anyone has been able to make. Now asteroid Braille looks to be a bigger chip off Vesta.

Given the match with Vesta, planetary scientists have a plausible story of how Braille, as well as eucrite meteorites, were born. As impact specialist Eileen Ryan of New Mexico Highlands University in Las Vegas, New Mexico, explained, Braille and the eucrites could have been blasted off Vesta in the huge impact that left a 460-kilometer crater, which is visible in Hubble Space Telescope images of the asteroid. The likely debris can be seen as small, Vesta-colored asteroids near their parent and strewn across the asteroid belt to a point where Jupiter's gravity could fling it in toward Earth. Braille hasn't yet gotten as far as the eucrites, but Soderblom noted that it will be drifting across Earth's path in the next few thousand years, possibly making it the planet's "Y6K" problem. –RICHARD A. KERR

BIOTECHNOLOGY

New Genes Boost Rice Nutrients

ST. LOUIS—The latest high-tech version of rice may look like the saffron rice of paella, but the pretty yellow color is far more than decoration. Described here last week at the 16th International Botanical Congress, the golden rice has been genetically engineered to contain β-carotene, the precursor to vitamin A, as well as a healthy dose of iron. This achievement, by plant molecular biologist Ingo Potrykus at the Swiss Federal Institute of Technology in Zurich and his colleagues, is not only a Herculean feat of gene transfer, but also a major leap on a more humanitarian front: It may offer improved nutrition for the billions of people in developing nations who depend on rice as a staple food.

Many researchers have already slipped one or two foreign genes into everything from tomatoes to cotton, endowing them with traits such as resistance to herbicides, plant pests, or pathogens. But the rice strain created by the Potrykus team carries a total of seven foreign genes from two separate pathways: Four encode enzymes that give rice grains the ability to make β-carotene, and three more allow the kernels to accumulate extra iron in a form that the human body can better absorb. Gene transfer on this scale, says plant biochemist Dean DellaPenna at the University of Nevada, Reno, "is tremendously exciting and should have an enormous impact."

"This is the first kind of rice that is genetically engineered for nutritional enhancement," adds Gurdev Khush, principal plant breeder at the International Rice Research Institute (IRRI) in Manila, Philippines, and the humanitarian payoff could be high. Vitamin A deficiency affects some 400 million people worldwide, leaving them vulnerable to infections and blindness. And iron deficiency—the number one micronutritional shortage, which a diet of rice can exacerbate—afflicts up to 3.7 billion people, particularly women, leaving them weakened by anemia and susceptible to complications during childbirth. In addition, because the endeavor was not industry-funded, Khush and Potrykus both point out, the poor farmers who most need the micronutrient-rich rice are likely to get it, free of charge.

The roots of the project go back 7 years, when Peter Burkhardt in Potrykus's laboratory took on the daunting task of inducing rice to make β-carotene, which the body readily converts to actual vitamin A. Although rice kernels contain absolutely no β-carotene, they do make a molecule called geranylgeranyl pyrophosphate that can be converted to β-carotene by a sequence of four enzymes in the vitamin A pathway. The Swiss researchers had access to the genes for those enzymes, cloned from daffodils by Peter Beyer at the University of Freiburg in Germany. The problem would be getting all four genes into the rice kernel and working in sync.

In the first stage of the work, Burkhardt attached the genes to regulatory sequences that would allow them to be turned on in rice kernels. But when he tried to shoot the four modified genes into rice plant cells with a "gene gun," a standard way of introducing new genes into plants, he couldn't get all four to work properly: Most shut down after settling into the rice genome. The team didn't succeed until graduate student Xudong Ye entered the lab and tried new strategies.

Golden grains. The yellow color of this genetically modified rice is due to its ability to make β-carotene.

Ye switched the source of two of the four genes from daffodil to the bacterium *Erwinia uredovora* and used the plant-infecting microbe *Agrobacterium tumefaciens* to ferry in the genes. When *Agrobacterium* infects plants, it injects them with a circular piece of DNA called a plasmid. Ye put the two daffodil genes on the plasmid of one *A. tumefaciens* strain and the *Erwinia* genes on the plasmid of another, and then let the bacteria do the job of introducing the genes into plant cells. The strategy worked, yielding plants that produced rice grains literally golden with β-carotene.

