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Research News

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High-Nutrition and Disease-Resistant Purple and Yellow-Fleshed Potato Clones Obtained
Source: ScienceDaily. Apr. 24, 2013

The Basque Institute for Agricultural Research and Development, Neiker-Tecnalia, has created four new potato clones which are characterised by their high antioxidant content, their good production both in size and number of tubers, as well as by their resistance to the usual diseases of this crop. The clones were obtained by natural methods through crossing varieties from South America with commercial varieties used in Europe. The result was three clones of the purple-fleshed potato and one with a markedly yellow flesh. The attractiveness and nutritional value of these types of potato make them a product highly regarded by professionals in gastronomy and by the public in general.

The work of creating the clones is part of the Potato Genetic Enhancement Programme drawn up by Neiker-Tecnalia. The research was led by agricultural engineer Ms Raquel

López, being the basis for her PhD thesis, and was presented at the University of the Basque Country. The aim of this specialist was to find potatoes which brought together the features of the South American varieties (their colour, resistance to pathogens and their nutritional and organoleptic properties) with those of the commercial varieties employed in our latitudes and characterized by their high productivity.

The Neiker-Tecnalia researchers brought 37 varieties from the Centro Internacional de la Papa, based in Peru. These native South American varieties were crossed in the greenhouse with commercial varieties, using natural procedures. The selection of and crossing between individuals with the best traits has given rise to the four clones mentioned. For the moment, these involve advanced clones and not commercial varieties, as they are not registered at the Spanish Office for Plant Varieties (OEVV in the Spanish acronym) or the European Community Plant Variety Office (CPVO). The process of registering is a long one, lasting about 15 years.

The varieties imported from Peru have a very low productivity in our latitudes, both in size and the number of tubers. Nevertheless, with the process of crossing and selection, the final clones having acceptable productivity has been achieved.

The four clones obtained are characterised by the high presence of antioxidants compounds, making them very attractive from a nutritional perspective. The three purple-flesh clones contain a large quantity of anthocyanins – a highly appreciated pigment in the preparation of high added value foods – , while the yellow flesh variety have carotenes – essential chemical components for the diet – and in greater quantities than in the usual commercial varieties.

Resistance to diseases is another of the achievements. The four clones show certain resistance to the pathogens analysed, such as the potato virus Y, as well as the Pectobacterium atrosepticum bacteria, which weaken the vegetable and considerably undermine its production.

Researcher Raquel López highlights the importance of taking into account the clones achieved. “It is beneficial for European producers to have varieties of purple flesh potato that are adapted to the climatological conditions of this continent. Moreover, these varieties incorporate natural antioxidant compounds, which are nutritionally and visually attractive, both for restaurant professionals and for end consumers”.

Square roots? Scientists say plants are good at math

Source: Reuters. Jun 23, 2013.

Plants do complex arithmetic calculations to make sure they have enough food to get them through the night, new research published in journal eLife shows.

Scientists at Britain's John Innes Centre said plants adjust their rate of starch consumption to prevent starvation during the night when they are unable to feed themselves with energy from the sun.

They can even compensate for an unexpected early night.

"This is the first concrete example in a fundamental biological process of such a sophisticated arithmetic calculation," mathematical modeler Martin Howard of John Innes Centre (JIC) said.

During the night, mechanisms inside the leaf measure the size of the starch store and estimate the length of time until dawn. Information about time comes from an internal clock, similar to the human body clock.

"The capacity to perform arithmetic calculation is vital for plant growth and productivity," JIC metabolic biologist Alison Smith said.

"Understanding how plants continue to grow in the dark could help unlock new ways to boost crop yield."

Fungus-Fighting Genes

By Ruth Williams. The Scientist, June 27, 2013

Two genes from wild relatives of wheat could save domestic wheat from fungal destruction.

A recently emerged strain of the wheat-destroying fungus called stem rust is threatening 90 percent of the world’s domestic wheat varieties. But, according to two papers published online today (June 27) in Science, this fungal threat may soon be thwarted thanks to genes from hardy wheat relatives that resist the fungus.

"These are the first genes cloned that resist the Ug99 stem rust race that is threatening wheat crops worldwide," said Bikram Gill, director of the Wheat Genetics Resource Center at Kansas State University in Manhattan, who was not involved in the research, "so it's very exciting news."

Domestic wheat varieties such as those made into bread and pasta provide a staggering 20 percent of the global populations' calorie intake. But wheat has an enemy in the form of an orangey-red fungus that grows on its stems, ultimately killing the plant. This stem rust fungus has been effectively controlled in domestic wheat for the last 50 years thanks to crossbreeding with varieties containing resistance genes.

In Uganda in 1999, however, stem rust upped the ante. A new strain, or race, of the fungus emerged that had overcome the resistance and quickly began destroying large expanses of domestic crops. Furthermore, subsequent testing of assorted domestic wheat varieties revealed that 90 percent of them were susceptible to the new race, called Ug99.

"The major fear people have is that the disease spread is extremely rapid," said Simon Kittenger, a botanist at the University of Zurich, in Switzerland, who also did not participate in the research. "It is now present in all of East Africa and South Africa, and has even spread into Yemen and Iran." If it spreads any further East, it could impact the world's two major wheat-producing countries, India and China—"the bread baskets of the world," as Kittenger referred to them. "It could potentially be a disaster," he said.

Because domestic wheat varieties are susceptible to Ug99, Evans Lagudah, a research scientist at the Commonwealth Scientific and Industrial Research Organization in Canberra, Australia, turned to a wild grass relative of wheat, Aegilops tauschii, known to carry a Ug99-resistance gene called Sr33. Meanwhile, Kansas State University plant pathologist Eduard Akhunov began investigating the primitive wheat, Triticum monococcum, which also carries an Ug99-resistance gene called Sr35.

Although the existence of Sr33 and Sr35 genes was known, their precise locations in the plants' genomes, as well as their identities, remained a mystery. The teams performed genetic mapping and DNA fingerprinting to narrow their searches to a few candidate genes, then pinpointed the precise genes by introducing mutations and seeing which ones caused a loss of Ug99 resistance.

A gene called AetRGA1e in the A. tauschii genome turned out to be the gene scientists had been calling Sr33, while the gene CNL9 from T. monococcum was identified as Sr35. When each of these genes was transferred into Ug99-susceptible wheat hosts, they conferred Ug99-resistance.

The two genes vary somewhat in the resistance they provide. CNL9 confers almost complete immunity to Ug99 and related races, but is susceptible to other forms of stem rust, while AetRGA1e is resistant to all races of stem rust tested so far, but in the case of Ug99 confers only moderate resistance. For that reason, Lagudah says the best plan to protect domestic wheat would be to combine the two genes in a single plant. "We need to be one step ahead of the fungus, because eventually it will mutate and overcome resistance," he said.

The quickest and easiest way to get both genes into a single wheat variety would be to use transgenic techniques, said Akhunov, while acknowledging the political controversy surrounding genetically modified crops. "We could transfer these genes into wheat using classical approaches, we can cross and select plants with the gene, but it takes a lot of time. It may take up to 5 to 7 years just to develop this plant." This could be a risky delay if the disease is spreading as fast as Kittenger reckoned. Creating the plant by transgenics, on the other hand, would take approximately 6 months, Akhunov said.

The other thing to bear in mind, said Akhunov, is that "the pathogen races are evolving very fast." Since the discovery of Ug99, another five or six derivative races have emerged, he said. So not only must the search for new resistance genes continue, he said, but also “we need to come up with faster ways of responding.”

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S. Periyannan et al., “The gene Sr33, an ortholog of barley Mla genes, encodes resistance to wheat stem rust race Ug99,” Science, doi: 10.1126/science.1239028, 2013.

C. Saintenac et al., "Identification of wheat gene Sr35 that confers tesistance to Ug99 stem rust race group," Science, doi: 10.1126/science.1239022, 2013.

Remaking Nature

By Kent H. Redford. The Scientist, August 1, 2013

Synthetic biologists need to work together with conservationists to understand the environmental consequences of this new technology.

The growth of human populations, the development of new technologies, and the scope of human enterprise mean that the Earth’s systems—and the ways in which people interact with them—are changing faster than ever before. Humans appropriate more than 40 percent of the net energy produced by the world’s plants, consume 35 percent of the energy produced on the oceanic shelf, and use 60 percent of freshwater runoff. In some sense, people are already masters of their environment, engineering it for their own uses. But the human transformation of the planet is now entering a new and categorically different era: the era of synthetic biology.

Proponents of this new field argue that it can improve on the messy, inefficient, and uncertain processes of natural evolution by engineering more reliable and efficient biological systems. Synthetic biology has the potential to revolutionize biotechnology in the energy, medical, and agricultural sectors by creating novel organisms and modifying existing ones. (See “Engineering Life,” here.) More public discussion of the implications of these areas of research is occurring, as engineers and scientists continue to push the frontiers of synthetic biology faster and further.

But what will this relentless pursuit of synthetic biology mean for the natural world and for conservation? The nature and extent of human impacts on the planet have already led to deep questions about the purpose of conservation and the measures of its success. In order to address these issues, the Wildlife Conservation Society convened a meeting in April 2013 to bring together the conservation and synthetic biology communities. These two groups had never formally met. Most of the conservationists had never heard of synthetic biology and, when briefed on it, did not see its particular relevance to what they were doing. In turn, synthetic biology researchers had paid little attention to how their work could impact, positively or negatively, the world’s biodiversity. During 3 days of presentations and discussion, the two communities learned about each other’s practices, hopes, and fears, and worked to find some common ground.

The meeting revealed two potentially worrisome types of interactions between the fields of conservation and synthetic biology. First, synthetic biology promises to produce novel organisms, to substantially modify naturally existing organisms, or even to restore extinct species—each with obvious direct implications for maintaining and restoring biodiversity. But these efforts may also have unknown consequences for the natural systems into which the novel or modified organisms are introduced. Given these concerns, it is unclear how the conservation community and the public will respond to the introduction of such organisms—including genetically modified American chestnut trees, now resistant to chestnut blight; species with DNA constructed from synthetic nucleic acids, not related to any other form of life on earth; and genetically modified, fuel-producing algae that might escape containment facilities and interact with natural communities.

The second type of anticipated interaction between synthetic biology and conservation, which is more likely to happen sooner and have a more dramatic effect on biodiversity, is indirect—and concerns the major expected commercial uses for synthetic biology. Potential applications fall into six categories: bioenergy, agriculture and food production, environmental protection and remediation, consumer products, chemical production, and human health. All of these products will require feedstocks and production facilities, with unknown knock-on effects on land use, land values, resource consumption, and businesses producing "traditional" versions of these products. For example, if palm oil synthesized by algae using synthetic biology techniques were to become economically competitive with oil produced from oil-palm plantations, what would happen with the land currently used to grow the palms, and where would the algae cultivation ponds be placed?

At this time we don't know what will happen when synthetic biology meets conservation. Nevertheless, it is imperative that conservationists engage with synthetic biologists. Without such informed engagement, it would be too easy for policy makers and politicians to incorrectly assume that synthetic biology solutions provide easy alternatives to expensive conservation efforts and have no negative consequences (PLOS Biol, 11:e1001530, 2013).

If conservationists choose to ignore synthetic biology, they do so at their own risk and the risk of the biodiversity they are devoted to protecting. Conservation needs new thinking and new strategies to cope with the challenges that human-made changes are inflicting on our planet. Although the nature and shape of the challenges are as yet unclear, synthetic biology is here to stay. The conservation community should engage and try to influence the field's practice and outcomes now, in these early stages of the development of syn-bio technologies. Conservationists need to consider the implications of synthetic biology for the practice of conservation, both positive and negative, and move aggressively to shape the emerging field to make it as "pro-conservation" as possible.

Likewise, the synthetic biology community must engage with the general public to make them aware of the implications of its practice for the natural world. As Eleonore Pauwels of the Synthetic Biology Project at the Woodrow Wilson International Center for Scholars in Washington, DC, observes (BioScience, 63:79-89, 2013), "When industry is trying to introduce a new technology, public trust has large strategic implications as the market for that technology develops. A key variable for consumers is whether companies handle this new technology in a socially and environmentally responsible manner."

Kent H. Redford is principal and founder of Portland, Maine–based Archipelago Consulting, established in early 2012 to help individuals and organizations improve their practice of conservation. He worked for 19 years in the conservation NGO world—for the Wildlife Conservation Society and The Nature Conservancy—and 10 years at the University of Florida. With Bill Adams of Cambridge University and Georgina Mace of University College London, he was an organizer of the recent meeting on synthetic biology and conservation.

Warming Climate Pushes Plants Up the Mountain
ScienceDaily, Aug. 14, 2013

Comparing plant communities today with a survey taken 50 years ago, a UA-led research team is providing the first on-the-ground evidence for Southwestern plants being pushed to higher elevations by an increasingly warmer and drier climate.

In a rare opportunity to directly compare today's plant communities with a survey taken in the same area 50 years ago, a University of Arizona-led research team has provided the first on-the-ground evidence that Southwestern plants are being pushed to higher elevations by an increasingly warmer and drier climate.

The findings confirm that previous hypotheses are correct in their prediction that mountain communities in the Southwest will be strongly impacted by an increasingly warmer and drier climate, and that the area is already experiencing rapid vegetation change.

In a rare opportunity to obtian a "before -- after" look, researchers studied current plant communities along the same transect already surveyed in 1963: the Catalina Highway, a road that winds all the way from low-lying desert to the top of Mount Lemmon, the tallest peak in the Santa Catalina Mountains northeast of Tucson.

"Our study provides the first on-the-ground proof of plants being forced significantly upslope due to climate warming in southern Arizona," said Richard C. Brusca, a research scientist in the UA's department of ecology and evolutionary biology who led the study together with Wendy Moore, an assistant professor in the UA's department of entomology. "If climate continues to warm, as the climate models predict, the subalpine mixed conifer forests on the tops of the mountains -- and the animals dependent upon them -- could be pushed right off the top and disappear."

The study, published in the journal Ecology and Evolution, was made possible by the existence of a dataset compiled 50 years ago by Robert H. Whittaker, often referred to as the "father of modern plant ecology," and his colleague, William Niering, who catalogued the plants they encountered along the Catalina Highway.

Focusing on the 27 most abundantly catalogued plant species, Brusca and Moore discovered that three quarters of them have shifted their range significantly upslope, in some cases as much as a thousand feet, or now grow in a narrower elevation range compared to where Whittaker and Niering found them in 1963.

Specifically, Moore and her team found that the lowermost boundaries for 15 of the species studied have moved upslope; eight of those species now first appear more than 800 feet higher than where Whittaker and Niering first encountered them. Sixteen of the studied species are now restricted to a narrower band of elevation, the researchers noticed. As far as the plants' upper elevation limits were concerned, the researchers observed a mixed trend: They found it to be higher for four species, lower for eight species and unchanged for 15.

For example, in 1963 Whittaker and Niering recorded alligator juniper as a component of upland desert and grassland communities in the Catalina Mountains, beginning at an elevation of just 3,500 feet. Today, one has to drive to the 5,000-foot elevation marker on the Catalina Highway to see the first live alligator juniper trees in upland habitats.

According to the authors, the main point emerging from the study is that plant communities on the mountain were different 50 years ago because plant species do not necessarily move toward higher elevations as a community. Rather, individual species shift their ranges independently, leading to a reshuffling of plant communities.

The scientists in this multidisciplinary group gathered the data during fieldwork in 2011, and included UA postdoctoral fellows and professors from several programs, including the UA departments of entomology and ecology and evolutionary biology, the Center for Insect Science and the Institute for the Environment, as well as botanists from the Arizona-Sonora Desert Museum.

Based on studies done by other scientists, including UA researchers, the researchers believe that a "thirstier" atmosphere might be a major driver behind the shifts in plant distribution, possibly even more so than lack of precipitation. As the atmosphere becomes warmer and drier, plants loose more water through their leave openings and become water-stressed.

According to the authors, the results are consistent with a trend scientists have established for the end of the Pleistocene, a period of repeated glaciations that ended about 12,000 years ago. By studying the distribution of plant seeds and parts preserved in ancient packrat middens, for example, paleo-ecologists have documented that as the climate warmed up, plant communities changed profoundly.

