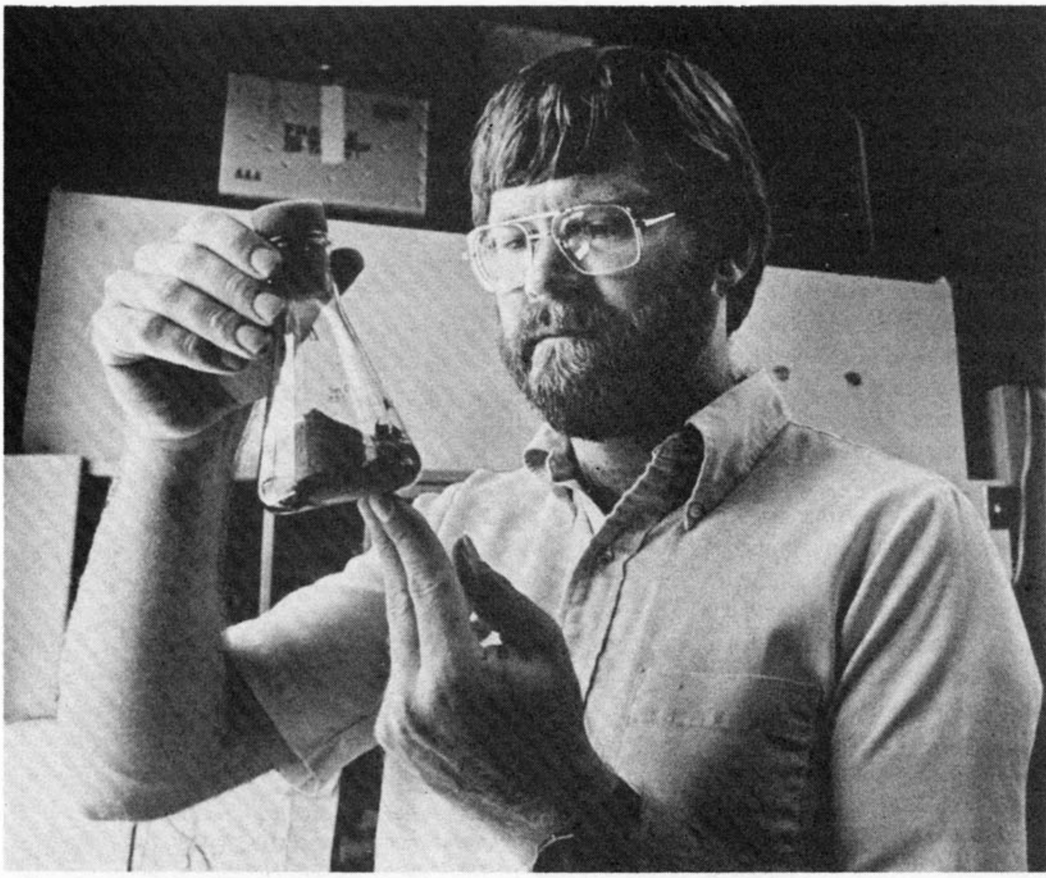
The Land scientists are studying ways to propagate improved crops. Here staff members examine carrot plantlets grown in test tubes, and meristem tissue taken from a potato plant.

Biotechnology is also important in shortening the time it would otherwise take to improve the stock of plant species used by man. Trees are a good example. Dr. Ralph Mott of North Carolina State University reported to a regional conference that emerging biotechnologies provide the first hope of surmounting one natural obstacle to breeding trees—time.

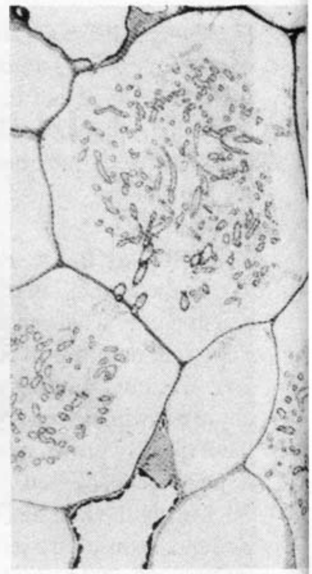
It can require 5 to 15 years to establish seed orchards and seed production for better-yielding trees with higher disease resistance, Dr. Mott stated. Then, an additional number of years is needed to propagate the new variety and produce seeds. He has done pioneering work in tree tissue culture to clone trees with superior qualities. That process can take from 5 to 15 years off the total time of improving trees. Mott and his associates have cloned thousands of trees that are in field tests across the southeastern part of the country.

