

31 Critical Questions in Agricultural Biotechnology¹

In March 2000, Barun Mitra of the Liberty Institute, a progressive free-market think-tank in India, sent questions concerning agricultural biotechnology to the AgBioView listserv, with the hope that expert members of the list would be able to address them.

He received a great number of responses, which he compiled and edited with the help of Matthew Metz², Andrew Apel³ and Gregory Conko⁴. Below are the 31 questions, along with answers from members of AgBioWorld. To read the original thread from our listserv, please refer to message #53 in our list server.

1. QUESTIONS ABOUT FOOD SECURITY
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1. QUESTIONS ABOUT FOOD SECURITY

Q 1: Is genetic engineering (GE) the only way of increasing food production?

No, it is not. It is only one of the tools we can use to increase food production. However, it is a powerful tool that will significantly increase our ability to produce the quantities of food that our growing world population will need.

Whether the genetic alteration is done haphazardly by selective breeding or in a more systematic way by directly altering the genome, increasing the useable food content of an organism requires some form of genetic engineering.

For grains and oilseed crops, increasing food production most often means the ability to produce better yields under the same conditions or, more generally, the ability to better resist weeds, insects and diseases. Many important improvements have been achieved by ordinary breeding, but it is a slow process. Given the rate at which the demand for food is likely to increase in future years, substantial productivity enhancements will still need to be made. In conjunction with other methods, GE can help agronomists make the productivity gains necessary to supply enough food at reasonable prices. It is thus not the only way, but it could in the future become the most efficient and economical way.

Another way to answer this question is to consider the growth in world population over the course of the past century and the impact that has had on farmlands.

World population in 1900 was roughly 1 billion people. In the year 2000, world population is about 6 billion people. And world population is projected to grow to 9 or 10 billion people by the year 2050. Until the Green Revolution spread to South America and then to Asia, beginning about 40 years ago, the only way for developing world farmers to keep up with population growth was to convert forests, jungles and deserts into farmland. More productive crop varieties developed during the Green Revolution allowed farmers to grow vastly more food on only slightly more land.

It is, of course, possible to increase crop yields by simply planting and harvesting more crops. This can be done by planting them more densely or increasing the number of acres devoted to growing them. Other methods include increasing the use of fertilizers, pesticides, herbicides and irrigation, each of which have well-known risks. Though effective at boosting yields, vast monoculture regions of intensively farmed land have had significant ecological affects, especially including the loss of biodiversity. Unless a viable alternative is devised the destruction of important ecosystems will increase as the need for more food production increases.

In the developed Western countries, advances such as hybridization, agricultural chemicals, and farm machinery have boosted production per acre of farmland to the point where it appears that the amount of food per acre has reached the limit of the ability of crop plants to convert sunlight to energy. As these western countries produce all the food they need – and are likely to need in the foreseeable future – their problems are not the same as those in the undeveloped

¹ Source: <<http://www.agbioworld.org/articles/critical.html>>

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countries, where poverty requires that low-cost solutions be implemented.

Local populations in the developing world will have to rely on low cost solutions that do not require unrealistic practices such as local farmers buying expensive chemicals or equipment. However, biotechnology could provide seed to farmers that is better adapted to their cultivation requirements. The engineered seeds will have the added benefit of pest resistance and tolerance to extreme environmental conditions such as drought that are needed to sustain village farms.

While pondering this question, it is also important to bear in mind that there is a danger that people will confuse prospective benefits with ones that have already been realized. Although there is ample reason to believe that GE may in the long term have substantial benefits for food production, there are many hurdles still to be overcome, both scientific and political.

This puts the proponents of GE in the dangerous position of over-selling the technology, and thus looking foolish when on occasions it fails to live up to its promise, or fails to do so quickly enough. The opponents of GE are equally in danger of denying access to a potentially useful technology for many people who might benefit from it.

Q 2: Is it possible to deal with widespread malnutrition with genetic engineering?

Malnutrition is a complex phenomenon, involving both the quantity and quality of food, as well as the distribution of that food among a growing population.

Genetic engineering is the latest in a number of strategies that have collectively been termed the "Green Revolution," which resulted in an enormous increase in the amount of food that is produced on the arable lands of the earth. It also prevented widespread starvation, which has been forecast at various times over the past half century.

Fundamentally, the problem of malnutrition must be treated with adequate food. We don't necessarily have to use genetic engineering, but it truly could help.

In many cases, biotechnology can certainly help farmers get higher yields from their land. If biotechnology is used to provide low cost solutions to improve village farms, then it can help to address world poverty. One example is efforts by such groups as the CGIAR centers around the world, or by WARDA in West Africa, or the potato center in Lima,

Peru, to develop genetically engineered pest resistant seeds for distribution to local farmers. Planting rice, banana, wheat, or potato that are hardier or resistant to major diseases, for example, will help provide improved yields while reducing the need for chemical applications.

The best recent success story is papaya in Hawaii, a very important crop for the local economy. A virus, called papaya ring spot virus, devastated farmers in Hawaii and many trees had to be cut down. The cost of planting replacement trees was quite high, however, and many farmers lost their livelihood. Researchers provided virus resistant trees to farmers at little or no cost, and crop production was restored. If this model can be applied to vegetable crops, tubers, and grains, biotechnology can have a major impact on food production without dramatically increasing costs to small farmers.