"In southern Arizona, some species moved north to the Colorado Plateau, others moved up mountain slopes, and others didn't move at all," said Moore, who has been collecting data on ground-dwelling arthropods, plants, leaf litter, weather, soil, and other ecological factors in the Santa Catalina Mountains for the Arizona Sky Island Arthropod Project based in her lab.

The Sky Islands encompass an "archipelago" of 65 isolated mountain ranges rising from the surrounding low-elevation desert and desert grassland in an area that constitutes the only major gap in the 4,500-mile long North American Cordillera, which runs from northern Alaska to southern

Mexico. The Sky Islands, often referred to as the "Madrean Sky Islands," span this gap in southeastern Arizona, southwestern New Mexico and northeastern Sonora, Mexico. They include the Santa Catalina Mountains, the Pinal Mountains and the Chiricahua Mountains.

Journal Reference: Richard C. Brusca, John F. Wiens, Wallace M. Meyer, Jeff Eble, Kim Franklin, Jonathan T. Overpeck, Wendy Moore. Dramatic response to climate change in the Southwest: Robert Whittaker's 1963 Arizona Mountain plant transect revisited. Ecology and Evolution, 2013; DOI: 10.1002/ece3.720

New Possibilities for Efficient Biofuel Production

ScienceDaily, Aug. 15, 2013

Limited availability of fossil fuels stimulates the search for different energy resources. The use of biofuels is one of the alternatives. Sugars derived from the grain of agricultural crops can be used to produce biofuel but these crops occupy fertile soils needed for food and feed production.

Fast growing plants such as poplar, eucalyptus, or various grass residues such as corn stover and sugarcane bagasse do not compete and can be a sustainable source for biofuel. An international collaboration of plant scientists from VIB and Ghent University (Belgium), the University of Dundee (UK), The James Hutton Institute (UK) and the University of Wisconsin (USA) identified a new gene in the biosynthetic pathway of lignin, a major component of plant secondary cell walls that limits the conversion of biomass to energy.

These findings published online in this week's issue of Science Express pave the way for new initiatives supporting a bio-based economy.

"This exciting, fundamental discovery provides an alternative pathway for altering lignin in plants and has the potential to greatly increase the efficiency of energy crop conversion for biofuels," said Sally M. Benson, director of Stanford University's Global Climate and Energy Project. "We have been so pleased to support this team of world leaders in lignin research and to see the highly successful outcome of these projects."

To understand how plant cells can deliver fuel or plastics, a basic knowledge of a plant's cell wall is needed. A plant cell wall mainly consists of lignin and sugar molecules such as cellulose. Cellulose can be converted to glucose which can then be used in a classical fermentation process to produce alcohol, similar to beer or wine making. Lignin is a kind of cement that embeds the sugar molecules and thereby gives firmness to plants. Thanks to lignin, even very tall plants can maintain their upright stature. Unfortunately, lignin severely reduces the accessibility of sugar molecules for biofuel production. The lignin cement has to be removed via an energy-consuming and environmentally unfriendly process. Plants with a lower amount of lignin or with lignin that is easier to break down can be a real benefit for biofuel and bioplastics production. The same holds true for the paper industry that uses the cellulose fibres to produce paper.

For many years researchers have been studying the lignin biosynthetic pathway in plants. Increasing insight into this process can lead to new strategies to improve the accessibility of the cellulose molecules. Using the model plant Arabidopsis thaliana, an international research collaboration between VIB and Ghent University (Belgium), the University of Dundee (UK), the James Hutton Institute (UK) and the University of Wisconsin (USA) has now identified a new enzyme in the lignin biosynthetic pathway. This enzyme, caffeoyl shikimate esterase (CSE), fulfils a central role in lignin biosynthesis. Knocking-out the CSE gene, resulted in 36% less lignin per gram of stem material. Additionally, the remaining lignin had an altered structure. As a result, the direct conversion of cellulose to glucose from un-pretreated plant biomass increased four-fold, from 18% in the control plants to 78% in the cse mutant plants.

These new insights, published this week online in Science Express, can now be used to screen natural populations of energy crops such as poplar, eucalyptus, switchgrass or other grass species for a non-functional CSE gene. Alternatively, the expression of CSE can be genetically engineered in energy crops. A reduced amount of lignin or an adapted lignin structure can contribute to a more efficient conversion of biomass to energy.

This research was co-financed by the multidisciplinary research partnership 'Biotechnology for a sustainable economy' of Ghent University, the DOE Great Lakes Bioenergy Research Center and the 'Global Climate and Energy Project' (GCEP). Based at Stanford University, the Global Climate and Energy Project is a worldwide collaboration of premier research institutions and private industry that supports research on technologies that significantly reduce emissions of greenhouse gases, while meeting the world's energy needs.

Journal Reference: Ruben Vanholme, Igor Cesarino, Katarzyna Rataj, Yuguo Xiao, Lisa Sundin, Geert Goeminne, Hoon Kim, Joanna Cross, Kris Morreel, Pedro Araujo, Lydia Welsh, Jurgen Haustraete, Christopher McClellan, Bartel Vanholme, John Ralph, Gordon G. Simpson, Claire Halpin, and Wout Boerjan. Caffeoyl Shikimate Esterase (CSE) Is an Enzyme in the Lignin Biosynthetic Pathway. Science, 15 August 2013 DOI: 10.1126/science.1241602

Do Herbicides Alter Ecosystems Around the World? Scant Research Makes It Hard to Prove

ScienceDaily, Aug. 16, 2013

The number of humans on the planet has almost doubled in the past 50 years – and so has global food production. As a result, the use of pesticides and their effect on humans, animals and plants have become more important. Many laboratory studies have shown that pesticides can harm organisms which they were not meant to affect. Intensive farming is also linked to collapsing populations of wild animals and the endangerment of species such as amphibians. Can the biochemical effects of pesticides upset entire ecosystems?

Professor Heinz Köhler and Professor Rita Triebskorn from the University of Tübingen's Institute of Evolution and Ecology (EvE) have published a study on the link between pesticides and changing ecological systems in the latest edition of Science. The two ecotoxicologists cite deficits in the research which have prevented recognition of the consequences of biochemical pesticide effects on a species population or on the composition of biological communities. "Although there are many indications of animal populations and ecosystems changing because of pesticides, there are few studies proving the connection without a doubt," Köhler and Triebskorn say. The researchers point to mathematical and experimental approaches which can be used to recognize links between the effects of pesticides in individuals and ecological changes in biological communities and ecosystems in regions where intensive farming is practiced.

An important role is played by number of rare studies combining experimental fieldwork and research on sections of ecosystems, as well as a broad selection of chemical and biological analyses. An interdisciplinary approach can plausibly demonstrate connections between the effects of chemicals in humans and animals and the often indirect consequences on the population, community and ecosystem levels.

Köhler and Triebskorn also postulate interdependent effects between pesticides and global warming. The researchers forecast changes to "natural" selection, the spread of infections, and the sexual development and fertility of wild animals. This in turn could have a knock-on effect on populations, ecosystems and food chains. The researchers say it is a further challenge for science to show how strongly the effects of pesticides are influenced by climate change -- and to find out which ecological processes are especially sensitive to this interdependence. "The links to the effect of pesticides at every level of increasing biological complexity require more thorough research," say Köhler and Triebskorn.

Journal Reference: H.-R. Kohler, R. Triebskorn. Wildlife Ecotoxicology of Pesticides: Can We Track Effects to the Population Level and Beyond? Science, 2013; 341 (6147): 759 DOI: 10.1126/science.1237591

Should Science Be for Sale?

By Victoria Doronina. The Scientist, August 20, 2013

The increasing push to commercialize research is destroying the scientific community.

I was born in the USSR and now work as a postdoc at University of Manchester in the United Kingdom. Once, my PI and I were returning to a hotel after dinner with our collaborators in a different UK city, where one of the postdocs had the same post-Soviet background as me. My boss commented that there seems to be a lot of people of Soviet extraction working in Western science and joked that we are close to taking over it. I replied that he doesn't have to worry; the supply of Soviet scientists is gone, never to be replaced.

After the demise of the USSR in 1991, science in the former Soviet Republics lost most of its funding, and as a result, most scientists lost their once-prestigious, middle-income jobs. The prevailing mood of the society changed; most of the population, including many scientists, decided that the only thing that mattered in life was earning money—fast. Many academics, such as Russian billionaire Boris Berezovsky, a former department head at The Institute of Systems Control of the Russian Academy of Sciences, changed their careers, leaving old professors and young PhD students alone in the lab. Without their mentors, many young researchers who actually cared about science abandoned their home universities for work in the West.

Fast forward 20 years: the devaluing of the pursuit of knowledge as a life goal in the former Soviet Republics has resulted in a significant drop in the quality of high-school teaching and, consequently, in the level and motivation of undergraduate students. Former Soviet professors have largely retired, and former Soviet PhD students, practically self-taught, now head those labs, and they say it is difficult to find a good graduate student or postdoc, who will work beyond a 9-to-5 day and actually care about the research he or she is doing. The people who embark on a postgraduate degree are doing it not because they are excited about science, but because they think that an advanced degree would be good for their careers, which has led to a tendency to minimize the work and fake the results.

And simply throwing money at the destroyed scientific community hasn't helped. Russian President Vladimir Putin recently admitted that while science funding increased 10-fold in the last 10 years and the total amount of money spent is now larger than that of Britain, this has not resulted in an increased scientific output. On the contrary, the number of Russian researchers who publish in the Western journals or file patents applications is decreasing.

This situation is not unique to the former Soviet Union, however. Even in my adopted home, the United Kingdom, where I work as a postdoc in the relatively sexy field of yeast prions, there seems to be a general lack of respect for knowledge for its own sake. When I tell my nonscientific acquaintances and high-school pupils about what I do, they don't ask what I have discovered, but what is the immediate practical application of what I do.

Sadly, there is an increased drive in Western science to commercialize discoveries—academics are encouraged to start spin-off companies, and applied research is actively promoted. It is very difficult to get funding for fundamental research, which may not show dividends for 10–20 years. Universities are run as for-profit companies, where students are paying customers, who get a "product" (a degree) and academics have as much value as the grants they bring in. And the job market for postgraduate scientists is growing increasingly similar to that of factory workers in the 19th century: we are considered to be easily replaceable and therefore have few rights beyond a short-term contract.

American political philosopher Michael Sandel argues in his book What Money Can't Buy that some things should not be for sale, such as human organs, medals for valor, and even undergraduate places in top universities. He says that an "everything-is-for-sale" mentality damages the functioning of society. I wonder if fundamental science should also be included in this list of things that are easy to commodify but even easier to devalue. If everything is for sale, and if the people who are doing science are not valued, then research loses something that is hard to define, but that is vital to the progress of science—as the situation in the former Soviet Union has so clearly demonstrated.

Victoria Doronina is a postdoc in the lab of Chris Grant at University of Manchester, where she studies oxidative stress as a cause of yeast prion formation.

Scientists Creating Plants That Make Their Own Fertilizer

Source: Washington University News Release, Aug. 22, 2013

Biologist Himadri Pakrasi's team is excited by the potential of a chemical apparatus for nitrogen fixation will be miniaturized, automated and relocated within plants so nitrogen is available when and where it's needed.

"That would really revolutionize agriculture," said Pakrasi, PhD, the Myron and Sonya Glassberg/Albert and Blanche Greensfelder Distinguished University Professor in Arts & Sciences and director of the International Center for Advanced Renewable Energy and Sustainability (I-CARES) at Washington University in St. Louis.

Although there is plenty of nitrogen in the atmosphere, atmospheric nitrogen is not in a form plants can use. Atmospheric nitrogen must be "fixed," or converted into compounds that make the nitrogen available to plants.

Much of modern agriculture relies on biologically available nitrogenous compounds made by an industrial process, developed by German chemist Fritz Haber in 1909. The importance of the Haber-Bosch process, as it eventually was called, can hardly be overstated; today, the fertilizer it produces allows us to feed a population roughly a third larger than the planet could sustain without synthetic fertilizer.

On the other hand, the Haber-Bosch process is energy-intensive, and the reactive nitrogen released into the atmosphere and water as runoff from agricultural fields causes a host of problems, including respiratory illness, cancer and cardiac disease.

Pakrasi thinks it should be possible to design a better nitrogen-fixing system. His idea is to put the apparatus for fixing nitrogen into plant cells, the same cells that hold the apparatus for capturing the energy in sunlight.

The National Science Foundation just awarded Pakrasi and his team more than $3.87 million to explore this idea further. The grant will be administered out of I-CARES, a university-wide center that supports collaborative research regionally, nationally, and internationally in the areas of energy, the environment and sustainability.

This award is one of four funded by the National Science Foundation jointly with awards funded by the Biotechnology and Biological Sciences Research Council in the United Kingdom. The teams will collaborate with one another and meet regularly to share progress and successes. The NSF release is available here.

As a proof of principle, Pakrasi and his colleagues plan to develop the synthetic biology tools needed to excise the nitrogen fixation system in one species of cyanobacterium (a phylum of green bacteria formerly considered to be algae) and paste it into a second cyanobacterium that does not fix nitrogen.

The team includes: Tae Seok Moon, PhD, and Fuzhong Zhang, PhD, both assistant professors of energy, environmental and chemical engineering in the School of Engineering & Applied Science at Washington University; and Costas D. Maranas, the Donald B. Broughton Professor of Chemical Engineering at Pennsylvania State University.

"Ultimately what we want to do is take this entire nitrogen-fixation apparatus — which evolved once and only once — and put it in plants," Pakrasi said. "Because of the energy requirements of nitrogen fixation, we want to put it in chloroplasts, because that's where the energy-storing ATP molecules are produced." In effect, the goal is to convert all crop plants, not just the legumes, into nitrogen fixers.

All cyanobacteria photosynthesize, storing the energy of sunlight temporarily in ATP molecules and eventually in carbon-based molecules, but only some of them fix nitrogen. Studies of the evolutionary history of 49 strains of cyanobacteria suggest that their common ancestor was capable of fixing nitrogen and that this ability was then repeatedly lost over the course of evolution.

The big hurdle to redesigning nitrogen fixation, however, is that photosynthesis and nitrogen fixation are incompatible processes. Photosynthesis produces oxygen as a byproduct and oxygen is toxic to nitrogenase, the enzyme needed to fix nitrogen. This is why most organisms that fix nitrogen work in an anaerobic (oxygenless) environment.

Cyanobacteria that both photosynthesize and fix nitrogen separate the two activities either in space or in time. Cyanothece 51142, a cyanobacterium Pakrasi's lab has studied for more than 10 years, does it through timing.

Cyanothece 51142 has a biological clock that allows it to photosynthesize during the day and fix nitrogen at night. During the day, the cells photosynthesize as fast as they can, storing the carbon molecules they create in granules. Then, during the night, they burn the carbon molecules as fast as they can. This uses up all the oxygen in the cell, creating the anaerobic conditions needed for nitrogen fixation.

Thus, the environment within the cell oscillates daily between the aerobic conditions needed for capturing the energy in sunlight and the anaerobic conditions needed for fixing nitrogen.

The scientists have chosen their proof-of-principle project very carefully to maximize the odds it will work.

Cyanothece 51142 is particularly attractive as a parts source for the project because it has the largest contiguous cluster of genes related to nitrogen fixation of any cyanobacterium. Roughly 30 genes are part of the same functional unit under the control of a single operating signal, or promoter.

The scientists hope this cluster of genes can be moved to another cyanobacterial strain in a single mega-transfer. The one they've picked as the host, Synechocystis 6803, is the best-studied strain of cyanobacteria. Not only has its genome been sequenced, it is naturally "transformable" and able to integrate foreign DNA into its genome by swapping it with similar native strands of DNA.

But it's actually the next step in the project that will provide the greater challenge for Pakrasi and his team. The scientists will need to figure out how to connect the transplanted nitrogen-fixing gene cluster to Synechocystis' clock. "Like every cyanobacterium," Pakrasi said, "Synechocystis has a diurnal rhythm. But how to tap into that rhythm, we don't know yet. We have some ideas we're going to test, but that's where the challenge lies."

Overcoming the challenge of sustainably producing food for a world population of more than 7 billion while reducing pollution and greenhouse gases will require more than luck. Odds are it will take a daring, "out of the box" idea like this one.