The tools of biotechnology can be used to produce crop plants that are disease resistant; more drought, heat, and cold tolerant; less perishable; and more nutritious.

One of the most promising applications of genetic engineering over the past 10 years has been the development of engineered bacteria that help prevent the formation of frost,



University of California



Dr. Steven Lindow, who pioneered the research in ice-minus bacteria, to protect fruits and vegetables, in his laboratory.

which kills between $1 and $3 billion of produce in the United States every year. The story of how this scientific work became the *cause célèbre* of this country's anti-technology extremists is instructive, and demonstrates why an educational effort to explain biotechnology research to the public is important.

Ice-minus bacteria

About half of the fruits and vegetables that are lost to frost each year in this country, suffer drops in temperature to not lower than 23°F. Frost damage is triggered by a common and naturally occurring bacterium—pseudomonas syringe. This organism produces a protein that serves as the nucleus for the formation of ice crystals on the plant. The bacterium also exists naturally in a non-ice-forming variety which does not produce the protein. This however, is not abundant enough in nature to displace the destructive variety.

Dr. Steven Lindow and Dr. Nickolas Panopoulos of the Plant Pathology Department of the University of California at Berkeley conservatively estimate that about half of the total lost could be saved with a non-destructive bacteria they have developed, and are now field testing. They used recombinant DNA techniques to delete the one gene that codes for the protein production in the bacteria, and produced a genetically-engineered non-ice-forming organism, which they describe as "ice-minus," written INA^-.

After extensive laboratory testing of the genetically engineered bacteria applied to plants, Lindow and Panopoulos in 1982 obtained approval from the National Institutes of Health to do open field testing of the bacteria on potatoes.

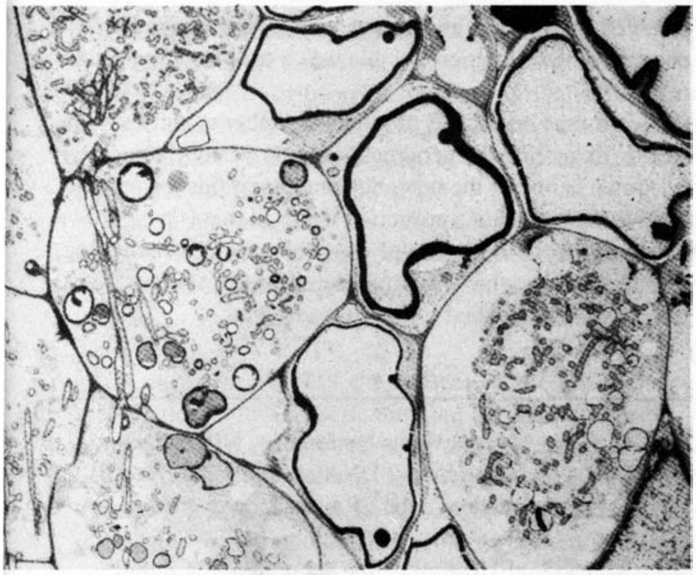
The method of the proposed experiment was to "preemptively" colonize the plants with the INA^-, giving it a head start as the dominant bacteria, replacing the ice-forming bacteria.

Extensive laboratory testing had already established that this altered bacteria has no harmful effects on plants, birds, insects, or animals (including man), that it thrives only on the leaves of plants and does not live long in the soil, and that it has no observable pathogenic effects of any kind.

That did not stop malthusian Jeremy Rifkin, who heads the Washington-based Foundation for Economic Trends, and citizens whom he organized, into trying to stop the research. They succeeded in delaying the testing for four years.

Even with the media on his side, however, Rifkin did not win the fight. In general, the people of this country are not sympathetic to the arguement made by Rifkin that God created a "fixed universe," and that the law of entropy dictates that we should not develop new technology to feed a growing world population, as he states in his book, *Entropy*.