Somewhat related to the question of the quantity of food is its quality: that is, whether it delivers the vitamins and minerals required to maintain human health. Here, too, genetic engineering can help. Recently, rice has been developed with added beta carotene (which is converted into vitamin A in the human body) and increased iron levels. Crops with higher protein levels and better amino acid balance are possible, as are crops that can enhance the bioavailable (or useable) content of other important micronutrients. These are just a few examples.

Even with plentiful, nutritious food, malnutrition also results from the inability of some to buy food. So proper nutrition is also a matter of family income and the price of food. Generally speaking, the more food produced, the lower the price and thus the less income needed for sufficient nutrition. By making agriculture more productive, GE can help increase the supply of food and therefore help keep prices low. Making village farms more productive can also help generate income if productivity grows large enough for small farmers to sell food. However, that's a tremendous task, so generating sufficient productivity gains to cure the income problem is unlikely in the near term.

It is reasonable to consider economic deprivation to be the major cause of starvation in the world. By most estimates, the Earth currently produces enough food to provide enough calories and nutrition to feed its entire population. However, food can only flow to the hungry if they could afford to pay for it. Consequently, giving small farmers the tools to become more productive can help greatly.

It's important to note, however, that given current estimates, the farmers around the world only produce

enough to feed the current population at such levels. If world population grows to 9 or 10 billion in the next 50 years (as the United Nations projects), hunger will become both an economic and physical reality if world food output is not increased.

Here again, access by the hungry to the improved crops now being developed (many with the help of genetic engineering) could depend on the financial status of the people who most need access to such innovations. The costs of developing such crops are high and the potential market is very poor. Thus, without major shifts in funding that would make the technology available at low cost to those who need it, the potential benefits are unlikely to be realized.

Developers of the beta carotene (Vitamin A) -enhanced golden rice have recently announced that they will donate that technology and improved selectable marker technology to developing nations. This project was funded by a consortium of public research institutions, private corporations, and charitable foundations. In addition, many research institutions in developing countries are funded by the US and European governments and by the United Nations with the aim of generating crop plants for developing countries.

If farmers are to produce enough food for their local populations, instead of relying on sparse currency with which to buy food, they need the products of modern biotechnology to make this possible – this includes crops produced with genetic engineering and other sophisticated biological technologies. Ironically, advocates of equality in food access come out in strong opposition to the very technologies that could help free poor populations from handouts or ‘redistribution’ of the food supply, which seems to be their preferred solution. An old saying has it that to feed a village for a day, give them fish. But to feed them for a lifetime, teach them how to fish. Shall we give the developing food for a day, or teach them how to use modern biotechnology and feed them for a lifetime?

Q 3: If food security is primarily a question of distribution insecurity, then how can increased production using GE address the question of food security?

If you increase production of food in an area, you reduce the need for food to be purchased and transported to that area. Insofar as genetic engineering allows people to become more self reliant in food production, their dependence upon potentially expensive transportation and redistribution schemes is decreased.

A complex approach to the question requires us to look at increasing food production without changing distribution channels. Producing more grains worldwide will not by itself increase the availability of grains to underdeveloped nations. The result is the coincidence of regional shortages in some areas and regional surpluses in other areas.

The availability of crops that can grow in more places and produce more nutritious food can help people become independent of redistribution or handouts. GE seeds allow farmers to produce food more productively, less expensively, and closer to the consumers. Land, which once would not grow corn, may now grow drought resistant strains. Other examples are easy to imagine.

In several recent famines, the countries concerned were still net exporters of food—in other words, the countries were producing enough food to feed their populations but the people concerned couldn’t afford to buy it and the countries had massive debts to service, as well as poor internal infrastructure and often problems with high level corruption.

This is a serious issue because, based upon current projections, the rate of increase in crop yields from conventional breeding methods is not sufficient to maintain the projected increase in the world’s population. Therefore even if distribution problems could be solved (a very large if) there could still be great difficulties.

2. QUESTIONS ABOUT ENVIRONMENTAL PROTECTION

Q 4: How can GE ensure environmental sustainability as well as increase food production when pressure on environmental resources like land and water is growing?

There are two ways in which GE can help promote environmental sustainability. One way is to increase total food production, thereby making it unnecessary to put marginal or environmentally sensitive areas under plow. The other way is to employ crop production methods that place fewer burdens on the environment.

First, consider productivity. Growing more food on a given area of land means that for any level of output (whether it’s enough to feed six billion people today, or nine billion people in 50 years) more land is available for other purposes. That’s important, because adding new cropland has historically meant plowing under virgin wilderness area. Greater productivity can be achieved with a combination of processes, including more traditional methods, as described in the answer to

Question 1 above. But GE technology is an important tool that allows agronomists to alter plants more quickly and more precisely than do older techniques.

Next, consider the ability to use less agricultural chemicals, including pesticides, herbicides, and synthetic nitrogen fertilizers. Rainwater tends to make these chemicals run-off farms into rivers, streams, and sensitive lands, sometimes upsetting the ecological balance of those systems. Agronomists know, however, that some crop plants, such as certain legumes, have the ability to "fix" nitrogen, absorbing it from the air. If we can splice the ability to fix nitrogen into other crop plants, we could reduce the need for synthetic chemical fertilizers and make a giant step in sustainability.