'Fountain of Youth' for Leaves Discovered
AgriGenomic, August 23, 2013

A team has identified an enzymatic fountain of youth that slows the process of leaf death.

In a series of experiments using the plant Arabidopsis thaliana, Gan and colleagues discovered a key regulator – S3H – that acts as a brake on the process of leaf death. When its levels are low, leaves senesce early; when it is present in high levels, it results in longer leaf longevity.

The study was published in the Aug. 19 issue of Proceedings of the National Academy of Sciences, with former Cornell postdoctoral associate Kewei Zhang (now at Brookhaven National Laboratory) as first author.

"It was serendipity – we weren't actually looking for this gene, but it turned up in an earlier survey of genes involved in leaf senesce," Gan said. "When we characterized it, we found more than we were looking for: a key step in the plant's pathway for controlling senescence that had been eluding scientists."

At the start of that pathway is salicylic acid, precursor of the active ingredient in aspirin, which is used by plants as a hormone to trigger development and to fire up a response to a pathogen attack. The gene product they discovered breaks down salicylic acid, effectively silencing the molecular command to die. In addition to affecting the timing of leaf death, it also affects its rate: While normal plants take more than nine days for a leaf to progress from living green to yellow, plants without the gene yellowed in fewer than three days.

The study provides insight into a highly regulated process with many molecular steps. According to Gan, plant senescence is estimated to involve 10 percent of genes in the genome. Plants use an expedited 'hypersensitive' process to thwart pathogens by sacrificing infected cells to protect the surrounding healthy tissues. The slower version of the cell-dying process is what lights up hillsides in autumn: botanical recycling that ensures the nutrients and proteins in the leaves have been stowed for use in next spring's flowers, seeds and leaves.

"What we have found is the convergence point between the slow and fast death systems," Gan said. "When the plant starts to accumulate salicylic acid, it turns on S3H, which then acts as a brake on the process by breaking down the salicylic acid, giving the plant enough time to recycle all the reusable parts."

In the current study, the increase in leaf longevity was significant but was tallied in days; Gan expects further research to enable the delay of senescence for weeks. In our transport and storage-based food system, senescence after harvest whittles away at fruit and vegetable quality. Gan envisions applications that will produce leafy greens that stay fresh in the fridge, flower bouquets that last longer, and crops that keep their nutrients with an extended shelf life and less post-harvest loss.

Manipulating this pathway also holds promise for bigger harvests and healthier plants.

"Much of the progress plant breeders have made in improving plant yields is actually due to delaying leaf senescence," Gan said. "You need long-lived green tissue to support the production of fruits, vegetables and seeds, so senescence limits the yield of many crops."

His lab group is already working with other genes in the salicylic acid pathway – including a master regulator gene – with promising results. When they switched the gene off using molecular tools, soybean yields were increased by up to 44 percent.

Golden Rice: Lifesaver?

By Amy Harmon. The New York Times. August 24, 2013

ONE bright morning this month, 400 protesters smashed down the high fences surrounding a field in the Bicol region of the Philippines and uprooted the genetically modified rice plants growing inside.

Had the plants survived long enough to flower, they would have betrayed a distinctly yellow tint in the otherwise white part of the grain. That is because the rice is endowed with a gene from corn and another from a bacterium, making it the only variety in existence to produce beta carotene, the source of vitamin A. Its developers call it "Golden Rice."

The concerns voiced by the participants in the Aug. 8 act of vandalism — that Golden Rice could pose unforeseen risks to human health and the environment, that it would ultimately profit big agrochemical companies — are a familiar refrain in the long-running controversy over the merits of genetically engineered crops. They are driving the desire among some Americans for mandatory "G.M.O." labels on food with ingredients made from crops whose DNA has been altered in a laboratory. And they have motivated similar attacks on trials of other genetically modified crops in recent years: grapes designed to fight off a deadly virus in France, wheat designed to have a lower glycemic index in Australia, sugar beets in Oregon designed to tolerate a herbicide, to name a few.

"We do not want our people, especially our children, to be used in these experiments," a farmer who was a leader of the protest told the Philippine newspaper Remate.

But Golden Rice, which appeared on the cover of Time Magazine in 2000 before it was quite ready for prime time, is unlike any of the genetically engineered crops in wide use today, designed to either withstand herbicides sold by Monsanto and other chemical companies or resist insect attacks, with benefits for farmers but not directly for consumers.

And a looming decision by the Philippine government about whether to allow Golden Rice to be grown beyond its four remaining field trials has added a new dimension to the debate over the technology's merits.

Not owned by any company, Golden Rice is being developed by a nonprofit group called the International Rice Research Institute with the aim of providing a new source of vitamin A to people both in the Philippines, where most households get most of their calories from rice, and eventually in many other places in a world where rice is eaten every day by half the population. Lack of the vital nutrient causes blindness in a quarter-million to a half-million children each year. It affects millions of people in Asia and Africa and so weakens the immune system that some two million die each year of diseases they would otherwise survive.

The destruction of the field trial, and the reasons given for it, touched a nerve among scientists around the world, spurring them to counter assertions of the technology's health and environmental risks. On a petition supporting Golden Rice circulated among scientists and signed by several thousand, many vented a simmering frustration with activist organizations like Greenpeace, which they see as playing on misplaced fears of genetic engineering in both the developing and the developed worlds. Some took to other channels to convey to American foodies and Filipino farmers alike the broad scientific consensus that G.M.O.'s are not intrinsically more risky than other crops and can be reliably tested.

At stake, they say, is not just the future of biofortified rice but also a rational means to evaluate a technology whose potential to improve nutrition in developing countries, and developed ones, may otherwise go unrealized.

"There's so much misinformation floating around about G.M.O.'s that is taken as fact by people," said Michael D. Purugganan, a professor of genomics and biology and the dean for science at New York University, who sought to calm health-risk concerns in a primer on GMA News Online, a media outlet in the Philippines: "The genes they inserted to make the vitamin are not some weird manufactured material," he wrote, "but are also found in squash, carrots and melons."

Mr. Purugganan, who studies plant evolution, does not work on genetically engineered crops, and until recently had not participated in the public debates over the risks and benefits of G.M.O.'s. But having been raised in a middle-class family in Manila, he felt compelled to weigh in on Golden Rice. "A lot of the criticism of G.M.O.'s in the Western world suffers from a lack of understanding of how really dire the situation is in developing countries," he said.

Some proponents of G.M.O.'s say that more critical questions, like where biotechnology should fall as a priority in the efforts to address the root causes of hunger and malnutrition and how to prevent a few companies from controlling it, would be easier to address were they not lumped together with unfounded fears by those who oppose G.M.O.'s.

"It is long past time for scientists to stand up and shout, 'No more lies — no more fear-mongering,' " said Nina V. Fedoroff, a professor at the King Abdullah University of Science and Technology in Saudi Arabia and a former science adviser to the American secretary of state, who helped spearhead the petition. "We're talking about saving millions of lives here."

Precisely because of its seemingly high-minded purpose, Golden Rice has drawn suspicion from biotechnology skeptics beyond the demonstrators who forced their way into the field trial. Many countries ban the cultivation of all genetically modified crops, and after the rice's media debut early in the last decade, Vandana Shiva, an Indian environmentalist, called it a "Trojan horse" whose purpose was to gain public support for all manner of genetically modified crops that would benefit multinational corporations at the expense of poor farmers and consumers.

In a 2001 article, "The Great Yellow Hype," the author Michael Pollan, a critic of industrial agriculture, suggested that it might have been developed to "win an argument rather than solve a public-health problem." He cited biotechnology industry advertisements that featured the virtues of the rice, which at the time had to be ingested in large quantities to deliver a meaningful dose of vitamin A.

But the rice has since been retooled: a bowl now provides 60 percent of the daily requirement of vitamin A for healthy children. And Gerard Barry, the Golden Rice project leader at the International Rice Research Institute — and, it must be said, a former senior scientist and executive at Monsanto — suggests that attempts to discredit Golden Rice discount the suffering it could alleviate if successful. He said, too, that critics who suggest encouraging poor families to simply eat fruits and vegetables that contain beta carotene disregard the expense and logistical difficulties that would thwart such efforts.

Identified in the infancy of genetic engineering as having the potential for the biggest impact for the world's poor, beta-carotene-producing rice was initially funded by the Rockefeller Foundation and the European Union. In a decade of work culminating in 1999, two academic scientists, Ingo Potrykus and Peter Beyer, finally switched on the production of beta carotene by adding daffodil and bacteria DNA to the rice's genome. They licensed their patent rights to the agribusiness company that later became Syngenta, on the condition that the technology and any improvements to it would be made freely available to poor farmers in the developing world. With the company retaining the right to use it in developed countries, potentially as an alternative to vitamin supplements, Syngenta scientists later improved the amount of beta carotene produced by substituting a gene from corn for the one from daffodil.

If the rice gains the Philippine government's approval, it will cost no more than other rice for poor farmers, who will be free to save seeds and replant them, Dr. Barry said. It has no known allergens or toxins, and the new proteins produced by the rice have been shown to break down quickly in simulated gastric fluid, as required by World Health Organization guidelines. A mouse feeding study is under way in a laboratory in the United States. The potential that the Golden Rice would cross-pollinate with other varieties, sometimes called "genetic contamination," has been studied and found to be limited, because rice is typically self-pollinated. And its production of beta carotene does not appear to provide a competitive advantage — or disadvantage — that could affect the survival of wild varieties with which it might mix.

If Golden Rice is a Trojan horse, it now has some company. The Bill and Melinda Gates Foundation, which is supporting the final testing of Golden Rice, is also underwriting the development of crops tailored for sub-Saharan Africa, like cassava that can resist the viruses that routinely wipe out a third of the harvest, bananas that contain higher levels of iron and corn that uses nitrogen more efficiently. Other groups are developing a pest-resistant black-eyed pea and a "Golden Banana" that would also deliver vitamin A.

Beyond the fear of corporate control of agriculture, perhaps the most cited objection to G.M.O.'s is that they may hold risks that may not be understood. The decision to grow or eat them relies, like many other decisions, on a cost-benefit analysis.

How food consumers around the world weigh that calculation will probably have far-reaching consequences. Such crops, Scientific American declared in an editorial last week, will make it to people's plates "only with public support."

Greenpeace, for one, dismisses the benefits of vitamin supplementation through G.M.O.'s and has said it will continue to oppose all uses of biotechnology in agriculture. As Daniel Ocampo, a campaigner for the organization in the Philippines, put it, "We would rather err on the side of caution."

For others, the potential of crops like Golden Rice to alleviate suffering is all that matters. "This technology can save lives," one of the petition's signers, Javier Delgado of Mexico, wrote. "But false fears can destroy it."

Is It Time For Scientist Activism Against GMO Fear-Mongering?

By David Kroll. Forbes, 8/25/2013

It's early Sunday morning but a round of contentious discussion began last night on Twitter when The New York Times posted today's Amy Harmon story on Golden Rice.

This strain of rice has been modified to produce beta-carotene, a nutrient that the body processes into vitamin A.

In areas of southeast Asia and Africa, vitamin A deficiency is common and can cause blindness. The World Health Organization estimates that 250 million children worldwide are vitamin A deficient, causing 250,000 to 500,000 children to become blind. Vitamin A is also important for immune system functioning and deficiencies can also lead to fatalities from bacterial or viral diseases.

The International Rice Research Institute (IRRI) has been field testing Golden Rice in the Phillipines, intending for it to be one solution to vitamin A deficiency in developing areas. Harmon reports that protestors vandalized a field site there on August 8th (YouTube video here).

This case exemplifies Harmon's investigation of the issues underlying the current dissent over foods containing gene modifications. For example, she wrote a lengthy and widely-discussed July 27th piece on the potential molecular biology solution to the bacteria causing citrus greening disease in Florida orange crops. In the article, an argument is presented that genetic modification of oranges may be essential to preserving the state's orange-growing industry.

In today's Golden Rice story, Harmon quotes a researcher involved in drafting a Change.org petition for global scientific condemnation of the Philippine rice field vandalism as saying, "It is long past time for scientists to stand up and shout, 'No more lies — no more fear-mongering.'"

The sentiment expressed is one that has been hotly debated, most recently in the climate change research field. A July 31st Guardian article by Dr. Tasmin Edwards presented the view that scientists should remain impartial where their science is related to public policy and that political activism for particular solutions risks the public trust in science.

Perhaps because my basic science training comes from the medicine and public health environment, I hold that scientists have a responsibility to hold forth on societal solutions where they have the expertise to educate the public and policymakers. My own education was underwritten by taxpayers and I hold that their investment in my knowledge deserves dividends. Hence, readers will find me here and elsewhere holding forth on the risks of drugs and dietary supplements, advocating for immunizations such as the human papillomavirus vaccine to prevent cervical and oral cancers and, yes, arguing that concerns about foreign, nonpathogenic DNA in foods are not based in fact.

So, do scientists have a responsibility to argue against fear-mongering about foods derived from genetic modification? Many arguments I read against G.M.O. foods are focused on disdain for the business practices of large agribusinesses such as Monsanto MON +1.73% and Syngenta . In fact, those defending the safety and utility of G.M.O. foods are often tarred with the lazy and intellectually offensive claim that they must somehow be pawns of industry. I've argued that one can still dislike business practices while still accepting the safety of G.M.O. foods. Others incorrectly note that G.M.O. foods are unregulated and not tested for safety, a point that Nathanael Johnson refutes in this Grist article.

I have yet to find a compelling argument against ingesting G.M.O. foods that is fully based in scientific fact. Harmon notes,

"Beyond the fear of corporate control of agriculture, perhaps the most cited objection to G.M.O.'s is that they may hold risks that may not be understood. The decision to grow or eat them relies, like many other decisions, on a cost-benefit analysis".

That's perhaps the finest two-sentence summary of the issues I've read to date.

My suggested solution is that if you're concerned about risks science cannot identify, pay the premiums to shop at Whole Foods or other stores where G.M.O. foods are not sold.

But should I as a scientist do more than make that suggestion? I open the discussion up to you, Dear Reader, to comment below. Note that you don't have to set up a Forbes.com account to comment. You can just sign in with one of your social media accounts.

The Truth about Genetically Modified Food

By David H. Freedman. Scientific American, August 26, 2013.

Proponents of genetically modified crops say the technology is the only way to feed a warming, increasingly populous world. Critics say we tamper with nature at our peril. Who is right?

Robert Goldberg sags into his desk chair and gestures at the air. “Frankenstein monsters, things crawling out of the lab,” he says. “This the most depressing thing I've ever dealt with.”

Goldberg, a plant molecular biologist at the University of California, Los Angeles, is not battling psychosis. He is expressing despair at the relentless need to confront what he sees as bogus fears over the health risks of genetically modified (GM) crops. Particularly frustrating to him, he says, is that this debate should have ended decades ago, when researchers produced a stream of exonerating evidence: “Today we're facing the same objections we faced 40 years ago.”

Across campus, David Williams, a cellular biologist who specializes in vision, has the opposite complaint. “A lot of naive science has been involved in pushing this technology,” he says. “Thirty years ago we didn't know that when you throw any gene into a different genome, the genome reacts to it. But now anyone in this field knows the genome is not a static environment. Inserted genes can be transformed by several different means, and it can happen generations later.” The result, he insists, could very well be potentially toxic plants slipping through testing.

Williams concedes that he is among a tiny minority of biologists raising sharp questions about the safety of GM crops. But he says this is only because the field of plant molecular biology is protecting its interests. Funding, much of it from the companies that sell GM seeds, heavily favors researchers who are exploring ways to further the use of genetic modification in agriculture. He says that biologists who point out health or other risks associated with GM crops—who merely report or defend experimental findings that imply there may be risks—find themselves the focus of vicious attacks on their credibility, which leads scientists who see problems with GM foods to keep quiet.

Whether Williams is right or wrong, one thing is undeniable: despite overwhelming evidence that GM crops are safe to eat, the debate over their use continues to rage, and in some parts of the world, it is growing ever louder. Skeptics would argue that this contentiousness is a good thing—that we cannot be too cautious when tinkering with the genetic basis of the world's food supply. To researchers such as Goldberg, however, the persistence of fears about GM foods is nothing short of exasperating. “In spite of hundreds of millions of genetic experiments involving every type of organism on earth,” he says, “and people eating billions of meals without a problem, we've gone back to being ignorant.”