The torturous history of gaining approval for the testing

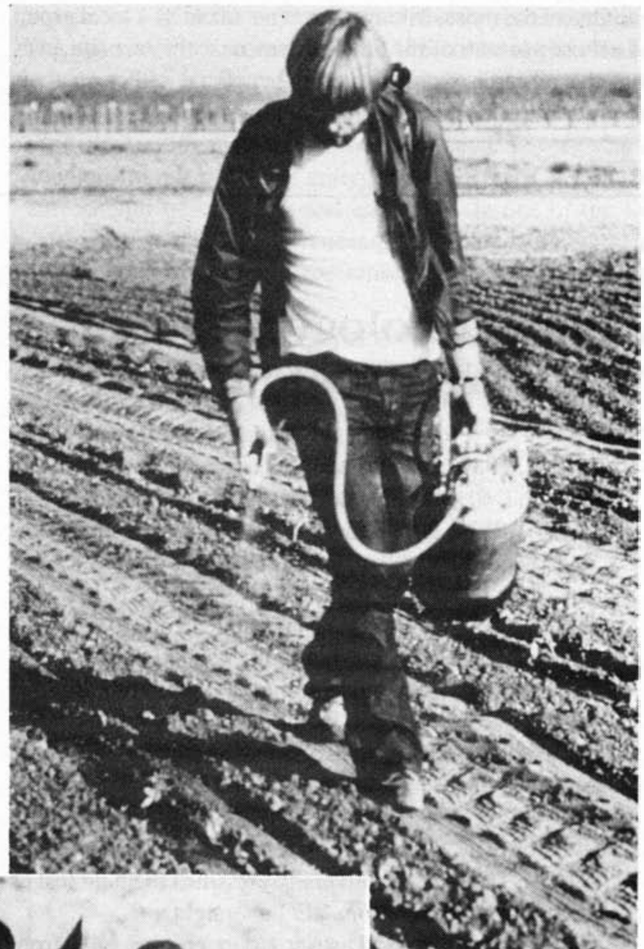


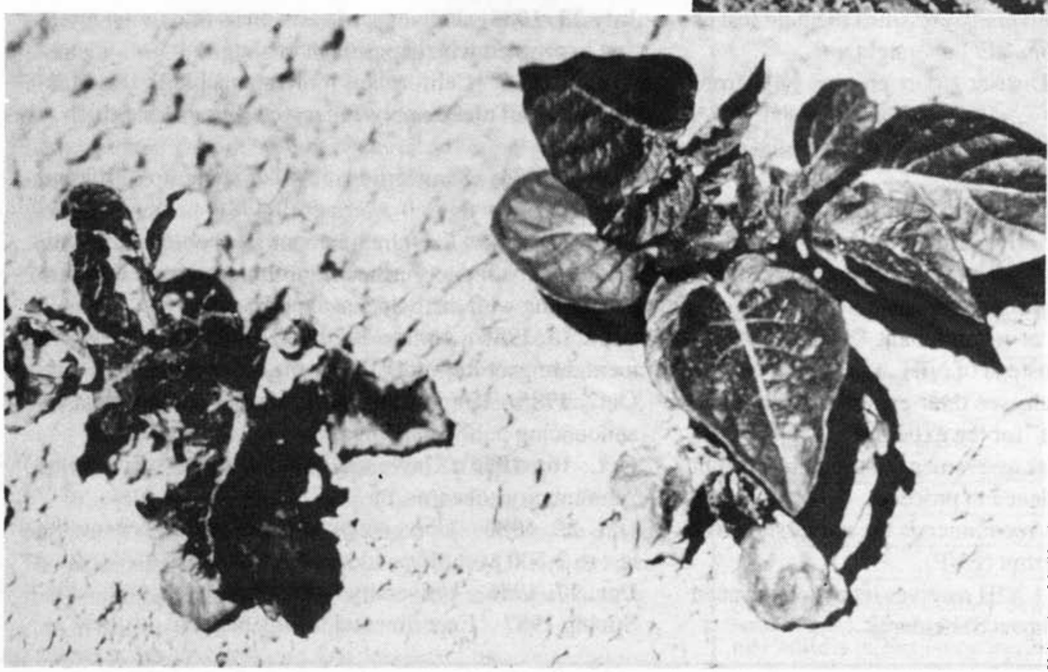
Nitrogen-fixing bacteria can be genetically engineered to increase agricultural productivity. In this micrograph, the naturally-occurring nitrogen-fixing bacteria, Frankia, in the shape of filaments, is seen inside the cells of an Australian pine tree.

of the the ice-minus bacteria is described in the accompanying box.