Similarly, if we can increase disease resistance in crop plants, that added trait would allow farmers to reduce the use of fungicides and improve no-till methods. Genetically engineered plants that are drought resistant, or enable the use of less toxic herbicides could also help achieve these goals. Glyphosate tolerance has shown itself to be a sound technology in this respect, as glyphosate is far less toxic than many other herbicides and becomes effectively inactive within a few days after spraying.

There are currently seed banks established around the world at CIMMYT, CGIAR, and other research centers that were established to maintain diverse germplasms that may provide useful traits for cultivated species. These seed banks are also a source for biotechnologists to identify useful genes that they can move between related species to improve crops. For example the Mlo gene was recently cloned from barley and it provides resistance to powdery mildew. Powdery mildew is a problem worldwide in cereals and other crops. GE allows us to take that gene and introduce it into other cereals. Then we can give that seed to farmers and the resistance should restore productivity in fields that are typically devastated by the disease.

An important part of the question is whether this technology will "ensure" sustainability. There is no reason to believe that GE or any one technique will by itself ensure environmental sustainability. There are numerous factors that lead to environmental degradation. For instance, the emissions and other waste created by an affluent, formerly starving nation could have a considerable impact. However, it is highly likely that the use of GE technology can help promote sustainability quite significantly.

Q 5: Won't herbicide-tolerant and pesticidal GE crops lead to intensified use of agro-chemicals?

Herbicide tolerance enables the use of fewer types of herbicides (reducing usually to one) and reduces the number of applications needed. Fewer, higher doses of the resisted herbicide are possible without damaging the crop. The end result is that close to the same amount of the resisted herbicide is used but many other herbicides are eliminated—an overall reduction.

Most current complaints about pesticides and genetic engineering concern the introduction of genes allowing the plants to produce biological insecticides such as *Bacillus thuringiensis* toxin. This, of course, directly reduces the need for applied synthetic chemical pesticides.

For example, Bt crops have saved about 1,000,000 liters of insecticide applications in the US during the past 4 years.

Q 6: How can GE deal with possible environmental threats such as "super weeds"?

The transfer of herbicide resistance from crop to weed is a possibility, and one that presumably increases with the likelihood of cross-pollination. However, agronomists know that many weeds and some crop plants develop resistance to herbicides through natural selection and evolution, over long-term exposure to certain herbicides. It is currently unclear whether the transfer of herbicide resistance is greater for genetically engineered resistance than the type of resistance that arises as a result of natural selection.

No matter what methods of weed control we use, the weeds that survive become "super weeds" for that method. An example is silver leafed nightshade in cotton fields. Before herbicides, persistence of silver leafed nightshade was a different type of problem: that is, there were no resistance issues, but farmers had to hoe the weeds twice to keep them under control. Soon after farmers started using herbicides, resistant strains began to arise. The same is true for every herbicide or management practice. Resistance to herbicides is an on going problem and it will require the continued development of new herbicides regardless of what technology we use. GE is just another tool. However, many of the newer herbicides developed over the past several years have much less impact on the environment than the ones they replaced. On balance, that should be viewed as a positive step.

Neal Stewart is a scientist who studies the transgene movement and persistence in crops and weedy wild relatives. He and his team are attempting to make "superweeds" by putting transgenes in wild relatives of transgenic crops and then looking at the ecological

performance. There is no doubt, he says, that transgenes will move into weeds. It is less clear what the ecological consequence would be. It is clear that herbicide tolerance genes will move from plant to plant—such a case could cause trouble for the farmer who is trying to control an herbicide tolerant weed in a field with herbicide tolerant crop. Stewart suspects that, using GE to make better crop plants could make slightly more problematic weeds. However, he doesn't think that using GE will create the superweeds that many GE critics predict.

Thus far, no threats from "superweeds" have arisen from genetically engineered plants.

If there is a concern about genes crossing into weedy relatives, there are ways to prevent it or mitigate against it. However, the first example of this—what has been dubbed "terminator" technology—was widely criticized by those who did not understand how it could be used to prevent gene flow into relatives.

It appears as though criticism of "terminator" technology arose less from a misunderstanding of the technology than from a realization that it would allow companies to commercialize a process that would prevent farmers from saving seeds for planting in subsequent years. There was an enormous protest about this, and most of the major agricultural biotech companies have agreed not to develop the technologies further. [Editor's Note: I was actually present at a scientific conference when the adoption of this technology was first announced, and many of the scientists there were quite literally horrified. -CSP]

Q 7: How can undesirable "genetic drifts" be controlled?

The ecological impact of GE crops is a complex issue, and a case-by-case evaluation of crops and biogeography is necessary.

For example, corn has no sexually compatible relatives in areas outside of Mexico and southward in the Americas. In other areas the possibility of genetic drift of transgenes does not exist. In this case, there is no problem.

In Canada, many wild relatives of canola exist in and near agricultural lands. The drift of genetic traits such as herbicide resistance (transgenic and non transgenic varieties exist) that are selected for in an agricultural setting are a real possibility in such a case.