So who is right: advocates of GM or critics? When we look carefully at the evidence for both sides and weigh the risks and benefits, we find a surprisingly clear path out of this dilemma.

The bulk of the science on GM safety points in one direction. Take it from David Zilberman, a U.C. Berkeley agricultural and environmental economist and one of the few researchers considered credible by both agricultural chemical companies and their critics. He argues that the benefits of GM crops greatly outweigh the health risks, which so far remain theoretical. The use of GM crops “has lowered the price of food,” Zilberman says. “It has increased farmer safety by allowing them to use less pesticide. It has raised the output of corn, cotton and soy by 20 to 30 percent, allowing some people to survive who would not have without it. If it were more widely adopted around the world, the price [of food] would go lower, and fewer people would die of hunger.”

In the future, Zilberman says, those advantages will become all the more significant. The United Nations Food and Agriculture Organization estimates that the world will have to grow 70 percent more food by 2050 just to keep up with population growth. Climate change will make much of the world's arable land more difficult to farm. GM crops, Zilberman says, could produce higher yields, grow in dry and salty land, withstand high and low temperatures, and tolerate insects, disease and herbicides.

Despite such promise, much of the world has been busy banning, restricting and otherwise shunning GM foods. Nearly all the corn and soybeans grown in the U.S. are genetically modified, but only two GM crops, Monsanto's MON810 maize and BASF's Amflora potato, are accepted in the European Union. Eight E.U. nations have banned GM crops outright. Throughout Asia, including in India and China, governments have yet to approve most GM crops, including an insect-resistant rice that produces higher yields with less pesticide. In Africa, where millions go hungry, several nations have refused to import GM foods in spite of their lower costs (the result of higher yields and a reduced need for water and pesticides). Kenya has banned them altogether amid widespread malnutrition. No country has definite plans to grow Golden Rice, a crop engineered to deliver more vitamin A than spinach (rice normally has no vitamin A), even though vitamin A deficiency causes more than one million deaths annually and half a million cases of irreversible blindness in the developing world.

Globally, only a tenth of the world's cropland includes GM plants. Four countries—the U.S., Canada, Brazil and Argentina—grow 90 percent of the planet's GM crops. Other Latin American countries are pushing away from the plants. And even in the U.S., voices decrying genetically modified foods are becoming louder. At press time, at least 20 states are considering GM-labeling bills.

The fear fueling all this activity has a long history. The public has been worried about the safety of GM foods since scientists at the University of Washington developed the first genetically modified tobacco plants in the 1970s. In the mid-1990s, when the first GM crops reached the market, Greenpeace, the Sierra Club, Ralph Nader, Prince Charles and a number of celebrity chefs took highly visible stands against them. Consumers in Europe became particularly alarmed: a survey conducted in 1997, for example, found that 69 percent of the Austrian public saw serious risks in GM foods, compared with only 14 percent of Americans.

In Europe, skepticism about GM foods has long been bundled with other concerns, such as a resentment of American agribusiness. Whatever it is based on, however, the European attitude reverberates across the world, influencing policy in countries where GM crops could have tremendous benefits. “In Africa, they don't care what us savages in America are doing,” Zilberman says. “They look to Europe and see countries there rejecting GM, so they don't use it.” Forces fighting genetic modification in Europe have rallied support for “the precautionary principle,” which holds that given the kind of catastrophe that would emerge from loosing a toxic, invasive GM crop on the world, GM efforts should be shut down until the technology is proved absolutely safe.

But as medical researchers know, nothing can really be “proved safe.” One can only fail to turn up significant risk after trying hard to find it—as is the case with GM crops.

The human race has been selectively breeding crops, thus altering plants' genomes, for millennia. Ordinary wheat has long been strictly a human-engineered plant; it could not exist outside of farms, because its seeds do not scatter. For some 60 years scientists have been using “mutagenic” techniques to scramble the DNA of plants with radiation and chemicals, creating strains of wheat, rice, peanuts and pears that have become agricultural mainstays. The practice has inspired little objection from scientists or the public and has caused no known health problems.

The difference is that selective breeding or mutagenic techniques tend to result in large swaths of genes being swapped or altered. GM technology, in contrast, enables scientists to insert into a plant's genome a single gene (or a few of them) from another species of plant or even from a bacterium, virus or animal. Supporters argue that this precision makes the technology much less likely to produce surprises. Most plant molecular biologists also say that in the highly unlikely case that an unexpected health threat emerged from a new GM plant, scientists would quickly identify and eliminate it. “We know where the gene goes and can measure the activity of every single gene around it,” Goldberg says. “We can show exactly which changes occur and which don't.” [For more on how GM plants are analyzed for health safety, see “The Risks on the Table,” by Karen Hopkin; Scientific American, April 2001.]

And although it might seem creepy to add virus DNA to a plant, doing so is, in fact, no big deal, proponents say. Viruses have been inserting their DNA into the genomes of crops, as well as humans and all other organisms, for millions of years. They often deliver the genes of other species while they are at it, which is why our own genome is loaded with genetic sequences that originated in viruses and nonhuman species. “When GM critics say that genes don't cross the species barrier in nature, that's just simple ignorance,” says Alan McHughen, a plant molecular geneticist at U.C. Riverside. Pea aphids contain fungi genes. Triticale is a century-plus-old hybrid of wheat and rye found in some flours and breakfast cereals. Wheat itself, for that matter, is a cross-species hybrid. “Mother Nature does it all the time, and so do conventional plant breeders,” McHughen says.

Could eating plants with altered genes allow new DNA to work its way into our own? It is theoretically possible but hugely improbable. Scientists have never found genetic material that could survive a trip through the human gut and make it into cells. Besides, we are routinely exposed to—we even consume—the viruses and bacteria whose genes end up in GM foods. The bacterium B. thuringiensis, for example, which produces proteins fatal to insects, is sometimes enlisted as a natural pesticide in organic farming. “We've been eating this stuff for thousands of years,” Goldberg says.

In any case, proponents say, people have consumed as many as trillions of meals containing genetically modified ingredients over the past few decades. Not a single verified case of illness has ever been attributed to the genetic alterations. Mark Lynas, a prominent anti-GM activist who last year publicly switched to strongly supporting the technology, has pointed out that every single news-making food disaster on record has been attributed to non-GM crops, such as the Escherichia coli–infected organic bean sprouts that killed 53 people in Europe in 2011.

Critics often disparage U.S. research on the safety of genetically modified foods, which is often funded or even conducted by GM companies, such as Monsanto. But much research on the subject comes from the European Commission, the administrative body of the E.U., which cannot be so easily dismissed as an industry tool. The European Commission has funded 130 research projects, carried out by more than 500 independent teams, on the safety of GM crops. None of those studies found any special risks from GM crops.

Plenty of other credible groups have arrived at the same conclusion. Gregory Jaffe, director of biotechnology at the Center for Science in the Public Interest, a science-based consumer-watchdog group in Washington, D.C., takes pains to note that the center has no official stance, pro or con, with regard to genetically modifying food plants. Yet Jaffe insists the scientific record is clear. “Current GM crops are safe to eat and can be grown safely in the environment,” he says. The American Association for the Advancement of Science, the American Medical Association and the National Academy of Sciences have all unreservedly backed GM crops. The U.S. Food and Drug Administration, along with its counterparts in several other countries, has repeatedly reviewed large bodies of research and concluded that GM crops pose no unique health threats. Dozens of review studies carried out by academic researchers have backed that view.

Opponents of genetically modified foods point to a handful of studies indicating possible safety problems. But reviewers have dismantled almost all of those reports. For example, a 1998 study by plant biochemist Árpád Pusztai, then at the Rowett Institute in Scotland, found that rats fed a GM potato suffered from stunted growth and immune system–related changes. But the potato was not intended for human consumption—it was, in fact, designed to be toxic for research purposes. The Rowett Institute later deemed the experiment so sloppy that it refuted the findings and charged Pusztai with misconduct.

Similar stories abound. Most recently, a team led by Gilles-Éric Séralini, a researcher at the University of Caen Lower Normandy in France, found that rats eating a common type of GM corn contracted cancer at an alarmingly high rate. But Séralini has long been an anti-GM campaigner, and critics charged that in his study, he relied on a strain of rat that too easily develops tumors, did not use enough rats, did not include proper control groups and failed to report many details of the experiment, including how the analysis was performed. After a review, the European Food Safety Authority dismissed the study's findings. Several other European agencies came to the same conclusion. “If GM corn were that toxic, someone would have noticed by now,” McHughen says. “Séralini has been refuted by everyone who has cared to comment.”

Some scientists say the objections to GM food stem from politics rather than science—that they are motivated by an objection to large multinational corporations having enormous influence over the food supply; invoking risks from genetic modification just provides a convenient way of whipping up the masses against industrial agriculture. “This has nothing to do with science,” Goldberg says. “It's about ideology.” Former anti-GM activist Lynas agrees. He recently went as far as labeling the anti-GM crowd “explicitly an antiscience movement.”

Not all objections to genetically modified foods are so easily dismissed, however. Long-term health effects can be subtle and nearly impossible to link to specific changes in the environment. Scientists have long believed that Alzheimer's disease and many cancers have environmental components, but few would argue we have identified all of them.

And opponents say that it is not true that the GM process is less likely to cause problems simply because fewer, more clearly identified genes are switched. David Schubert, an Alzheimer's researcher who heads the Cellular Neurobiology Laboratory at the Salk Institute for Biological Studies in La Jolla, Calif., asserts that a single, well-characterized gene can still settle in the target plant's genome in many different ways. “It can go in forward, backward, at different locations, in multiple copies, and they all do different things,” he says. And as U.C.L.A.'s Williams notes, a genome often continues to change in the successive generations after the insertion, leaving it with a different arrangement than the one intended and initially tested. There is also the phenomenon of “insertional mutagenesis,” Williams adds, in which the insertion of a gene ends up quieting the activity of nearby genes.

True, the number of genes affected in a GM plant most likely will be far, far smaller than in conventional breeding techniques. Yet opponents maintain that because the wholesale swapping or alteration of entire packages of genes is a natural process that has been happening in plants for half a billion years, it tends to produce few scary surprises today. Changing a single gene, on the other hand, might turn out to be a more subversive action, with unexpected ripple effects, including the production of new proteins that might be toxins or allergens.

Opponents also point out that the kinds of alterations caused by the insertion of genes from other species might be more impactful, more complex or more subtle than those caused by the intraspecies gene swapping of conventional breeding. And just because there is no evidence to date that genetic material from an altered crop can make it into the genome of people who eat it does not mean such a transfer will never happen—or that it has not already happened and we have yet to spot it. These changes might be difficult to catch; their impact on the production of proteins might not even turn up in testing. “You'd certainly find out if the result is that the plant doesn't grow very well,” Williams says. “But will you find the change if it results in the production of proteins with long-term effects on the health of the people eating it?”

It is also true that many pro-GM scientists in the field are unduly harsh—even unscientific—in their treatment of critics. GM proponents sometimes lump every scientist who raises safety questions together with activists and discredited researchers. And even Séralini, the scientist behind the study that found high cancer rates for GM-fed rats, has his defenders. Most of them are nonscientists, or retired researchers from obscure institutions, or nonbiologist scientists, but the Salk Institute's Schubert also insists the study was unfairly dismissed. He says that as someone who runs drug-safety studies, he is well versed on what constitutes a good-quality animal toxicology study and that Séralini's makes the grade. He insists that the breed of rat in the study is commonly used in respected drug studies, typically in numbers no greater than in Séralini's study; that the methodology was standard; and that the details of the data analysis are irrelevant because the results were so striking.

Schubert joins Williams as one of a handful of biologists from respected institutions who are willing to sharply challenge the GM-foods-are-safe majority. Both charge that more scientists would speak up against genetic modification if doing so did not invariably lead to being excoriated in journals and the media. These attacks, they argue, are motivated by the fear that airing doubts could lead to less funding for the field. Says Williams: “Whether it's conscious or not, it's in their interest to promote this field, and they're not objective.”

Both scientists say that after publishing comments in respected journals questioning the safety of GM foods, they became the victims of coordinated attacks on their reputations. Schubert even charges that researchers who turn up results that might raise safety questions avoid publishing their findings out of fear of repercussions. “If it doesn't come out the right way,” he says, “you're going to get trashed.”

There is evidence to support that charge. In 2009 Nature detailed the backlash to a reasonably solid study published in the Proceedings of the National Academy of Sciences USA by researchers from Loyola University Chicago and the University of Notre Dame. The paper showed that GM corn seemed to be finding its way from farms into nearby streams and that it might pose a risk to some insects there because, according to the researchers' lab studies, caddis flies appeared to suffer on diets of pollen from GM corn. Many scientists immediately attacked the study, some of them suggesting the researchers were sloppy to the point of misconduct.

There is a middle ground in this debate. Many moderate voices call for continuing the distribution of GM foods while maintaining or even stepping up safety testing on new GM crops. They advocate keeping a close eye on the health and environmental impact of existing ones. But they do not single out GM crops for special scrutiny, the Center for Science in the Public Interest's Jaffe notes: all crops could use more testing. “We should be doing a better job with food oversight altogether,” he says.

Even Schubert agrees. In spite of his concerns, he believes future GM crops can be introduced safely if testing is improved. “Ninety percent of the scientists I talk to assume that new GM plants are safety-tested the same way new drugs are by the fda,” he says. “They absolutely aren't, and they absolutely should be.”

Stepped-up testing would pose a burden for GM researchers, and it could slow down the introduction of new crops. “Even under the current testing standards for GM crops, most conventionally bred crops wouldn't have made it to market,” McHughen says. “What's going to happen if we become even more strict?”

That is a fair question. But with governments and consumers increasingly coming down against GM crops altogether, additional testing may be the compromise that enables the human race to benefit from those crops' significant advantages.

This article was originally published with the title Are Engineered Foods Evil?.

Restoring Tomato Flavor

By Nancy Stamp. The Scientist, August 28, 2013

Commercial tomatoes rarely have that fresh vine-ripened flavor that everyone loves, but the ideal recipe for tomato taste is now known. Will growers embrace the new cultivars?

Tomatoes are the #1-selling fruit or vegetable in the world today. Yet consumers complain about blandness of supermarket tomatoes and yearn for the old timey summer-fresh, off-the-vine taste. In a recent symposium at the 2013 annual meeting of the

American Association for Advancement of Science, Harry Klee, a horticultural scientist at the University of Florida, reminded us that it is only in the last 50 years or so that “we’ve done damage to tomato,” referring to the creation of the industrial variety—a prolific yielder with inferior flavor. He also noted that with the recent publication of the tomato genome sequence and subsequent identification of key flavors and aroma genes, it may now be within our power to create a good-tasting and high-yielding fruit.

The goals of commercial tomato breeders have changed over time. In the late 1800s, the best seed men sought large, round, smooth fruit, over the lumpy or furrowed tomatoes, and they also selected for good taste. They sold their seeds to growers, who often sold directly to consumers. But after World War II, in response to the steadily increasing consumer market for tomatoes worldwide, breeding was heavily targeted for crop yield and shelf-life during distribution. Now the growers’ customer is the distributor, not the consumer. As Klee explained in his talk, “It is all about money. The growers simply are not paid for good flavor. . . . The grower is paid for producing pounds of product.”

As a result, the market for a really good tasting, cheap commercial tomato available year-round remains unfulfilled. But if tomato genetics are so malleable—as evidenced by the rapid disappearance of flavor in the face of breeding for crop yield and shelf-life—why is the supermarket tomato still so disappointing?

Tomato taste is a unique combination of five tastants—sweet, sour, salty, bitter, and savory (umami) compounds—as well as the aroma of volatiles, many from the breakdown of the carotenoid pigments, such as the bright red antioxidant lycopene. The modern tomato plant was bred to produce more fruit, diluting the relatively fixed amount of nutrients and tastants the plant has to offer. But that is only part the story.

Researchers at the University of California, Davis, recently discovered that a genetic mutation that occurred about 70 years ago, and was then selected by breeders for its effect of causing tomatoes to ripen uniformly, came at the cost of less sugar and carotenoids in the fruit (Science, 336:1711-15, 2012). Breeders also grew gas-able fruit, cultivars that respond well to ethylene to trigger ripening during post-harvest, thus allowing tomatoes to be picked while still green. However, it is difficult to gage when green tomatoes have matured to the point of forming the seed gel so rich in acid and umami. If picked too soon, the fruit will not ripen well.