Testing of the treatment finally began in the spring of 1987. Lindow reports that in the first year of a two-year test program, the behavior of the bacteria was similar to the laboratory experiments, and some frost protection of potato plants was observed. When this writer asked Lindow if there were plans for testing other crops or testing other varieties of bacteria, he said that he had no such plans at this time, because "it is too expensive."

During the four years when the University of California was fighting the environmental extremists, over *half a million*





University of California

Dr. Lindow demonstrating the spraying procedure used in the field test experiments, to see if his genetically-engineered bacteria can protect plants from frost. Inset: Frost-injured and frost-protected potato plants.

dollars was spent on legal briefs, preparing reports for government agencies, running public education events for the local citizenry, and preparing a multi-hundred-page environmental impact report. During the testing, vandals uprooted 100 potato plants, which the scientists had to replant, and paid security guards had to be placed around the test plot.

One of the most striking comments made by a local group of officials in one of the small towns near the test site, was that the research would have no beneficial effect on their community. Considering that the "community" is mainly engaged in farming, and that the ice-minus bacteria would protect some of their crops, this was a truly irrational statement.

Ice-minus research is of interest to other countries of the world. Extending the geographic region where produce can be grown is one of the potential benefits of this technology, in addition to saving a portion of the food that is now grown but lost to frost. It is certainly possible, though distressing, that this work, which was pioneered in the United States, may have to be applied somewhere else first.

Biotechnology research sabotaged for four years

Sept. 17, 1982 Scientists apply to the National Institute of Health (NIH) for field-test approval.
Oct. 24, 1982 NIH Recombinant DNA Advisory Committee meeting, with the public invited to attend and comment.
Jan. 10, 1983 NIH approval is withheld due to concerns expressed at the Advisory Committee meeting.
March 3, 1983 Scientists submit a revised proposal for testing.
June 1, 1983 NIH grants permission for testing.
Sept. 14, 1983 Lawsuit filed against NIH claiming violation of EPA and Council on Environmental Quality regulations, by Jeremy Rifkin, et al.
Sept. 30, 1983 The university classifies the field test as categorically exempt from CEQ oversight.
May 16, 1984 U.S. District Court enjoins NIH from approving the deliberate release of recombinant DNA products until it reaches final judgment on potential environmental impact.
Dec. 27, 1984 Scientists notify the EPA of intent to conduct field tests.
Dec. 31, 1984 Office of Science and Technology Policy in the White House publishes proposal under which certain deliberate releases of recombinant DNA may go to the EPA for approval, instead of NIH.
Jan. 21, 1985 NIH releases their evaluation that there is "no significant impact" for the experiment.
Feb. 15, 1985 EPA risk assessment states there is slight risk but insufficient evidence to proceed.
March 15, 1985 EPA recommends the university have an Experimental Use Permit (EUP).
April 24-May 17,1985 NIH receives letters on the need for an Environmental Impact Statement.
Dec. 17, 85 At legal status conference, NIH agrees to follow EPA for recombinant DNA research and the university will not challenge the EPA decision to require an EUP.
Dec. 30, 1985 EUP application submitted by Lindow.
March 7, 1986 EPA sends out EUP for review by Scientific Advisory Panel, and other federal agencies.
April 17, 1986 EPA personnel do on-site inspection at field station Tulelake.
April 21, 1986 In Federal District Court, plaintiffs agree to vacate a preliminary injunction preventing NIH from approving other deliberate release of recombinant DNA material without EPA approval.
May 1, 1986 An initial date is proposed for the experiment.
May 12, 1986 EPA grants the EUP application.
June 2, 1986 Modoc County Board of Supervisors passes resolution opposing the experiment.
June 11, 1986 Siskiyou County Board passes resolution opposing the experiment.
July 23, 1986 University issues press release on intention to proceed with experiment on Aug. 6.
Aug. 1, 1986 Californians for Responsible Toxics Management of Tulake apply for restraining order, which is denied.
Aug. 4, 1986 Same group reapplies again, to a different judge.
Aug. 19, 1986 Legal agreement reached that the University will conduct further environmental review before proceeding with the field test experiment.
Sept. 18, 1986 Notice of Preparation of Draft Environmental Impact Report (EIR) by the university.
Oct., 1986 University places ads in local newspapers announcing public meetings.
Oct. 16, 1986 University holds public meeting on "community concerns."
Oct. 25, 1986 University sends notices describing the test to 2,500 post office addresses in the area.
Dec. 17, 1986 University issues draft EIR.
Spring 1987 Experimental testing begins.