Wild relatives of rice exist in many parts of the world where agricultural varieties are grown, and genetic drift

is prevalent. The movement of (trans)genes could bring genetic material for nutritional enhancement or increased seed production into weeds.

The primary question, however, should not be whether gene flow will occur, but whether the movement of genes from crops to weedy relatives would provide the weeds with a selective advantage. If it confers no advantage on the weeds, then weeds with the new genes would not out-compete other wild plants, and the gene flow is unlikely to pose any real problem.

Q 8: Shouldn't biotech companies bear total liability for any harm to environment and public health?

In the US and most other countries, standard product safety laws already cover this issue. Furthermore, there is the opportunity for harm to be redressed by lawsuits. In other words, biotech companies are clearly liable for harm to the environment and public health as well.

Such responsibilities are the same as they have previously been: Inventors are liable for the safe operation of their products; growers are responsible for following guidelines to safeguard the environment; processors are responsible for safe, hygienic handling of materials; and consumers are responsible for knowing their own health concerns (e.g. allergies to foods like wheat or dairy) and consuming prudently. No one party has 'total' responsibility.

3. QUESTIONS ABOUT HUMAN HEALTH

Q 10: Shouldn't it be possible to demand zero risks from GE?

We do not demand zero health or environmental risks from anything else—including medical treatment, providing water and power to cities, building cheap housing for poor people. In all these cases, risks are minimized and policed to an acceptable safety standard. But these things can never truly be made "risk free".

The question we should ask is whether there is evidence of risk or harm beyond what we are already experiencing when we grow traditionally bred crops and eat the foods made from those traditionally bred crops. There is no hard evidence that food or environmental safety is any less than what we are used to with non-engineered crops or foods.

Conventional breeding mixes tens of thousands of genes from two (or more) organisms together, and involves sorting through many progeny for the desired

characteristics. The functions of many if not all the genes being introduced to each other are not known. Consider the genes that are being introduced to each other in two hypothetical cases:

Conventional Breeding mixes 40,000 unknown genes from one plant with 40,000 unknown genes from another plant.

Genetic Engineering mixes just 1-10 genes with known functions with the 40,000 unknown genes of the recipient plant.

Of course, zero risk cannot be promised by any technology, nor can it be ensured by preventing the use of any technology. Even with these older methods of breeding, there have been some unwanted traits: For example, wheat, a hexaploid, is allergenic to many people. Nevertheless, the risk/benefit assessment of the traditional cross-breeding experiment (the last 10,000-plus years of agriculture) can be examined: our population has enjoyed substantial biological success.

Similarly, consider what is the known about the risks associated with pesticide use. What are we gaining by having a GE seed that requires less pesticide? Next, evaluate if the risk of GE seed is known or unknown, probable or implausible. The analysis here should focus on the risks associated with the practices GE will help curtail.

We need not forget about the possible benefit of GE foods. For example if you can increase nutrient content in rice resulting in less disease or blindness, what risk are you willing to take to solve a known problem? Too often when dealing with GE issues we forget to look at the dangers we are reducing with the new inputs as well as forget to look at the tremendous societal advantages that can come from GE seeds. Only when these critical factors are examined alongside any possible risk of GE technology, can we determine our risk tolerance level.

Q 9: What about the health risks from GE, such as antibiotic resistance?

GE critics have raised the possibility that anti-biotic resistant genes used in genetic engineering, could spread to harmful bacteria, making infectious diseases difficult or impossible to treat. The problem we currently have with antibiotic resistant bacteria is principally a product of the indiscriminate use of antibiotics in humans. However, there are some issues to consider with GE.

Sometimes, engineered plant cells don't take up the genes for a desired trait, or don't take them up in a manner that allows the desired trait to be expressed. Consequently, when scientists engineer plants, we usually introduce two genes: one that confers the desired trait, such as resistance to the mold *Fusarium*, and another that confers resistance to an antibiotic, such as ampicillin. The plants are then grown in the presence of ampicillin so that we can identify transgenic plants from non-transgenic plants in the laboratory. Cells that haven't taken up the resistance genes won't grow in the presence of ampicillin, and only the truly transgenic plants will survive.

After we have analyzed our plants to confirm that they express the desired traits, we give the seeds to the agronomists. The agronomists then cross-breed the transgenic variety with commercial varieties to introduce the desired trait into plants and seeds that will be distributed to farmers.

There are two scenarios. In scenario one, cross-breeding may incorporate the desired trait into the cultivated varieties, but not ampicillin resistance. So there is no problem. However, breeders have little control over which genes are incorporated into the final plants, so this doesn't always happen. In scenario two, cross-breeding does incorporate the antibiotic resistance. Is this a problem? Not generally. For example, eating a tomato that is ampicillin resistant does not make you ampicillin resistant—just like eating a tomato doesn't make you turn red, or grow leaves. We eat genes and DNA in almost all food (all foods start out with DNA, though some processing methods break down DNA), but the genetic material is destroyed in the digestive process.

In addition, studies that have looked at this issue have not shown that the transmission antibiotic resistance from transgenic plants to microbes occurs at a detectable frequency. Recent attempts to get microbes to pick up the trait suggested that it would not occur at all.

Besides, not all crops have been engineered with antibiotic marker resistance, so if this is really a legitimate concern, there are ways to avoid the use of these markers as well. One way is to use the mannose-based selectable marker recently developed by Novartis.