Even for the mature green tomatoes, postharvest ethylene gassing by itself cannot fully substitute for the flavor developed by true vine ripening. For example, green fruit receives most of its sugar from leaves, but also has chloroplasts that, when bathed in sunshine, can make more sugar directly within the fruit. Picked and stored fruit, of course, is stored in the dark, and thus neither receives nor produces sugar. And because tomatoes are a delicate fruit, they are also bred for a tougher (and distasteful) skin to withstand picking, packing, and transport. The final nail in the flavor coffin is refrigeration. Despite knowing it ruins the taste by reducing the volatiles so crucial for good flavor, wholesalers and retailers refrigerate tomatoes to prolong shelf-life during distribution.

To achieve a better-tasting tomato, Harry Klee and his colleagues turned the breeding process on its head. First, they analyzed more than 152 heirlooms plus some supermarket varieties, examining sugars, acids, and 28 volatiles (Current Biology, 22:1035-39, 2012), and found a surprising result: despite having endured several genetic bottlenecks as it hopped from South America to Mesoamerica to Europe, the tomato still has as much as a 3,000-fold variation in volatile content across the cultivars. A 100-person consumer panel then tasted 66 tomato cultivars, rating them for intensity of flavor, sweetness, sourness, and overall likeability. As expected, sweetness was most effective in swaying the panelists. However, there was a startling poor correlation between the amount of sugar and people’s perception of sweetness. For example, the Yellow Jelly Bean variety has more sugar than the Matina tomato, but people perceived Matina as twice as sweet. This discrepancy may be explained by the accompanying volatiles: Matina has a high concentration of volatiles that enhance our perception of sweetness and low concentration of sweetness suppressors; Yellow Jelly Bean has the opposite.

We detect the volatiles sniffed through our nose and also from food as we chew, as volatiles enter the nasal cavity from the back of the mouth. It is the latter that is so essential to detecting flavor. Whereas olfactory signals go to the prefrontal cortex, the volatile signals from the back of the mouth interact with taste signals in various parts of the brain. Based on extensive screening of heirlooms, both molecularly and with flavor-preference panels, Klee claimed that he and his colleagues now "have the recipe—we know what the content of the ideal tomato is."

However, while they have crossed the best tasting heirlooms with modern varieties to create hybrids that taste as good as the heirlooms and are disease resistant and produce more fruit than the heirlooms, the hybrids aren't the bonanza producers that commercial varieties are. And until a plant can produce as much fruit as those that supply the supermarkets, growers are unlikely to switch cultivars. As long as people don't want to pay more, the growers will favor the heavy-producing, inferior-tasting industrial varieties.

Nancy Stamp is a professor at Binghamton University–State University of New York. Using the tomato plant as a research system, her research focuses on why some plants are so well-defended against insects while others are susceptible to herbivory.

Soil→roots→stem→atmosphere…
AoB blog. 29th of August 2013

That is the usual route taken by water within plants. And for most of them that is all there is. However, not all plants are the same (see the earlier Brachypodium ≠ Arabidopsis blog post). Take for instance plants that live in cloud forests. Despite the general persistence of water-bearing cloud or fog cover, when that life-sustaining envelope of hydration is absent – and coupled with the aridity that accompanies those ecosystems' high elevations – such habitats experience seasonal drought and can be quite arid. Consequently, plants in that habitat can't always rely on soil-stored water and several employ other, additional mechanisms for water abstraction.

Although foliar water uptake (FWU) is a widely recognised water-acquisition strategy for such plants, its prevalence and importance to water and carbon economy of tropical cloud forest species is largely unknown. Using studies both in glasshouse and in the 'field' (sorry, I just can't get used to calling a mountain habitat study area a field…), Cleiton Eller et al. have demonstrated the importance of FWU for Drimys brasiliensis (Winteraceae). They have shown that fog water diffuses directly through leaf cuticles(!), is transported through the xylem to below ground, and enhances leaf water potential, photosynthesis, stomatal conductance and growth relative to plants sheltered from fog. They drily conclude that 'Foliar uptake of fog water is an important water acquisition mechanism that can mitigate the deleterious effects of soil water deficits for D. brasiliensis'.

This also messes up anyone's 'linear teaching model' where we tell our students that water travels unidirectionally – upwards – in the xylem, photosynthates travel bidirectionally in the phloem (no, not in the same sieve tubes at the same time… or does it..?). Plant biology, eh, certainly has its ups – and its downs…

Reference: Eller et al. Foliar uptake of fog water and transport belowground alleviates drought effects in the cloud forest tree species, Drimys brasiliensis (Winteraceae). New Phytologist. Vol. 199, Issue 1, pages 151–162, July 2013.

Farming a Toxin To Protect Crops, Pollinators and People
By Ferris Jabr. Scientific American, September 3, 2013

Genetically modified crops that produce the pest-killing toxin Bt increase yields and reduce the use of noxious chemical insecticides. But like any powerful tool, they must be used responsibly.

The familiar teardrop eggplant, with its deep purple luster, is but one member of a large and diverse botanical family. Some eggplants are long, lean and pendulous, like smooth-skinned cucumbers. From a distance, ripening kumba eggplants are indistinguishable from miniature pumpkins. And oblong white cultivars that look like they were plucked from beneath chickens and ostriches explain the etymology of “eggplant."

Nowhere is the entire spectrum of eggplant shapes and colors more apparent or celebrated than India—the vegetable's birthplace and its second-largest producer worldwide. India grows more than a dozen cultivars of eggplant—or brinjals, as they are known locally—and is home to many wild eggplant relatives as well. Equally multifarious diseases and pests routinely ravage this abundance, but one does more damage than any other. Every year Indian farmers lose around half of their crops to the eggplant fruit and shoot borer—a moth whose larvae eat their way through brinjals in Africa and Asia. In really bad years the larvae may destroy 90 percent of crops.

To combat this vermin, farmers in India slather brinjals in organophosphates and other chemical pesticides that are known to linger in the environment, kill all kinds of beneficial insects and make people sick even at low doses—the kinds of chemicals the U.S. and many other developed countries have banned or restricted. Such applications are often ineffective because the larvae remain concealed and protected within the eggplant itself. Any surviving brinjals are coated with a thick white film of insecticide residue as much as 500 times the maximum permissible level. "The amount of pesticides sprayed on brinjal, cauliflower and cabbage is amazing—frightening," says P. Ananda Kumar, director of the Institute of Biotechnology at Acharya N.G. Ranga Agricultural University in Hyderabad, India. "If you saw it you would you never ever touch a vegetable in India."

Starting in the mid 1990s, Kumar and other scientists working for both universities and biotechnology companies in India—including Mahyco, a seed company partially owned by Monsanto—began devising a way to deter the fruit and shoot borer and dramatically increase eggplant yields without using so many noxious insecticides. They would still rely on a toxin to kill the larvae, but instead of synthetic chemicals they would use poisonous proteins produced by a common soil bacterium called Bacillus thuringiensis (Bt)—toxins organic farmers had safely used as a form of biological pesticide since the 1920s. Rather than formulating a spray or powder, though, the researchers were going to borrow the bacterium’s toxin-making gene and insert it into the eggplant’s DNA so the plant could produce Bt toxin on its own. The resulting Bt eggplants would kill only the fruit and shoot borer and possibly closely related species, leaving other insects and creatures unharmed.

Mahyco succeeded in creating Bt eggplant seeds and, in collaboration with Cornell University and the U.S. Agency for International Development, gave them to several Indian universities, where researchers began to breed them with local brinjal varieties. The plan was to sell the insect-resistant offspring to rural farmers for very little money or dispense them for free. By 2009 different teams of scientists had produced several types of Bt brinjals and extensively tested them to make sure they were not poisonous to people or animals and that wild eggplant relatives would not become less diverse or too unruly if they exchanged pollen with genetically modified (GM) strains. In October 2009, based on the recommendations of expert committees, the Indian government approved Bt brinjal for commercialization.

But Indian Environment and Forests Minister Jairam Ramesh intervened. Thousands of angry and alarming faxes and e-mails from Greenpeace and other anti-GM organizations flooded Ramesh’s office. Several scientists known to oppose genetic modification urged Ramesh to ban Bt brinjal. And farmers riled up by the opposition protested in the streets. Opponents argued that, despite the safety testing—and despite the fact that farmers in India had grown Bt cotton since 2002 with great success—Bt brinjals endangered people's health and the environment. In February 2009 Ramesh imposed a moratorium on the release of Bt brinjals until India arrived at a "political, scientific and societal consensus" about their safety and benefits.

What many consider a disastrous imbroglio continues to stew in India. "Most of the concerns raised are devoid of any logic and not based on any proper scientific analysis," Kumar says. "Science has taken a backseat to politics." Elsewhere, after nearly 20 years of growing Bt corn, cotton and soybeans around the world and almost 100 years of using Bt sprays, researchers have reached a consensus about many of Bt's advantages and risks. At this point, the evidence overwhelmingly demonstrates that Bt toxins are some of the safest and most selective insecticides ever used. Claims that Bt crops poison people are simply not true. When properly managed, Bt crops increase yields and make croplands far friendlier for insect populations as a whole by reducing the use of broad-spectrum chemical insecticides that kill indiscriminately. Fewer chemical sprays also translate to cleaner grains, legumes and vegetables mixed into processed foods and sold whole in the produce aisle.

Bt crops are not entirely benign, however, nor are they a panacea. Despite the unparalleled specificity of Bt toxins, recent studies indicate that in a few rare cases they may inadvertently kill butterflies, ladybugs and other harmless or helpful insects, although so far there is no solid evidence that they poison bees. Even more concerning, agricultural pests can, will and have become resistant to Bt crops, just as they inevitably develop immunity to any form of pest control. If biotech companies prematurely release new Bt varieties without proper testing or farmers do not take adequate precautions when growing them, Bt crops ultimately fail and, ironically, encourage the use of chemical pesticides they were meant to replace. Most recently, some farmers in the Midwestern U.S. have realized that one kind of Bt corn no longer repels voracious root-chomping beetle larvae.

"Genetic engineering can be a powerful tool and provide opportunities for managing insects we have never had before, potentially with far less harmful environmental impact and certainly less threat to human health," says entomologist Kenneth Ostlie of the University of Minnesota. "The true challenge is good stewardship."

B. thuringiensis is a ubiquitous bacterium that lives primarily in the soil as well as in water, on plants and in grain silos. In times of stress—when nutrition is scarce, for example—B. thuringiensis forms an endospore: a resilient, dehydrated version of its former self. Such spores are seriously durable, especially when protected from the elements; one group of scientists managed to revive 250-million-year-old Bacillus spores embedded in salt. During the sporulation process, the microbe also produces a diamond-shaped crystal packed with poisonous proteins known as cry toxins. The evolutionary advantage of these crystals remains something of a mystery, but they seem to help the bacteria infect various insects and continue their reproductive cycle within the bugs' bodies. In fact, B. thuringiensis conducts most its conjugal activity inside the larvae of moths, beetles, mosquitoes and other insects, rather than in the soil.

In the wild, caterpillars and other larva munching on a plant teeming with B. thuringiensis will ingest spores and toxic crystals. Juan Luis Jurat-Fuentes of University of Tennessee and other entomologists have spent years studying what happens next in detail. Once inside the alkaline environment of the insect's intestines, the cry toxins in the crystal separate from one another, bind to proteins embedded in gut cells and create pores that burst the cells. The insect's hemolymph—its equivalent of blood—flows into its intestine and its gut juices seep into its body cavity, which alters the overall pH and impels the spores to germinate. In turn, the reanimated spores release a concoction of chemicals that further predisposes the insect to infection. Within hours all the internal chemical chaos disrupts communication between neurons and paralyzes the insect. Several hours or days later—consumed by a severe infection of B. thuringiensis and other opportunistic bacteria—the insect dies and the microbes use its decaying tissues as energy for a frenzied orgy.

People have been manipulating B. thuringiensis for their own purposes for nearly 100 years. In 1901 Japanese scientist Shigetane Ishiwata discovered that a particular strain of bacteria was killing large numbers of silkworms. He named the bacterium Bacillus sotto. Ten years later, Ernst

Berliner rediscovered this same species of bacteria on a dead moth in a flour mill in the German state Thuringia; he gave the species the name that stuck: Bacillus thuringiensis. An easily duplicated living creature that killed insect pests without endangering other animals or people was an incredibly serendipitous find. But no one it in the early 1900s could have foreseen the extent to which this microscopic organism would eventually transform agriculture around the world.

Farmers began to use Bt spores and crystals as a biological pesticide as early as the 1920s. France produced the first commercial Bt insecticide, Sporine, in 1938. And the U.S. started manufacturing such sprays in 1958. By 1977, scientists had identified 13 Bt subspecies that made different kinds of crystals, all toxic to different types of moth larvae. Soon enough researchers isolated Bt strains that specifically killed flies, mosquitoes and beetles. Scientists have now catalogued more than 80 subspecies of B. thuringiensis and more than 200 distinct cry toxins. In most cases each subspecies and the crystals it produces evolved to kill only one or two insect species, even within the same insect family. B. thuringiensis subspecies tolworthi, for example, easily slays fall armyworm caterpillars (Spodoptera frugiperda), but is not nearly as lethal to larvae of the oriental leafworm moth (Spodoptera litura), which is in the same genus (the taxonomic level just above species).

In the 1980s, as crop pests developed increasing resistance to synthetic pesticides, more and more growers turned to Bt, which became especially popular among organic famers. In addition to their selective lethality, the bacterial toxins degraded in sunlight and washed away in rain, rather than contaminating wild habitat and sources of drinking water. This transience was both appealing and problematic for farmers, however, forcing them to reapply Bt sprays as often as every three days. And Bt formulations contained more than just spores and crystals; they were also full of synthetic chemicals that helped the bacteria spread over and stick to plants. Some of those chemicals were known to poison rodents and other mammals. The rapidly advancing technology of genetic engineering promised a cleaner and more precise way to use Bt. If it worked, farmers would never have to spray Bt in liquid form again; in fact, they could spend far less time and money on typical pesticides in general.

Scientists have several sophisticated tools for modifying plant DNA. Often, they recruit a rather unique and almost uncannily convenient microbe known as agrobacterium tumefaciens, which evolved to inject genetic material into plants to aid infection. In 1987 Plant Genetic Systems in Belgium isolated a gene encoding a cry toxin from one subspecies of B. thuringiensis and used agrobacterium to insert it into the genome of embryonic tobacco plants, creating the very first Bt plant life. That was just the beginning. Biotech companies in several different countries continued to improve this technique. Less than 10 years later, in 1996, the U.S. commercialized Bt corn and cotton. Farmers across the country readily adopted Bt crops because of their obvious benefits. "There's no question that Bt allowed us to grow and harvest more corn," says David Linn of Correctionville, Iowa, who has been farming his whole life. He explains that, before working with Bt corn, he would painstakingly search his fields for the eggs of a pest known as corn borer, trying to figure out when to spray chemical pesticides; the chemicals kill the newly hatched larvae only during a short window of time before they tunnel into the corn and out of reach. He often lost as many as 30 bushels of corn per acre to borers. "Bt corn meant not driving through fields, not spraying toxic chemicals, not using up fuel," he says. "It makes things a whole lot simpler when Bt is in the corn."

As of 2013, 76 percent of the corn grown in the U.S. and 75 percent of the cotton are Bt varieties. In 1996, 1.7 million hectares of genetically engineered crops were grown worldwide (a single hectare is about the size of the grass lawn in the middle of a standard athletic track). By 2012, the number had increased to more than 170 million hectares, at least 58 million of which were plants that produce Bt toxin.

Some opponents of Bt crops and genetic engineering in general contend that government scientists and researchers at universities have not conducted long-term studies, or any studies, on the health risks of GM foods—that such experiments simply do not exist. Even a cursory search of the research literature refutes these claims. The independent nonprofit educational organization Biology Fortified, Inc., hosts a growing online database of 600 GM plant safety studies. Manufacturers have tested every GM food on the U.S. market to make sure they are not toxic and do not cause allergies and began selling such foods only after the U.S. Food and Drug Administration reviewed and approved the results of those tests. It's in the manufacturers' best interest to do so: After all, if something goes wrong after a company markets a GM product, there will be serious legal and financial repercussions.