Nitrogen-enhancing bacteria

There are other important microorganisms that are now being genetically engineered to increase agricultural productivity. Scientists at the University of Florida are examining the use of blue-green algae, called cyanobacteria, to enhance the delivery of nitrogen to plants.

The nitrogen required for plant growth is usually supplied either by the farmer in the form of ammonia fertilizer, or by the biological fixation of nitrogen in the atmosphere by bacteria accompanying legume plants, such as soybeans and peas.

In the natural process, the nitrogen fixation, or metabolic assimilation of atmospheric nitrogen by microorganisms, is catalyzed by an enzyme called nitrogenase that is present in the bacteria. Some bacteria produce ammonia, and rather than using it for their own growth, they pump it out and make it available to surrounding plant roots. However, in naturally occurring bacteria, nitrogen fixation is very energy-intensive, and the energy is taken from the surrounding plant.

Dr. K.T. Shanmugum and colleagues at the University of Florida have been studying nitrogen availability in growing rice. Specifically in rice paddies, the free-living nitrogen-fixing bacteria do not release the fixed nitrogen, but use the ammonia for their own growth. To increase the productivity of the crop, researchers have been experimenting with a mutant strain of cyanobacteria where the fixed nitrogen is not assimilated by the bacteria, but, rather, is made available to the plants.

In these experiments, rice plants grown with the altered bacteria, called SA-1, had an eightfold increase in dry weight compared to the control group, which had been given no nitrogen supplements. The rate of growth was 18 times higher, and not significantly different from that of plants that had been fertilized. The scientists hope that the bacteria can supplement growth in cases where fertilizers are not yet available.

The total nitrogen content of the plants in the experiment demonstrated that the SA-1 bacteria did supply them with nitrogen for growth, because their nitrogen content was 5.8 times larger than the control group, though it was lower than the fertilized plants. In these experiments, the amount of SA-1 added was low, and it has been reported that the effect is enhanced with more concentrated treatment.

These two specific examples of ongoing research in genetic engineering in agricultual biotechnology are a very small sample of the broad range of research under way.

Crucial factors: education and funding

In a two-hour seminar held after the formal dedication ceremonies on Oct. 7 at the Kraft pavilion, Land manager Dr. Robitaille and Dr. Alvin Young of the USDA stressed that funding and skilled manpower are key to continued progress in this field.

Dr. Robitaille reported that, recently, the congressional Office of Technology Assessment released a report titled, "U.S. Investment in Biotechnology." According to Robitaille, the report emphasized that federal support for research in crop plants has been neglected by Congress, and must be increased.

He stated, "The potential impact of biotechnology on all aspects of life in the next century are truly mind-boggling. The economic consequence to the U.S. of losing the lead in biotechnology to our competitors, is staggering."

Dr. Young reported that, according to the USDA, 50,000 additional young men and women are "needed every year to maintain our agricultural enterprise." Of these, he stated, 29% should be scientists and engineers. In one of the Department's regional conferences, Dr. Young had commented, "Regulatory restraints are inhibiting innovation and commercialization."

As in such fields as superconductivity, the United States can easily lose the lead in biotechnology. One outcome of the Kraft exhibit will hopefully be not only to dispel the fears and myths the public may have about these frontier technologies, but also to increase awareness of why this research should have a higher priority and funding profile.

Marsha Freeman is an associate editor of 21st Century Science & Technology *magazine.*