Q 11: What is the sound scientific basis for considering GE to be safe?

Safety is a relative concept. Agriculture and animal husbandry have inherent dangers, as do the consumption of their products. Any sound evaluation

of the safety of genetic engineering must also consider the "safety" of current methods of producing food. As mentioned above, nothing is risk free.

Nonetheless, every GE crop plant that is now on the market has been extensively studied in toxicity and environmental impact tests, and in most countries the results of those tests are available through the government. Second, many crops have been placed into the field over the past 20 years and experience has shown they are not a problem. There also exist data for both food safety and ecological safety of GE in the food supply.

Moreover, the experience of over 200 million consumers in North America over the past four years, and the planting of tens of millions of acres of genetically engineered crops over that time, gives us additional evidence that the products of genetic engineering we have today are safe.

Q 12: Critics of biotechnology say that while reductionist biologists claim patents on life, they believe that 95 percent of DNA is "junk" (with unknown functions). On the other hand, genetic engineers have to use this junk DNA to get their results.

Science often progresses ahead of our understanding. Intron sequences, what we commonly call "junk DNA", are not known to carry any meaningful information. However, they somehow still contribute to enhanced gene expression. Thus, we often include these sequences and the process of understanding them in the scientific literature and in practical applications. Nevertheless, all GE organisms are extensively tested, and there is no reason to believe that intron sequences in GE organisms pose any heightened risk.

Q 13: If GE does not directly benefit consumers, why should consumers bear any possible risk?

It would be a mistake to view GE as not benefiting consumers. Presumably, as the cost of producing a bushel of wheat goes down, so will the price. In other cases, where enhance productivity does not result in increased output, the efficiency gains will free up labor and resources for other activities. Also, there are indirect benefits to the environment that affect consumers. Likewise, in underdeveloped nations, GE can allow for more targeted food production enhancements that more directly benefit the people of those countries. Some products, such as GE rice that is modified to contain essential vitamins, actually will benefit consumers directly. GE plants now being

studied can be used to produce medicines and plastics that are non-petroleum based.

Also, one cannot objectively concede there is any substantial or unusual risk from GE organisms. Zero risk is absolutely impossible and would not ever be required for drugs or any other food products. Theoretically, we might imagine a future harm by GE organisms. But there is no credible evidence that would indicate that the harm is anything more than theoretical.

Q 14: Isn't biotechnology, such as GE techniques, substantively different from conventional breeding methods?

Conventional breeding and biotechnology both depend on moving genes around to produce a plant with desired traits. Distinctions about the source of the genes or the manner of moving them are largely artificial. Only the results of such efforts are meaningful or relevant.

The primary difference is that biotechnology is precise and fast. In principle it is like conventional breeding in that new combinations of genetic material are created. It is also different in a second respect, in that millions fewer variables (genes) are involved each time it is performed.

Q 15: In conventional breeding within species, it is said that "vertical transfer" of genes takes place. However, biotechnology allows "horizontal transfer" of genes across species. Isn't such horizontal transfer unnatural, and therefore possibly unsafe, as well as unethical?

The question makes a false assumption. Horizontal transfer of genes across species has been occurring naturally for millennia. Therefore, it is natural. For example, one of the techniques scientists use to create transgenic plants is to splice new genes into a naturally occurring soil bacterium called *Agrobacterium tumefaciens*. This is especially useful, because *A. tumefaciens* is known to readily insert genes into the DNA of live plants, a naturally occurring case of horizontal gene transfer.

It would be better to ask why anyone would think it is "unethical" to improve foodstuffs? It's much more unethical to leave millions of innocent people hungry.

In an important sense, everything about modern agriculture is "unnatural." If we were to have to grow only wild tomatoes, maize or soybeans, we would all starve. The entire recorded history of the human race

has been fueled by "unnatural," that is, man-made advances in agriculture by intervening in the DNA of plants and animals.

Q 16: Is there a difference between applications of biotechnology in agriculture and medicine? Why are the two perceived differently?

Producers of GM seeds focused first on introducing production traits that most directly benefit farmers, millers, and manufacturers. To the consumer there is little difference, if any, between foods made with and without genetic engineering. This makes the benefits of genetic engineering less noticeable than the benefits of medicine.

More importantly, though, present-day civilization does not regard agriculture as highly as medicine. Why? Because it is very clear how medicine saves people from dying, but less clear how agriculture keeps people from dying. Few in developed countries notice that they are alive today because of the food they eat. They take it for granted.

Undernourishment is a disease that needs treatment with food. Only the well fed think differently about 'medicine' and food.

Q 17: Applications of biotechnology range from development of vaccines, to pollution cleaning bacteria, biodegradable plastics, colored cotton, herbicide- and pest-resistant crops, and nutritionally-enhanced crops. Isn't it possible to draw a line between permissible and impermissible applications of biotechnology?

It is possible not only to draw lines between permissible and impermissible applications of biotech, it is also possible to justify these lines on the basis of considerations other than mere human whim. The justifications will involve both ethical considerations and more tangible issues of human health and environmental safety.