Scientists at universities with no stakes in the biotech industry have also questioned and rigorously evaluated the risks of B. thuringiensis and its toxins ever since farmers started using Bt sprays in the 1920s. Numerous laboratory and field tests have concluded that Bt is not toxic to fish, birds, mammals or people, even at doses thousands of times greater than what a person or animal would ever encounter outside the lab. Over the years researchers have injected or piped billions of Bt spores and toxic crystals directly into the skin, lungs, blood, stomachs and brains of mice, rats, cows, pigs, hens and quails; time and again the animals survived the experiments with few, if any, ill effects. The same is true for rats that ate one billion Bt spores a day for two years as well as for three successive generations of rats fed Bt corn. Joel Siegel, now at the U.S. Department of Agriculture, spent more than 10 years investigating the toxicity of Bt. "My conclusion was this was a very safe product," he says. "You could probably eat a pound of it and nothing would happen to you.”

In the 1950s volunteers for an experiment that today's ethical committees would probably never approve did in fact eat Bt. Each day for five days 18 people ingested one gram of a Bt spray called Thuricide—containing approximately three billion Bacillus spores and crystals—and inhaled 100 milligrams of the insecticide. Detailed physical examinations, blood tests and x-rays on the sixth day and five weeks later revealed no unusual or harmful changes. Although no one has ever developed a serious illness or died from ingesting B. thuringiensis or Bt crops, research suggests that a small percentage of people routinely or accidentally exposed to plumes or splashes of commercial Bt sprays have suffered skin rashes and irritated eyes. When they work as intended, Bt crops eliminate this danger and reduce workers' exposure to pesticides in general. Bt crops also indirectly improve human health. More than half of corn grown worldwide is infected with fusarium fungi, which sneak into the plants via tunnels formed by boring insects and, once established, produce toxins that damage the kidney, liver, nerves and cardiovascular system if ingested in high doses. Bt crops that kill such insects have 90 percent fewer fungal toxins than conventional crops.

A small minority of anti-GM scientists say that a handful of worrisome studies counter the decades of research demonstrating that Bt is not poisonous to people. In each case the greater scientific community has thoroughly criticized and often outright rejected the supposedly alarming studies because they were flawed, invalid and sometimes masked ulterior motives.

Gilles-Eric Séralini of the University of Caen Lower Normandy in France has published several highly controversial studies purporting that GM plants cause tumors, kidney failure and other maladies in rodents, sometimes killing them, and that Bt toxins harm human cells. Numerous scientists and scientific organizations—including those with no ties to the biotech industry—have excoriated Séralini’s experiments, stressing their defects: they have generally lacked the necessary statistical power to rule out illness due to chance; some studies used short-lived, lab-bred rats that are prone to tumors; the experiments using naked cells in petri dishes in no way reflected how the human body comes into contact with Bt; and the studies were often vague on important details or excluded them altogether.

“The authors’ conclusions cannot be regarded as scientifically sound,” pronounced the exceedingly cautious European Food Safety Authority in a statement summarizing independent evaluations of Séralini's work by Belgium, Denmark, France, Germany, Italy and the Netherlands. Séralini founded the Committee of Research and Independent Information on Genetic Engineering (CRIIGEN) because he regarded safety studies of GM food as inadequate; he has received funding from anti-GM organizations, such as Greenpeace; and he has offered journalists a preview of his upcoming publications only if they agreed not to discuss the research with any other scientists—a strategy science writer Carl Zimmer called "a rancid, corrupt way to report about science." Many journalists agreed anyway.

In other instances the media has exaggerated or essentially manufactured apprehension about Bt toxins. In 2011, a Canadian study claimed to find evidence of a cry toxin—Cry1Ab—circulating in the blood and umbilical cords of pregnant women. Although the study itself hardly mentioned health risks, alarming headlines proliferated. In truth, there was never any cause for concern. Some cry toxins—indeed many different proteins we eat—may in fact survive the journey from intestines to blood more or less whole, but it is by no means an easy feat. First of all, cooking and industrial processing break down and inactivate most cry toxins. The vast majority of food ingredients made from Bt corn and soybeans are mixed into highly processed products like cereals and cooking oils, although some U.S. farmers grow a single variety of Bt sweet corn for the produce aisle (which, presumably, most people would eat cooked). Secondly, cry toxins evolved to work in the high pH environment of the insect gut; our much more acidic low pH stomachs easily destroy them (which has been demonstrated in animal studies and confirmed with experiments using imitation stomach acid). And, if a cry toxin did get past the stomach and intestines into the blood, it would have no way to bind to our cells; it evolved to attach to insect cells that have very different surface proteins. Finally, any rogue cry toxins circulating in our blood are not necessarily from Bt crops. In fact, a far more likely source is organic food that has been treated with Bt sprays or any food with soil residues containing B. thuringiensis. Most of us eat small amounts of Bt every day.

Even if cry toxins in our food do not enter the bloodstream, our gut bacteria could grab Bt genes and start pumping out toxins, some researchers and GM opponents have proposed. This is biologically feasible, but highly unlikely. Many bacteria are famous for their ability to sponge up DNA from their surroundings and exchange genes with other bacteria and even with organisms from different kingdoms of life, such as plants. In Japan some people’s gut bacteria stole a gene for digesting seaweed from ocean bacteria on raw seaweed the people ate. Perhaps our gut bacteria could pick up the Bt gene from Bt corn. Perhaps, but they have had a similiar opportunity for millions of years because people have always eaten food with some traces of B. thuringiensis-laced soil. And there is no reason our intestinal companions would pilfer genes from GM food specifically, rather than from foods of all kinds and the many bacteria they harbor. Plus, if the microbes in our intestines did manage to acquire the Bt gene, they do not necessarily have the right cellular equipment to make the toxin; and even if they made the toxin, it would be harmless to human cells.

Despite the prodigious evidence of Bt’s safety, some people still worry about unanticipated illness and worst-case scenarios. A decade-old ruckus surrounding one particular type of Bt maize illustrates that the government can swiftly retract any GM products that slip past safety regulations. In 1998 the U.S. Environmental Protection Agency approved an Aventis (now Bayer) CropScience variety of Bt corn known as StarLink for use in animal feed, but did not allow farmers to grow it for human consumption. Tests indicated that the cry toxin (Cry9C) produced by StarLink plants did not degrade as easily in the human gut as other toxins and might cause allergies, even though it did not match the molecular structure of any known allergens.

In September 2000 a coalition of anti-GM groups discovered StarLink DNA in Kraft’s taco shells in Washington, D.C., grocery stores. Evidently, some growers were not strictly segregating StarLink corn from other varieties; the chaotic journey from field to supermarket aisle probably contributed to the muddle as well. In the first-ever recall of a GM food, Kraft, Taco Bell and other food companies yanked millions of dollars' worth of taco shells off the shelves and out of restaurants. More than 30 people reported ostensible allergic reactions to StarLink, but after evaluating blood samples the FDA and U.S. Centers for Disease Control and Prevention found no evidence of true allergies. By November, however, the FDA had recalled another 300 corn-based products and the EPA began regularly screening the food supply for StarLink. Remnants of StarLink have been "virtually nonexistent since 2003," the EPA says on its Web site; the organization is so confident in its disappearance that is has stopped screening.

How Bt crops threaten insect ecosystems and the environment is much less straightforward than whether they are safe enough to include in our diet. The massive mat of monoculture rolled across the U.S.—vast adjacent fields, each consisting of a single crop—is a relatively new kind of man-made ecosystem that has replaced much more diverse wild habitat. Long before GM plants of any kind, farmland displaced many native species. Still, cropfields are abuzz with life, some of which has evolved to survive on the farm. Overall, Bt crops around the world have been a boon for all kinds of insects and arthropods because this highly selective form of pest control has greatly diminished the use of chemical pesticides that kill buggy friend and foe alike. Bt crops reduced insecticide applications in the U.S. by 56 million kilograms between 1996 and 2011, according to one estimate. A recent experiment examined insect populations in 36 different sites in northern China using data collected between 1990 and 2010. Widespread adoption of Bt cotton buoyed the numbers of ladybugs, spiders and lacewings—all of which eat pests like aphids and do not harm crops.

Some Bt toxins may poison insects other than agricultural pests, but so far this danger seems to be negligible, especially when contrasted with the most likely alternative: the carnage of synthetic insecticides. In a small but widely publicized 1999 study, 44 percent of monarch butterfly larvae that ate milkweed leaves dusted with Bt corn pollen died. Monarch caterpillars feed exclusively on milkweed, and butterflies lay their eggs on milkweed plants growing near and within cornfields throughout the summer, when corn pollen abounds. Many scientists quickly pointed out serious flaws in the study, however, such as the fact that it did not quantify the amount of ingested pollen. Other teams of researchers performed more careful follow-up experiments and concluded that some forms of Bt pollen are harmful to monarchs in concentrations greater than 1,000 grains for every square centimeter of milkweed leaf; only 170 grains per square centimeter, on average, coat milkweed growing among cornfields. Pollen from one of the earliest strains of Bt corn, however—Bt 176—was toxic to butterflies at just 10 grains per square centimeter. A few years later Bt 176 had been largely phased out of the U.S. market.

Accumulating evidence indicates that in a few rare instances, researchers may have overlooked how Bt crops threaten other benign bugs. In a recently published three-year study, researchers found fewer ladybugs among plots of Bt corn than in fields of nonengineered corn—and insects living in the former died sooner on average. Bt corn, however, was still much less harmful to ladybugs than chemical pesticides. As for honeybees and native bee species, studies have consistently failed to find any evidence that Bt toxins hurt the pollinators.

Far more worrying to farmers—and ultimately to ecologists as well—is how quickly destructive insects become impervious to Bt crops. "Any entomologist would be stupid to say you're not going to get resistance," says Brian Federici, an entomologist and Bt expert at the University of California, Riverside. Whenever farmers fight pests the same way over and over again, pests adapt and outwit that strategy. Consider one of the oldest methods of pest control: crop rotation. By growing different kinds of plants in the same field each season farmers can disrupt insects' life cycles. Corn rootworm beetles lay their eggs on corn in the fall so that when their white larvae hatch in the spring they can feast on the plants' roots. But if larvae find themselves surrounded by soybeans instead, they will have nothing to eat. Several species of corn rootworm eventually caught onto this trick. Some have evolved delayed hatching, emerging a year two later than usual, when a farmer is more likely to be growing corn again. Others have adapted by laying their eggs among soybeans instead of corn, since a soybean field will probably be a cornfield the following season.

Farmers will always be in an evolutionary arms race with pests regardless of whether they grow organic, use chemical pesticides or choose Bt crops. Where Bt crops have the advantage, however, is in delaying pest resistance for longer periods of time than any other pest-control strategy—if they are carefully engineered and grown responsibly. Bt crops are most effective when farmers and biotech engineers satisfy two key conditions. First, researchers must make the crop extremely lethal to the target pest, ideally killing 99.99 percent of any invaders. That way if some insects do evolve immunity, they will likely have two copies of the genetic mutation that made them immune; any pest with a single copy of the gene would not have been strong enough to survive. Second, farmers are supposed to grow Bt crops alongside "refuge areas"—blocks or strips of conventional crops where pests can prosper. As a consequence, the few pests that evolve resistance among the Bt crops will mate with the much more numerous susceptible insects in the refuges, diluting the genetic mutations responsible for their immunity and producing offspring that are vulnerable to Bt crops.

This is not a foolproof scheme, but when both biotech companies and farmers follow the rules, it works extremely well. In 1996, when Bt corn and cotton were first commercialized in the U.S., some researchers predicted that pests would evolve resistance within three to five years. In most cases this forecast was far too pessimistic. Farmers in the U.S. have been growing Bt corn designed to slay the European corn borer for 17 years without any evidence of resistance whatsoever. In contrast, when Bt crops do not kill a high enough proportion of insects or farmers do not devote enough land to refuges, Bt can become nearly as costly to farmers and the environment as chemical insecticides.

The EPA requires farmers to grow refuges alongside most, but not all, Bt crops. In general, entomologists recommend refuges comprising between 20 and 50 percent of a given field. In some cases, however, the EPA has lowered its refuge requirements to as little as 5 percent of total acreage. And "for some pests, such as cotton bollworm, refuge requirements have been abolished in large areas because Monsanto produced data suggesting natural refuges would be abundant enough," explains Yves Carrière of the University of Arizona. "Personally, I think it's a risky decision." Data suggests that U.S. farmers have become less compliant with the EPA's regulations over the years; after all, a refuge area will probably endure more pest damage and produce a smaller harvest.

At least three kinds of pests around the world have developed some level of resistance to Bt: one in Puerto Rico, one in the continental U.S. and one in South Africa. Carrière and his colleague Bruce Tabashnik think two other pests in the southeastern U.S. and India may have become less vulnerable to Bt as well, although other researchers disagree. Considering that Bt crops target 13 major pests—and more than 50 different pests overall—that's an excellent track record. Still, despite the general preparedness of farmers and scientists, a few pests evolved resistance to Bt toxin with unexpected swiftness.

The most recent and alarming example in the U.S. is corn rootworm, the story of which is documented in studies by Aaron Gassmann of Iowa State University and his colleagues. The first Bt crops designed to kill rootworm hit the market in 2003. Given the ongoing success with other Bt crops at the time, most researchers thought the pests would evolve resistance in 15 to 20 years. By 2009, however, some farmers in Iowa, Minnesota, Nebraska and other states spotted pockets of Bt corn that had fallen over—a classic sign of root damage. Whereas Bt corn tailored to destroy European corn borer kills 99.9 percent or more of pests, Bt corn engineered to eradicate rootworm is less reliably lethal, killing 85 to 98 percent of the larvae. Biotech companies and the EPA nonetheless figured that the benefits outweighed the risks.

It seems they miscalculated. Unbeknownst to researchers, rootworm populations already had relatively common variants of genes for resistance to cry toxins, explains the University of Minnesota's Ostlie. Perhaps they evolved those genes in response to the ubiquitous presence of B. thuringiensis itself. Planting Bt corn only multiplied the frequency of resistance genes by creating an environment in which larvae carrying such genes had the best chance of surviving, mating and laying eggs. And any farmers failing to plant refuge areas made things worse. Some farmers whose Bt crops have succumbed to rootworm have now resorted to chemical insecticides. A similar but even worse situation unfolded in Puerto Rico, where man-made refuges were practically nonexistent and fall armyworm became impervious to Bt corn just three years after the crop's introduction in 2003. By 2007, seed companies had voluntarily pulled that variety of Bt corn from the Puerto Rican market.

In India and other developing countries rural farmers may not know about refuge requirements, if they exist at all; others will outright ignore them because they do not have the space or cannot afford to devote any land to vegetables that will probably become a buffet for bugs. Since introducing Bt cotton in 2002 India has become the second-largest producer of cotton in the world, after China. So far cotton pests are not worryingly resistant. One explanation is that India's farmlands are generally more diverse than those in the U.S., varying greatly within and between districts; the hodgepodge of different crops creates natural refuges. Many researchers argue that concerns about pest resistance should not stand between GM crops like Bt brinjals and the rural farmers that sorely need them. "The general idea is to get the plants out there, monitor changes in pest susceptibility and modify as we go along," says Anthony Shelton of Cornell University, who develops insect management strategies for vegetable crops and has worked extensively on Bt brinjals in India.

To address increasing pest resistance, Monsanto, Syngenta and other biotech companies have started selling seed mixes of 5 to 10 percent conventional corn or cotton and 90 to 95 percent Bt crop. When using such a "refuge in a bag," farmers do not have to go to the trouble of designating sections of their land as refuges; the conventional crops and Bt crops automatically intermingle wherever growers plant the seed mix. Such planting should be especially effective at delaying resistance in species like rootworm, the adult beetles of which tend to mate with nearby insects rather than traveling to a different part of a field. A mosaic of Bt plants and typical crops makes it difficult, however, for farmers to treat only damaged plants with pesticides. Biotech companies have another solution: they are expanding their inventory of "pyramid" Bt crops engineered with two or more toxins against the same bug. Even adding one more toxic protein to a Bt crop makes it far more difficult for pests to acquire immunity because they must not only evolve multiple genetic mutations but also inherit enough copies of each of those mutations to survive. Of course, if an insect has already evolved resistance to one of two toxins a plant makes, there's really only a single hurdle left.