Meanwhile, Potrykus and graduate student Paolo Lucca were working on the iron supplementation project, which involved introducing three genes into rice plants. One was aimed at doing away with a molecule in rice that makes people on a high-rice diet prone to iron deficiency. Called phytate, this sugarlike molecule ties up 95% of dietary iron and so keeps the human body from absorbing it. The Swiss pharmaceutical giant Hoffmann-La Roche in Basel provided a fungal gene for an enzyme known as phytase, which breaks down phytate. Whereas most enzymes unfold and lose their activity when heated, the Hoffmann-La Roche enzyme carries a mutation so that it can withstand cooking temperatures. One of the other two genes introduced by Lucca comes from the French bean and encodes the iron-storage protein ferritin, which doubles iron levels in the rice grains. And the third gene, from basmati rice, makes a metallothionein-like protein, which is rich in cysteine, a sulfur-rich amino acid that helps in iron absorption in the human digestive system.

In the final step of their 7-year odyssey, the Potrykus team crossbred their β-carotene– and iron-rich rice strains, producing hybrids that combined both improvements. As little as 300 grams of the cooked rice per day—a typical Asian diet—should provide almost the entire daily vitamin A requirement, Potrykus says. In addition, the experimental rice appears to be fertile and to grow normally in greenhouses. The success so far doesn't mean that the new crop is ready for market, however. Potrykus and his colleagues used the lab workhorse japonica strain of rice for their experiments, while indica rice is the most common commercial strain. So scientists at IRRI will now take on the task of crossbreeding the new strain with indica rice and field-testing the hybrids. If all goes well, Khush estimates, the golden rice could land in the fields of developing countries in 2 to 3 years—assuming, that is, that it doesn't meet with regulatory barriers such as those imposed by Britain, which currently has issued a moratorium on all genetically altered foods.

Khush and Potrykus think that won't happen. Because the potential benefits seem great and the potential health and environ-

CREDIT: I. POTRYKUS AND P. BEYER

mental risks small, the two researchers say, the new rice strain may draw less opposition from the critics of genetically engineered foods than other modified crop plants now being marketed (*Science*, 28 May, p. 1442). DellaPenna hopes they are right. These results, he says, "are wonderful and what needs to be done." –TRISHA GURA

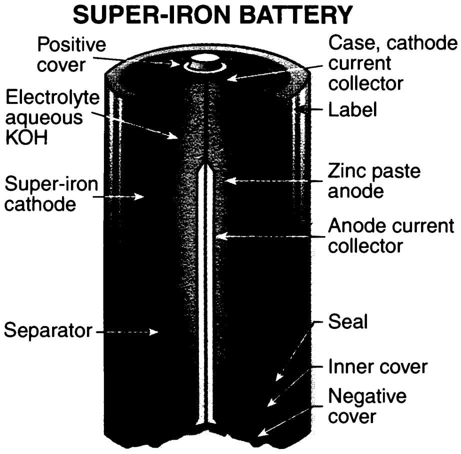
Trisha Gura is a free-lance writer in Cleveland, Ohio.

ELECTROCHEMISTRY

"Super-Iron" Comes to The Rescue of Batteries

Georges Leclanché, the French chemist who developed the dry battery nearly 140 years ago, would probably recognize the basic elements of a flashlight battery today. Most such batteries still contain a zinc anode and a cathode made of a mixture of carbon and manganese dioxide. But now a team led by Stuart Licht at the Israel Institute of Technology, or Technion, in Haifa reports on page 1039 the development of a

SUPER-IRON BATTERY



Charge it. It looks like a regular battery, but the difference is in the cathode.

new class of batteries that have greater capacity, a faster discharge rate, and are rechargeable. The difference is in the cathode, which is made from unusual iron-based molecules known as iron(VI), or "super-iron," compounds that absorb more electrons than manganese dioxide. "Their performance in a battery system is very astounding," says Jeff Dahn of Dalhousie University in Halifax, Canada.