For example, it is ethically justifiable to develop applications of biotech that will, without any adverse environmental or social consequences, help to feed hungry children. It is ethically unjustifiable to develop applications of biotech that will do no good, but may kill hungry children. It is ethically justifiable to develop GE organizations that will allow more efficient use of arable land, provide nutrients and vitamins to malnourished people, and reduce the use of synthetic chemicals in agriculture. It is ethically unjustifiable to develop GE organizations that could produce superweeds (canola genes moving into and wild

brassicus) without a consideration of how to prevent this from occurring or mitigate against it.

We also draw lines based on considerations having to do with moral facts, such as individual human rights, the duty to do no harm to innocents, the duty to take into consideration the beauty, integrity, and balance of nature, the duty to help liberate the oppressed and to maximize the ratio of good over evil in the world.

However, the main consideration for what is impermissible should not be drawn on a categorical basis: such as prohibiting GE crop plants, or GE microorganisms for environmental remediation. Each individual application should be evaluated on the basis of the potential dangers it is likely to pose and the dangers it is likely to avert.

Q 18: Isn't the credibility of regulatory agencies influencing the popular perception of genetic engineering? Is fear of biotechnology a failure of the regulatory agencies or is it a failure of the market and corporate ethics as such?

The credibility of regulatory agencies has had a strong influence. Loss of it in the UK has resulted in a pronounced fear of biotechnology. Maintenance of it in the US has coincided with a majority of consumers worrying little about genetically engineered foods.

However, the credibility of those agencies often has more to do with how people see the agencies, than what the agencies actually do. When fearful people do not see their concerns addressed by the regulatory process, they question the regulatory process.

Corporate ethics has also been influential. Trade protectionism has motivated many European food producers to help fuel fear of biotechnology products made by their competitors overseas. The failure in the market is more of a failing in our education system that has left many people so scientifically illiterate that they are easily manipulated by misinformation.

Other factors contribute indirectly to the credibility of regulatory agencies. In Europe, mad cow disease and other food-related scandals have made many fearful of their food, and this prompts them to think that regulatory agencies could have prevented them from happening.

It is also important to realize that regulators are going to make mistakes. The food supply never can or will be 100 percent safe.

4. QUESTIONS ABOUT SOCIO-ECONOMIC ISSUES

Q 19: How can modern profit-driven agricultural biotechnology meet the basic needs of the poor?

As previously noted, the amelioration of malnutrition in the short term appears to be one major promise of biotechnology. One example is the development of more nutritionally complete crops that have the potential to reduce the prevalence of specific food deficiencies in areas dependent upon diets with little variety. Though publicly funded research is important, efforts that benefit large numbers of low-income people need not be unprofitable.

Poor nutrition is one factor in low productivity, and genetically engineered crops might thus provide a benefit more general than the relief of malnutrition. Similarly, if the use of more robust and more nutritionally complete crops becomes widespread, small village farmers could become productive enough to improve their financial condition. These are only two examples of how biotechnology, which is no more profit driven than current agricultural practice, might meet the "basic needs" of the poor.

The big question is whether the cost can be kept low enough for poor farmers. Put simply, this may appear unlikely (and may indeed be unlikely in the short term), as the development of agricultural biotechnology is carried out primarily by large multinational corporations.

However, a very common misconception is a belief that the products of agricultural biotechnology are being developed solely in the private sector. To cite only three examples: such products as nutritionally enhanced rice, virus resistant cassava, and vaccine-carrying bananas are under development in public sector research institutions. These innovations are specifically targeted at reducing the ills of poor populations.

Furthermore, it may seem paradoxical, but it actually can be profitable to help the poor. "Poor" countries are often key marketing opportunities for a seed corporation such as Monsanto or Novartis. While costly to create the seed, the increased yields and pest resistance of the crops may well justify the additional cost of the technology even to small farmers. One of the key concerns of developing countries is trying to minimize the yield swing between good and bad years. By helping crops better deal with environmental stresses, such as droughts, diseases, and insect pests,

GM can help farmers better manage the feast or famine effect of having several inches too little rain.

GM crops are only tools in the struggle for sustainable agricultural initiatives in developing countries, but they are a critical tool because of their ease to use and their dramatic yield increases, especially when arable land is scarce.

On whole, the net increase in yield and crop protection should outweigh the modest cost of the seeds, even in developing countries. If this were not the case, GM producers would have lots and lots of inventory they could not sell to any farmer, anywhere.

Q 20: Would not the poor farmers in developing countries become dependent on commercial biotech corporations?

In the developed countries, all farmers are dependent on the large input suppliers for 90% of inputs. Seed is the basis of agricultural production, and nobody can be competitive with outdated cultivars.

A better question might be, is such a dependence always a negative?

Whether this is better or worse than being dependent upon the vicissitudes of current production, or donor aid, is a debatable issue.

There is no obligation to purchase GM seed. Nor is there reason to suspect that there would be a lack of traditional seed available to small farmers who save seed from year to year. The only time a developing country or individual farmers in a developing country would purchase GM seed at a premium over traditional seed is if they believed the seed to be worth the extra cost.

Generally speaking—though not always—the amount of additional crop produced from GM seeds greatly outweighs the modest cost of the technology. Even in the absence of markedly improved yields, GM seeds tend to require substantially fewer inputs, such as synthetic pesticides or herbicides. In those cases, many farmers will also find it worth paying the premium for GM seeds.