In parallel to steering insect evolution, Bt crops may also alter other plants in unintended ways by mating with them. Because of differences in the shapes and sizes of pollen grains and the floral pads to which they stick, most plants can only pollinate their own species and closely related ones. Whether genetically engineered or not, many crops pollinated by insects or the wind inevtiably exchange genes packaged inside pollen grains with nearby fields of the same crop—including those owned by different farmers. Cotton and soybean flowers can pollinate themselves without much assistance; their pollen is generally not windborne, but it will hitch a ride with insects when they are around. Corn pollen, however, can travel half a mile in a few minutes in a moderate wind, despite being relatively large and heavy. Most likely, insects and gusts of wind have already scattered genes meant to stay within Bt cornfields—and other genetically engineered crops—among receptive neighbors. With an assist from people and modern transportation, such transactions seem to have surreptitiously crossed country borders as well.

In the fall of 2000, David Quist, then at the University of California, Berkeley, discovered genes from Bt crops in corn growing in the mountains of Oaxaca, Mexico—where GM crops were not approved. Farmers in Mexico may have planted imported GM corn kernels that were intended only for animal feed; once grown, they could have spread their genes to nearby cornfields. Other scientists questioned Quists's results, however, and pointed out inadequacies in the way he tested for introduced genes. In 2003 Allison Snow of The Ohio State University and her colleagues collected kernels from 870 corn plants in 125 Oaxaca fields and searched them for genes from GM crops. They found none. But in two later experiments, Elena Alvarez-Buylla of the National Autonomous University of Mexico and her team scrutinized corn in Oaxaca and discovered the same genetic sequences Quist originally uncovered. "I think it's inevitable that GM corn has gotten into Mexico and will continue to cross borders," Snow says. She thinks the incidence is very rare, though, explaining the discrepancies between her studies and later surveys.

Whether such cross-pollination is beneficial or harmful depends entirely on the plants and genes in question and whether you look at the situation from a plant or person's perspective. In one of Snow's studies, the offspring of Bt sunflowers and their wild counterparts deterred caterpillars much more effectively than typical sunflowers and produced an average of 55 percent more seeds. That would be fantastic for wild sunflowers but horrifying for farmers in the Midwest who regard the pervasive seed-spewers as weeds that compete with their crops. In the U.S., corn, cotton and soybean have few if any closely related native species, so the chances of Bt genes finding their way into wild cousins are small. In contrast, were Bt brinjal commercialized in India, it could spread the Bt gene among the many different types of wild and cultivated eggplants. Such promiscuity would probably benefit most domesticated cultivars and would be unlikely to give wild weedy eggplant relatives a large enough survival advantage to make them a nuisance. Wild brinjal cousins are already far hardier than the eggplants farmers grow to eat. "Cultivated eggplants are pretty much wimps—they are watered, fertilized and protected," Shelton says.

For the past four years, much more resilient eggplants have been poised to join corn, cotton and soybeans as the major Bt crops grown worldwide. All the available evidence—including research in India itself—confirms the safety of Bt crops for human consumption and demonstrates that their advantages vastly outweigh their risks. "If you take a global perspective, are things better since Bt crops? Absolutely, yes," says Tabashnik of the University of Arizona. "Now the question is: how can we optimize the use of these crops to maximize benefits?" Yet the moratorium Minister Ramesh originally imposed on Bt eggplants in 2009 stands stalwart with no signs of crumbling anytime soon, even though a new minister took his place. Gorgeous, healthy Bt brinjals exist, but they are trapped in the fenced-off fields of organizations that intended them for the public. "The past three years have been a very, very rough ride," Kumar says. "Environmental lobbies, anti-GM lobbies and anti-biotech lobbies are having a field day, going largely unopposed. Scientists do not speak much and, if they do, they do not speak in loud tones."

On August 23 India's Supreme Court was scheduled to meet and review a report by the latest expert committee tasked with assessing the safety of Bt brinjals. In the days before the meeting, Kumar tried to stay optimistic, but he knew that, in all likelihood, nothing would change. Indeed, for vague reasons, the report was "not available to the government counsel." So the eggplant fruit and shoot borer will continue to worm its way into the majority of cultivated brinjals; farmers will keep soaking their crops in pesticides; and, instead of transforming eggplant farming across India to the benefit of millions of people, insects and the environment alike, the plants that could change everything will remain under indefinite house arrest.

Buddhist Economics and A GMO rethink
By Pamela Ronald. Scientific American, September 6, 2013

Discussions about plant genetic engineering often reflect two starkly opposing narratives. On the one side are the angry mobs who invade research farms to destroy fragile green rice seedlings deemed “GMOs”. On the other, are the scientists who call for calm and respect for publicly funded research. Too often, it seems, there is little mutual understanding.

But times may be changing.

In a forum yesterday hosted by the Boston Review Magazine, a group of journalists, activists, plant biologists, and farmers as well as academic experts in food security, international agricultural and environmental policy sat around a virtual table to find common ground. All accepted the broad scientific consensus that the process of GE does not pose inherent risks compared to conventional approaches of genetic alteration and that the GE crops currently on the market are safe to eat and safe for the environment. That agreement allowed the discussion to move forward to a more societally relevant issue- the use of appropriate technology in agriculture.

Few consumers question the utility of reading Scientific American’s Food Matters online or using the most efficient technology to do it. Yet many are hesitant to embrace technology when it comes to food and farming. Some find the use of plant genetic engineering (GE), a modern form of plant breeding particularly distasteful.

Yet GE is just one of many technologies used to alter the genetic makeup of our crops. Today virtually everything we eat is produced from seeds that have been genetically altered in some manner.

Conventional methods include grafting or mixing genes of closely related species through forced pollinations, as well as radiation treatments to induce random mutations in seeds. Such approaches are imprecise, resulting in new varieties through a combination of trial and error, without knowledge of the function of the genes affected.

GE introduces one to few well-characterized genes resulting in fewer genetic changes. In contrast to most conventional approaches, GE allows for introduction of genes from distantly related species, such as bacteria. Over the last twenty years, scientists and breeders have used both conventional and GE technologies to create crop varieties that thrive in extreme environments or can withstand attacks by pests and disease.

What criteria can scientists, farmers and consumers use to assess which type of these genetic technologies is most appropriate for agriculture?

In his 1973 book Small is Beautiful, economist E. F. Schumacher states that an appropriate technology should be low cost, low maintenance and promote values such as health, beauty, and permanence. Environmentalist Stewart Brand used a similar framework to select new technologies for inclusion in his 1969 Whole Earth Catalog. One of the purposes of the Whole Earth catalog was to facilitate a creative or self-sustainable lifestyle.

We can apply Brand and Schumacher’s Buddhist economic criteria to evaluate modern agricultural technologies.

Take, for example, Golden Rice, a provitamin A–enriched rice developed through genetic engineering that comprises many of the properties advocated by Schumacher and Brand. Consumption of Golden Rice, within the normal diet of rice-dependent poor populations, could provide sufficient vitamin A to reduce substantially the 6,000 deaths caused every day by vitamin A deficiency and save the sight of several hundred thousand people per year. This “biofortification” approach is important to poor farmers and their families in developing countries who lack nutrients and cannot pay the price of improved seed. It is widely considered an improvement on conventional supplementation programs, such as the World Health Organization’s distribution of Vitamin A pills, which costs 40 times more and often does not reach the rural poor who have little access to roads.

Golden Rice is an excellent example of how a particular genetic technology can appropriately serve a specific societal purpose – in this case, enhancing the health and well-being of farmers and their families. It is a relatively simple technology that scientists in most countries, including many developing countries, have perfected. The product, a seed, requires no extra maintenance or additional farming skills. The seed can be propagated on the farm each season at no extra cost through self-pollination and improved along the way.

Can we conclude from the example of Golden Rice that all GE seeds fall into the category of appropriate technology? Unfortunately it is not that simple. Each agricultural technology must be evaluated on a case-by-case basis. It is not informative to group all "GMOs" together without regard to the purpose of the engineering, the needs of the farmer, or the social, environmental, economic, or nutritional benefits.

This central point is addressed by several participants in the Boston Review forum. Journalist Marc Gunther highlights the conspiratorial narrative about GE technology favored by some corporate supported anti-GMO activists. Greg Jaffee, Director of Biotechnology at the Center for Science in the Public Interest points out that better farm management is crucial to ensure that future GE crops benefit farmers, consumers and the environment. Margaret Mellon, Senior Scientist at the Union of Concerned Scientists argues that GE is not a transformative technology. Rosamond Naylor, Director of the Center on Food Security and the Environment at Stanford University discusses the ethics of GMOs in light of persistent hunger and malnutrition. Robert Paarlberg, author of Food Politics: What Everyone Needs to Know outlines the effectiveness of anti-GMO campaigns in blocking the use of modern technologies in the developing world. Nina Fedoroff, Professor of Biology at Pennsylvania State University and former President of the American Association for the Advancement of Science describes the pervasive disconnect between what is true and what people believe to be true about GMOs. Tim Burrack, Farmer and Vice Chairman of Truth About Trade and Technology gives an account of today's farmers who are growing more food on less land than ever before using biotechnology as an essential ingredient. Jennie Schmidt, Farmer and registered dietician reports that farmers choose GE crops because they are economically and environmentally advantageous. Jack Heinemann, Lecturer in Genetics at the University of Canterbury reminds us that reliance on seed technology alone will not avert agricultural catastrophes. Their commentaries are posted online (just click on names to view each one) and the entire forum will be available in print form in the September Issue of the magazine. Kudos to Boston Review's editor Deborah Chasman and Managing Editor Simon Waxman for launching this forum.

One unusual and important aspect of the forum compared to many other discussions on GE crops is that it was science-based, critically reviewed and included the perspectives of farmers –the 1% of US workers that actually produce the food that the rest of us eat and who are at the forefront of evaluating the effectiveness of specific agricultural technologies.

Despite the massive number of technical reports attesting to the safety and environmental benefits of GE crops over the pasts decade, science-based information about food, farming and genetics has only trickled out to the public through government agencies and science-based blogs such as Biofortified.org, Ucbiotech.org, Academicsreview.org. Recently, however, to the delight of plant biologists, farmers, food security experts and skeptics, this trickle has turned into a torrent of excellent reporting.

Consider for example the investigative reporting by a bevy of talented journalists such as New York Times Pullitzer Prize winning author Amy Harmon, DotEarth's Andy Revkin, Slate's Daniel Engber, the New Yorker's Michel Specter, Grist's Nathaneal Johnson, Discover magazine's Keith Kloor, Greenwire's Paul Voosen, and Genetic Literacy Project's Jon Entine. All have tackled the science behind GE crops eloquently and accurately. A number of informative and entertaining books on the subject have been published over the last few years as well. See for example, Stewart

Brand's Whole Earth Discipline, Michael Specter's Denialism, and James McWilliam's Just Food.

As more information is made available demystifying what farmers and plant breeders actually do, the public dialog about GE crops is becoming more sophisticated. Even chefs are taking time out of the kitchen to reevaluate their stance on modern agricultural technologies. Mark Bittman, widely admired for his culinary skills (check out his practical lunch tips) and beautiful prose, recently visited one of my neighbors here in the Central Valley (the source of 50 % of U.S. fruits, nuts and vegetable) to learn about tomato farming. He wrote an unusually thoughtful and respectful piece on the approaches the Rominger farm in Winters is taking to advance ecologically based management practices using modern technologies.

What technology then is truly "appropriate" for agriculture? There is no simple answer to this question. Instead of focusing on how a seed variety was developed, we need to frame discussions about agriculture in the context of environmental, economic, and social impacts—the three pillars of sustainability. We must ask what most enhances local food security and can provide safe, abundant, and nutritious food to consumers. We must ask if rural communities can thrive and if farmers can make a profit. We must be sure that consumers can afford food. And finally we must minimize environmental degradation. This includes conserving land and water, enhancing farm biodiversity and soil fertility, reducing erosion, and minimizing harmful inputs. The most appropriate technology for addressing a particular agricultural problem depends on the context.

Technology evolves. Just as today we source tools through the internet rather than the Whole Earth Catalog (Steve Jobs called the Whole Earth Catalog "Google in paperback form"), few breeders now rely on primitive domestication for seed production.

As the physicist and philosopher Jacob Bronowski pointed out fifty years ago, "We live in a world which is penetrated through and through by science and which is both whole and real. We cannot turn it into a game by taking sides. . . . No one who has read a page by a good critic or a speculative scientist can ever again think that this barren choice of yes or no is all that the mind offers".

Microbes help beetles defeat plant defensas

By Andrea Elyse Messer. Penn State News. September 9, 2013

Symbiotic bacteria living inside potato beetles causes plants to resist the wrong invader.

Some symbiotic bacteria living inside Colorado potato beetles can trick plants into reacting to a microbial attack rather than that of a chewing herbivore, according to a team of Penn State researchers who found that the beetles with bacteria were healthier and grew better.

"For the last couple of decades, my lab has focused on induced defenses in plants," said Gary W. Felton, professor and head of entomology. "We had some clues that oral secretions of beetles suppressed defenses, but no one had followed up on that research."

Seung Ho Chung, graduate student in entomology working with Felton, decided to investigate how plants identified chewers and how herbivores subverted the plants defenses.

"I thought we could identify what was turning the anti-herbivore reaction off," said Felton. "But it was a lot more difficult because we had not considered microbes."

According to Felton, the beetles do not have salivary glands and so they regurgitate oral secretions onto the leaves to begin digestion. These secretions contain gut bacteria.

Plant defenses against chewing insects follow a jasmonite-mediated pathway that induces protease inhibitors and polyphenol oxidase, which suppress digestion and growth. Plant defenses against pathogens follow a salicylic acid mediated pathway. When the antimicrobial response turns on, it interferes with the response to chewing, allowing the beetles to develop more normally.

Chung and Felton used tomato plants to identify exactly what was turning off the response to chewing. They note, however, that the Colorado potato beetle also attacks eggplant and potato plants. They report the results of their work in the current online edition of the Proceedings of the National Academy of Sciences.

The researchers allowed beetle larva to feast on antibiotic-treated leaves and natural leaves and found that on the antibiotic-treated leaves, the beetles suffered from the plant's anti-herbivore defense, but on the natural leaves the larva gained more weight and thrived.

Chung and Felton then investigated expression of genes in the anti-herbivore pathway and the production of enzymes. They found that the presence of bacteria decreases the anti-herbivore response.

The researchers also isolated and grew the bacteria from the Colorado potato beetle guts. They found 22 different types of bacteria, but only three types suppressed the anti-herbivore response. During a variety of other experiments, they found that in all cases presence of the bacteria that could suppress the anti-herbivore response led to healthier beetles.

The researchers are now beginning to see if these bacteria are present in Colorado potato beetles all over the U.S. and also in Europe.

Also working on this project were Cristina Rosa, research associate in entomology; Erin D. Scully, graduate student in the intercollege program in genetics; Michelle Peiffer, research assistant in entomology; John F. Tooker, assistant professor of entomology; Kelli Hoover, professor of entomology and Dawn S. Luthe, professor of plant science.

Reference: Chung et al. Herbivore exploits orally secreted bacteria to suppress plant defenses. PNAS. Published online before print September 9, 2013, doi: 10.1073/pnas.1308867110

Contrary to popular belief

Nature Biotechnology 31, 767 (2013), doi:10.1038/nbt.2700
Published online10 September 2013

Three decades after transgenes were first introduced into plants, why do so many consumers remain so negative about genetically modified (GM) food?

GM food has an uncanny ability to spook consumers. It does not matter that many of us have been consuming GM cornflakes, sweet corn, starches and sugars in processed food for over a decade. It does not matter that no adverse health effects have been recorded from eating them. Nor does it matter that august agencies, such as the World Health Organization, the US National Academy of Sciences, the European Commission or the American Medical Association, have come out with ringing endorsements of their safety. The fact is, negative attitudes remain entrenched and widespread. And changing them will require a concerted and long-term effort to develop GM foods that clearly provide convincing benefits to consumers—something that seed companies have conspicuously failed to do over the past decade.