When a battery discharges, electrons absorbed from the electrolyte by the zinc anode pass through an electric circuit and end up in the cathode, where two manganese dioxide (MnO_2) molecules join to form a manganese sesquioxide (Mn_2O_3) molecule, absorbing two electrons in the process. In the new super-iron compounds—which contain oxygen, as well as potassium, barium, and other elements—each iron atom is missing six electrons. During discharge, the iron is converted into a form of ferric oxide (Fe_2O_3)—common rust—that is three electrons short of its normal complement. Each iron atom thus absorbs three electrons, one more than two manganese dioxide molecules absorb.

This larger appetite for electrons translates directly into increased storage capacity. The Technion team has produced batteries with super-iron cathodes that have capacities up to 47% greater than standard manganese dioxide batteries of the same size. They also found that the batteries' performance at high discharge rates was better because super-iron compounds are also better conductors of electricity. Another advantage is rechargeability: The team reports some 400 charge-discharge cycles.

The team searched a long time before settling on super-iron compounds. "Previously we looked at sulfur, hydrogen peroxide, and a variety of materials, each of which have very unusual electrochemical properties, but were not compatible with the existing systems," says Licht. Some other possible compounds were also ruled out because "we specifically wanted to start with an [environmentally] 'clean' material," says Licht. The rust generated by discharging this battery is preferable to the somewhat poisonous manganese compounds that remain in the batteries presently used, notes Licht.

Even so, super-iron compounds were not an obvious choice, because they are considered too unstable. "When these [compounds] were made in the past and you put them in a solution, they disappeared within minutes, decomposing into rust," says Licht. The team solved this problem by carefully eliminating two catalysts, nickel and cobalt, that usually contaminate these compounds. The researchers found that, even in very small quantities, they cause the super-irons to break down. "We have demonstrated lifetimes of the super-irons without any change on the order of a month and extrapolated lifetimes of years," says Licht. Denis Dees of Argonne National Laboratory in Illinois says, however, that he would like to see evidence that such batteries can survive for 6 to 12 months on the shelf and still be discharged. Because of the questionable stability of iron(VI) compounds, he says, "it is interesting that they have made it work at all."

If the cathodes do prove durable, Licht says the batteries should not be difficult to make. "We have been able to take it from a concept very quickly to conventional-sized batteries, and that is very promising," he says. Another plus is that the starting materials are inexpensive and more easily available than manganese compounds. –ALEXANDER HELLEMANS

Alexander Hellemans is a writer in Naples, Italy.

CREDIT: (LEFT) LICHT *ET AL.*

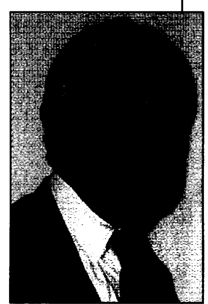
ScienceScope

India's Science Summit Indian scientists want their government to create a pair of autonomous commissions that would help improve the country's performance in biotechnology and sustainable technologies. The recommendation, made last week by more than 150 researchers attending the first National Science Summit in Bangalore, aims to build on the success of panels that have channeled new resources into space and nuclear power.

The summiteers, gathered by the nonprofit education group Bhartiya Vidya Bhawan, also took stock of India's science record. Although many cheered advances in space research, agriculture, and other areas, others worried that success remains uneven. "There are icebergs of good science floating in a sea of bad," said biophysicist Padmanabhan Balaram of the Indian Institute of Science in Bangalore and editor of *Current Science*, a leading journal.

It's too soon to know whether the proposed panels will ever set sail. The politicians who would have to approve them are in the thick of an election campaign that ends in October.

Science Succession Democrats have a new leader on the House Science Committee. As expected, Rep. Ralph Hall (below) of Texas last week officially inherited the leadership slot left open by last month's death of Rep. George Brown (*Science*, 23 July, p. 509).



Hill watchers don't expect any immediate changes in the committee's slant under Hall, who will lead the 22 Democrats serving on the 47-member panel. But the Texan—who has served on the committee for almost 2 decades and is a former head of its space subcommittee—is far more conservative than his predecessor, often voting with Republicans on fiscal and social matters. Although that history may smooth relations with feisty panel head James Sensenbrenner (R–WI), House aides say it is unclear what it means for science policy. Says one: "He is further right, but those partisan labels often don't mean much in science politics."

Contributors: Rachelle H. B. Fishman, Bruce Agnew, Pallava Bagla, and David Malakoff