Indeed, the corporations become dependent on their customers in a commercial relationship just as much as the reverse is true.

Q 21: How can the interests of developing countries be safeguarded?

In general, a primary interest in developing countries is to produce more food, and to produce more nutritious food. Genetic engineering can help safeguard this interest.

Accordingly, the biggest threat is preventing developing countries from being able to use biotechnology. The dogmatic ideology of activist groups currently constitutes the greatest danger to them.

It is overly simplistic to think that food security will happen purely by the development of the appropriate crops. Farmers in developing nations need a suitable political and social infrastructure to ensure that the application of the new technologies is effectively handled and does not cause more problems than it solves.

Developing countries definitely can benefit from the yield increases of GM seeds. The question is how can we make it profitable for seed companies to provide GM products to developing countries. In part, developing world governments with support from the World community (or individual UN members) may have to help subsidize the cost of the technology in their countries.

To build the necessary infrastructure, one key for developing countries is to secure financing for "sustainable agriculture", a whole collection of farming practices, which should include GM seeds. Current aid programs focus on providing assistance largely only when there is an emergency. But some public and charitable funding has been available for improving farming methods in the developing world. Greater investment in promoting sustainable agriculture can help developing nations substantially.

Q 22: Won't GE crops accelerate the trend towards fewer varieties of crops? Will not such a loss of crop diversity make agriculture more vulnerable?

The narrowing of the genetic base of crops has already occurred through conventional breeding, which farmers have carried on for thousands of years. It is more likely that genetic engineering will help reverse this trend.

The current evolution of agriculture in the US and other industrialized countries, including the move toward genetic engineering, has generated a select few highly specialized crops. If it is possible to move a gene into a land race or other locally adapted variety and make it more productive or better able to resist disease, this will preserve its use, and therefore help preserve diversity as well.

With conventional breeding a particular trait of interest has to be melded with other desired traits, to the exclusion of unwanted traits over many generations of selective breeding. With genetic engineering a single desired trait can be added to any already optimized breed in a much more directed and quicker manner. This will make it easier to diversify crops.

As GM crop development begins to introduce targeted production traits, such as resistance to certain pests in certain regions, the technology can actually improve crop diversity. Of course, it is enormously expensive to introduce a gene trait; so many producers will be interested in introducing traits for which consumers will pay a premium. Variety will be further increased as GM seed manufacturers introduce new consumer-focused traits, such as added nutritional components or improved longevity.

Genetic engineering may also expand the variety of crops by "domesticating" currently unused plants. Some plants are used for food in only limited geographical regions due to problems with naturally occurring toxins or other problems. Cassava, for example, is often used as a food source in sub-Saharan Africa. But cassava naturally contains high levels of cyanide that can only be removed with very careful preparation. Reduced toxicity and increased palatability would increase the number of species that could be used for food.

Finally, seed banks and DNA banks around the world preserve a multitude of natural varieties, for future resurrection if it should be desirable.

Q 23: What are the social and ethical implications of GE?

The issues can be broken down into two areas: intrinsic and extrinsic. Intrinsic concerns are those that have to do with moral concerns about the very process of GE: that it is unnatural or against religious views for one or more reasons.

If intrinsic objections are held, then the extrinsic ones are irrelevant, in the same way that if you object to capital punishment on moral grounds, you don't argue about the methods by which it should be carried out.

In New Zealand, for instance, the indigenous people (Maori) do not approve of mixing genes from different species. Their objection is a spiritual one, based on their belief that ancestors are like gods—to be revered—and ancestral heritage and inheritance are therefore also sacred. However, the Maori culture never had to deal with such complexities as GE until

recently. It is fair to say that an 'intrinsic' spiritual argument is the only one which cannot be refuted by an ethics committee.

Other 'intrinsic' objections include: GE is unnatural; trying to play God; arrogating to ourselves historically unprecedented levels of power; disrespecting life by patenting it; "commodifying" life; illegitimately abrogating species boundaries or exhibiting arrogance, hubris, and disaffection. Such objections are difficult, if not impossible to refute, because they rest on strongly-held beliefs, rather than on facts.

Extrinsic objections, which rest more on facts and reasoning, have to do with consequences arising from the application of the technology.

Such objections include claims that GE organisms may have disastrous effects on animals, ecosystems, and humans. Potential harms to animals include unjustified pain to individuals used in research and production. Potential harms to ecosystems include possible environmental catastrophe, inevitable narrowing of germplasm diversity, and irreversible loss or degradation of air, soils, and waters. Possible harms to humans include perpetuation of social inequities in modern agriculture, decreased food security for women and children on subsistence farms in developing countries, a growing gap between well capitalized economies in the Northern hemisphere and less capitalized peasant economies in the South, risks to the food security of future generations, and the promotion of reductionistic and exploitative science.

Consider the fable of Prometheus giving fire to mortals. When he brought fire, did mankind extinguish it? Or did we attempt to learn how to use it to the best of our ability?

Increasing yields and decreasing inputs can only benefit society. Genetic engineering is merely the latest in a long line of technologies that humanity has devised to improve its prospects. Technophobes will produce arguments that it is unethical. Technophiles will defend it. But passions aside, most agree that societies would be far better served by carefully using technology, while critically monitoring its progress and performance.