On p. 794, our Feature asks why the same circuitous debates and concerns keep circulating regarding the health risks of GM food. This time last year, a peer-reviewed paper by French scientists, claiming that glyphosate-resistant corn causes tumors in Sprague Dawley rats (Food Chem. Toxicol. 50, 4221–4231, 2012), sparked a media circus about the cancer risks of eating GM corn. This methodologically and statistically flawed study—the claims of which have since been debunked—grabbed headlines around the world and provided shocking images of animals overgrown with tumors.

The report and others like it making extraordinary claims about health risks represent a tiny minority of all the peer-reviewed studies on GM food. But each time one is published, anti-GM activists seize upon it, no matter how flimsy the evidence or flawed the study design. And all too often, an uncritical and sensationalist media leaps upon negative findings, continuing the cycle of scares, urban myths and downright mistruths about GM food, all of which serve to stoke consumer paranoia. How can there be smoke without fire?

After decades of controversy, the public now mistrusts most mainstream sources of data on GM food—large corporations, regulators, governments and even scientists.

In contrast, nongovernmental organizations, environmentalists and advocacy groups (that often oppose GM food) are treated with credulity. They are, after all, more aligned with 'consumer interests'.

Consumers are concerned about the close (some might say cushy) relationships between regulators and companies. They are concerned about food safety data being difficult to obtain from regulatory agencies. The revolving door between agribusiness and regulatory agencies and the amounts spent on political lobbying also raise red flags. Even academics have fallen in the public's esteem, especially if there's a whiff of a company association or industry funding for research.

Of course, the public's misgivings about GM food go beyond just the risk to health. Corporate control of the food supply, disenfranchisement of smallholder farmers, the potential adverse effects of GM varieties on indigenous flora and fauna, and the 'contamination' of crops grown on non-GM or organic farms all play into negative perceptions. And for better or worse, GM food is now inextricably linked in the public consciousness with Monsanto, which has seemingly vied with big tobacco as the poster child for corporate greed and evil.

A more fundamental problem is that the public debate has been framed in the wrong terms all along. For consumers, the question revolves around GM food or non-GM/organic food. But in terms of risk, how a food crop is created is totally irrelevant—it is what is in the food that is important.

This has not stopped European regulators from deepening existing prejudices against these products by creating a regulatory system that singles out GM products as sufficiently threatening to merit special attention. Even Monsanto and the biotech industry unwittingly have enhanced the false GM/non-GM dichotomy by parroting the agronomic benefits of any products under the GM umbrella. This has led to a debate framed by oversimplified pro-GM or anti-GM stances. Instead, the discussion should be about pros and cons of individual products: Bt corn or EPSPS soybeans and so on.

In the decades to come, children born into a world where GM food is more commonplace may come to see it as less alien and threatening. In the meantime, a key aim in overcoming negative perceptions about GM products should be to focus on crops addressing consumer needs as well as producer needs, which cannot be produced via other means.

In the Philippines, beta carotene–enriched Golden Rice is currently being prepared for regulatory submission. Golden Rice can provide a useful adjunct to diets in areas like the Philippines, where lack of vitamin A frequently causes blindness, simply because alternative vitamin A supplements are a never-ending expense for families. In contrast, the benefits of Bt brinjal for Filipino consumers are equivocal (p. 777).

In the 1990s, pioneering efforts led to the creation of two disease-resistant varieties of GM papaya in Hawaii, where the non-GM crop was almost wiped out by ringspot virus. Today, these comprise ~80% of the harvest. If genetic modification had not been available, papaya fruit would likely have disappeared from Hawaii, and consumers would have been affected.

A recent story in The New York Times (July 27, 2013) outlined a similar scenario unfolding in the orange groves of Florida, where the harvest is being threatened by citrus greening disease. Genetic modification is currently the only feasible route to create resistance. Until recently, growers had rejected GM oranges for fear of a consumer backlash. But reluctance has dwindled as they have been confronted with the possibility of having no oranges left to grow. Presumably, if OJ becomes a rarer and more expensive commodity in supermarkets, consumer attitudes to GM oranges may change, too.

Public perception of GM food will not become more positive overnight. But as more products meet unmet needs, small victories may be won. In the end, necessity may turn out to be the mother of acceptance.

Spotting genes in plants

The University of Western Australia, 12 September 2013

An international team of scientists led by the UK's John Innes Centre and including scientists from Australia, Japan, the US and France has perfected a way of watching genes move within a living plant cell.

Using this technique scientists watched glowing spots, which marked the position of the genes, huddle together in the cold as the genes were switched "off".

The results published in the international journal Genes & Development reveal how genes respond to environmental changes in living organisms where previously plant genes were studied by cutting up plants, killing the cells and fixing them to glass slides.

"What is remarkable about this finding is that we saw genes move within the nucleus in response to changes in the environment, and that this movement seems to be involved in genetic control," Associate Professor Joshua Mylne said.

"The gene we studied, FLOWERING LOCUS C, (FLC) allows plants to respond to changes in the season. When FLC gets turned off (by cold), the plant starts to make flowers instead of leaves. We knew FLC was switched off by cold, but we had no idea that FLC genes would congregate as they get switched off."

"Studying gene motion could improve our understanding of how environmental cues and nurture impact on nature and gene expression," said lead author Dr Stefanie Rosa from the John Innes Centre.

Although the study is of interest to researchers by providing an understanding of how FLC moves as it is turned off, it can be applied to any gene in plants or animals.

"What we want to know now is what is happening at these sites where the genes are congregating," Associate Professor Mylne said. "Are the genes going somewhere special inside the cell? What takes them there and how do the chromosomes move and let the genes congregate? How many other genes congregate like this when they get turned off?

"There are so many new questions this discovery will help us answer."

The study Physical clustering of FLC alleles during Polycomb-mediated epigenetic silencing in vernalization was supported in part by the Australian Research Council.

Associate Professor Mylne initiated the scientific approach almost a decade ago as he embarked on his career in the UK. He is an ARC Future Fellow at The University of Western Australia's School of Chemistry and Biochemistry and the ARC Centre for Excellence in Plant Energy Biology.

Forthcoming meetings

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Second International Symposium on the Nitrogen Nutrition of Plants
November 18 - 22, 2013. Puerto Varas, Chile
http://www.nitrogen2013.cl/

32nd New Phytologist Symposium: Plant interactions with other organisms: molecules, ecology and evolution
November 20 – 23, 2013. Buenos Aires, Argentina
The goal of this symposium is to bring together researchers working in a wide range of disciplines in plant biology, ecology and evolution in the field of plant interactions with other organisms. The central objective is to discuss and integrate information from different approaches and perspectives in order to create a synthetic framework for understanding these interactions. Our hope is to have a diverse and dynamic group of scientists, who are willing to step out of their disciplinary comfort zone and engage in an effort to participate in discussions spanning the range from molecular approaches to ecosystem implications.
http://www.newphytologist.org/symposiums/view/2

Keystone Symposia Conference on "Plant Signaling: Dynamic Properties"
February 5 - 10, 2014. Breckenridge, CO, USA.
http://www.keystonesymposia.org/index.cfm?e=web.RegisterSelf&MeetingID=1305

Sustaining the Future of Acacia Plantation Forestry
March 18 – 21, 2014. Hue, Vietnam
This is a joint conference of the recently formed IUFRO Working Party WP 2.08.07 on **Acacia Genetics and Silviculture**, WP1.02.06 on **Ecology and Silviculture of Acacia** and WP 2.04.01 on **Population, Ecological and Conservation Genetics** and will be hosted by the Vietnamese Academy of Forest Sciences (VAFS). The conference will include invited and contributed presentations and posters, discussion sessions, satellite and business meetings, and in-conference and post-conference tours.
This 4 days' conference with the theme, **"Sustaining the Future of Acacia Plantation Forestry"** will be structured so as to promote discussion between geneticists, breeders and scientists concerned with management regime development and interactions of the crop with its biotic and abiotic environment. This broad ranging review should provide scientific support to those responsible for developing and implementing forest plantation management policies. While our primary interest is in tropical acacias we recognize that there is a much more established tradition of planting temperate species such as *A. mearnsii*, and we will welcome contributions from scientists working on those crops.
To be included in the mailing list for updates on the conference, please contact:
Email: J.L.Harbard@utas.edu.au
For more information please follow the link: http://www.iufro.org/science/divisions/division-2/20000/20800/20807/

9th International Workshop: Sulfur Metabolism in Plants.
April 14 – 17, 2014. Freiburg. Germany
Molecular Physiology and Ecophysiology of Sulfur.
Registration, Abstract Submission and detailed programme on our congress website:
www.sulfur-workshop.com

2014 Spring International Conference on Agriculture and Food Engineering (AFE-S)
April 16 – 18, 2014. Shanghai China,
More info: http://www.engii.org/scet2014/Home.aspx

33rd *New Phytologist* Symposium
May 14 – 16, 2014. Zurich, Switzerland
Title: Networks of Power and Influence: A symposium on the ecology and evolution of symbiotic associations between plants and mycorrhizal fungi
Description: In this symposium, we will bring together a wide range of scientists from different disciplines working on mycorrhizal fungi and plant-microbe interactions. We aim to provide an overview of the advances in mycorrhizal ecology in the last decade. In addition to this, specific talks will highlight new research areas and address the big questions for future research.
Website:
http://www.newphytologist.org/symposiums/view/4

SEB Manchester 2014.
July 1 – 4, 2014. Manchester, UK.
The main Meeting of the Society for Experimental Biology
http://www.sebiology.org/meetings/Manchester/sessions.html

34th *New Phytologist* Symposium
July 15 – 18, 2014. Lake Tahoe - Tahoe City, USA

Title: Systems biology and ecology of CAM plants

Description: We aim to promote basic research in crassulacean acid metabolism (CAM) by integrating functional genomics with biochemistry, physiology, development, ecology, and evolutionary studies to gain new insights into the regulatory mechanisms and evolutionary origins of the pathway. We will highlight the potential of CAM research for tackling bioenergy and environmental challenges pertaining to water security and resource limitation and the maintenance of productivity and ecosystems services in a changing world. In addition to this, specific talks will look at new research areas and address the big questions for future research.

Website: http://www.newphytologist.org/symposiums/view/5

Positions available

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PREDOC

International PhD in Agrobiodiversity

Call for Applications - Academic year 2013-2014

Five scholarships will be granted to eligible candidateship's (net amount: € 12.500).

Applications must be submitted online by 30 October 2013 (12.00 CET).

Candidates must provide:

A research project proposal, prepared following the instructions included in the Call

Any document and/or publication that they deem worthy of consideration, including any association with research institutions in their country or elsewhere.

The PhD Programme will start on January 20, 2014

The submitted research project proposal is meant for evaluation purposes and should preferably address one the subjects currently being investigated in the Labs of Scuola Superiore Sant'Anna.

For a list of the scientific topics studied at the Plantlab, please visit http://plantlab.sssup.it/research and/or contact Dr. Francesco Licausi f.licausi@sssup.it.

Ph.D. Programme in "**Agrobiosciences**" - **Call for application 2013-2014**

The PhD Programme in Agrobiosciences at Scuola Superiore Sant'Anna offers three-year scholarships to carry out advanced research activities in the following fields:

- Genomics and Crop Science (Plant biotechnology, genetics and molecular physiology).
- Agriculture, Environment and Landscape (agroecology, organic, integrated or low-input agriculture, functional biodiversity in agroecosystems).

Six positions are supported by a grant (amounting to € 14.500 per year + Campus facilities): 4 positions for EU candidates and 2 positions for non –EU candidates.

Candidates are requested to apply online by **October 30, 2013, 12 a.m. Italian Time**. In case of problems with the online application, please contact the PhD Administration Office (tel. +39.050 883.358/336, e-mail: infophd@sssup.it).

Candidates will be selected on the basis of **titles**, a **research project** written by the applicants and an **oral interview**.
More details can be found at http://www.sssup.it/agrobiosciences.
The submitted research project is meant for evaluation purposes and should preferably address one of
subjects currently studied in the Labs of the Scuola Superiroe Sant'Anna. For a list of the scientific topics studied at the Plantlab, please visit http://plantlab.sssup.it/research and/or contact Dr. Francesco Licausi f.licausi@sssup.it.

A joint PhD grant between the laboratory "Reproduction et Développement des Plantes", located at the Ecole Normale Supérieure de Lyon, Lyon, France and the School of Biosciences at the Sutton Bonington Campus, University of Nottingham, UK is available starting from October 2013.
We are looking for a highly motivated and independent student to conduct studies on the role of auxin signaling in cell differentiation in meristems of the model species Arabidopsis thaliana. The work will focus on elucidating the molecular basis for cell sensitivity to auxin and on the analysis of the gene network controlling cell fate specification in response to auxin in both shoots and roots.
This position is opened **only to EU applicants**.
The work will be conducted both at the Ecole Normale Supérieure de Lyon and at the University of Nottingham, under the direction of Teva Vernoux and Anthony Bishopp.
An expertise in genomics, molecular biology, live imaging and developmental biology is highly desirable. An experience in network analysis would be appreciated.
Contact: Applicants should send a CV and two recommendation letters to **Teva Vernoux** (teva.vernoux@ens-lyon.fr) and **Anthony Bishopp** (Anthony.Bishopp@nottingham.ac.uk).

Vienna Biocenter PhD Programme in Life Sciences
RNA biology, gene regulation and epigenetics
Bioengineering and computational biology
Biochemistry, structural and cell biology
Evolutionary and population biology
Stem cells, developmental biology
Molecular medicine
Neurosciences
Plant biology
Application form and further details available at:
www.vbcphdprogramme.at
Application deadline: 15 November 2013
International campus where English is the working language, full employment contract with competitive salaries
Multi-disciplinary research, state-of-the-art facilities and a dynamic scientific environment
PhD Degrees granted through the University of Vienna

POSTDOC

Postdoctoral position in plant molecular biology and genetics
In the group of Dr. Karel Riha (Gregor Mendel Institute, Vienna, Austria, and Central European Institute of Technology, Brno, Czech Republic).
The successful applicant will undertake a project aiming at deciphering molecular mechanisms that regulate meiosis and meiotic progression in plants (for reference see: PLoS Genetics 2013, 9(5): e1003508, Plant Cell 2010, 22:3791-3803).
The project involves genetic and genomic approaches, biochemistry and cell biology techniques to identify and characterize novel factors
involved in meiotic progression and plant reproduction.

The applicant should have a PhD degree in Molecular Biology, Genetics, Cell Biology, Biochemistry or related Life science disciplines.
Experience in plant molecular biology/biochemistry and/or NGS data analysis is welcome, but not essential.

Further inquiries should be addressed to Dr. Karel Riha (karel.riha@gmi.oeaw.ac.at).
Applications should include CV, a brief motivation letter and contact information to at least two referees.
Lab webpage: http://www.gmi.oeaw.ac.at/research-groups/karel-riha

Courses

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The Distributed European School of Taxonomy (DEST, http://www.taxonomytraining.eu), originally funded by the EC in the framework of the EDIT project, has launched two types of training courses at various European research facilities and universities. The programme is open to participants from Europe and from outside of Europe.

The Modern Taxonomy programme 2013-2014 offers intensive theoretical courses in subjects as varied as nomenclature and DNA-barcoding. The Expert-in-training programme 2013-2014 enables graduate students and early career researchers to develop and strengthen their taxonomic research skills through on-the-job-training. The programme includes a great diversity of topics and covers various groups such as diatoms, rotifers and tropical plants.

Several courses with botanical subjects might be of particular interest to you.

Botanical Nomenclature (Royal Botanic Gardens Kew, U.K., 27-31 January 2014)

http://www.taxonomytraining.eu/content/botanical-nomenclature-2

(registration deadline 17 October 2013)

Tropical Plant Identification course (Royal Botanic Gardens Kew, U.K., 21 April–2 May 2014)

http://www.taxonomytraining.eu/content/tropical-plant-identification-course-1 (registration deadline 20 December 2013)

Wood Biology training (Royal Museum for Central Africa, Tervuren, Belgium, dates to be decided)

http://www.taxonomytraining.eu/content/wood-biology-training-0 (registration deadline 31 January 2014)

New training providers are most welcome to participate in training delivery within the Distributed European School of Taxonomy. For more information, please mail us at dest-training@naturalsciences.be or have a look at: http://www.taxonomytraining.eu/content/interested-training-delivery