Q 24: Shouldn't consumers have the right to know whether they are consuming GE?

Opinion on this topic is strongly divided.

Some want GE food products to be labeled because they personally would prefer to consume such

products, and want to have a means for finding them. Others want such products to be labeled because they wish to avoid them.

Whether or not such desires require the creation of a "right" to know if they are consuming GE food products is another matter entirely. It is generally agreed that consumers have a right to know things that are directly relevant to their health and safety. For instance, if a food contains allergens, or is high in sodium or cholesterol, the consumer is considered to have a right to know.

Governments typically prescribe what aspects of foods consumers have a legal right to know, with the view to making an optimal amount of useful information available. In most cases, ingredients that are generally agreed to be safe and do not form major proportions of the product need not be listed. Otherwise, labels would be encyclopedic lists that practically no one would consult. As long as genetically engineered ingredients are subject to the same rules as any other product, most scientists agree that there is no need to expand the consumer's legal right to know beyond what is necessary and useful.

If a consumer's right to know goes beyond legitimate health and safety matters, no one has yet proposed how extensive that right would be. Some will want to know about the pesticides, manure, trace elements, fertilizer, or variety of crop, to mention only a few.

Q 25: Shouldn't GE foods be labeled? If not, why not?

If we assume that a consumer has a legal right to know whether a food has been produced with GE, then it would be appropriate to assume that such foods should be labeled.

Questions of the "right to know" aside, a more reasonable question would be: Should all consumers be forced to accept the cost of this knowledge?

The costs include: 1) farmers needing to segregate grains; 2) silos needing to be extremely careful about when they take deliveries to keep GE and non-GE grains separate; 3) food processors needing to test shipments; and so on down the food chain.

If you ask 100 people if they would want to know if there were GE materials in their foods, most would say yes. If you asked the same 100 people if they would want to know if there was GE material in their food AND that finding out would cost them 5 cents a loaf of bread and 25 cents a pound of beef, fewer would be

interested. But surveys also show that, if you told that same group of people that, in the judgment of scientific experts, there was no difference in safety or nutrition, fewer still would demand that GE foods be labeled.

Should the majority of consumers who understand that there is no health difference between GE and non-GE foods or simply do not care, be forced to pay the cost of providing information to a minority of consumers who what it? Is that fair?

Some suggest that the markets rather than government regulation should dictate whether or not consumers would prefer low food costs or labeling, and this underpins the notion that labeling should be optional, not mandatory. This would lead to a traditional food market and a niche market for non-GE foods similar to the niche market for organic foods. The customer would pay a premium for non-GM foods and retail grocery stores would have a much larger margin on such products. Likewise, farmers would be paid a premium for non-GM maize. In the end, it is the consumers who actually want that information who would bear the cost of providing it.

If the issue really is of concern to consumers, then consumers will be willing to bear the cost of the labeling process.

Q 26: Is it fair to grant patents on GE organisms?

This is a complex issue, having to do with different appreciations of what is meant by ownership. Patenting does not in fact give patent-holders ownership; it temporarily gives them the exclusive legal right to use some process or to exploit some information that they have discovered. That exclusive right, in turn, enables individuals and companies to protect their investments when making inventions available to the public.

Without patents, much innovative research would not be done. Universities and companies typically must invest several million dollars to discover a novel gene, and to learn how to use it. Regulatory requirements and developmental difficulties often add several million dollars more to the overall cost. An assurance that the discoverers will have a protected right to recoup this investment is essential.

This is exactly similar to human medicine or even to conventional crop breeding. As one inventor says: "No patents, no progress." Even public institutions such as the CGIAR centers need patents to justify and protect their investments.

With some modest variability, patents usually last only about 20 years. Much of this time tends to be devoted

to developing the technologies to the point where they become useful commercial products. Once patents expire, anyone is then free to use the innovation.

More contentious, is the issue of taking a process or a crop that has been used by a country or culture for a long time, making a scientific analysis of the use, and patenting some aspect of it that may prevent or limit traditional uses. The WTO under the GATT agreement has surprisingly wide ranging legal powers in this regard. However, agreements do appear to be emerging which may either restrict this kind of thing, or at least ensure that some appropriate financial remuneration is made.

It should be recognized, however, that much of the objection to patenting (and indeed to the further commercialization of agriculture, of which GE is only a small part) arises from deep seated cultural differences. Some cultures regard certain assets as part of the commons (an equal heritage, communally shared), while others regard all aspects of social assets as commodities, which can ultimately be exploited.

Socially, the current prevailing world view held in developed nations is the latter view, and advocates argue that this increases the efficiency with which these resources can be used.

Q 27: Doesn't patenting life forms encourage violence: first by treating life forms as mere machines and denying their self-organizing capacity; and second, by denying self-reproducing capacity (that is, by allowing patents on future generations of plants and animals)?

Much of the heat in discussions of biotechnology results from a genuine clash of world views. Unfortunately, when such clashes occur, reason is not always a sufficient tool to sort out the difficulties and disagreements.

However, human cultures have permitted ownership of specially bred plants and animals for eons—from livestock given as dowries to grains held as tribal property. Viewing such ownership as a violent injustice is not typical in any part of the world, so sociologically, it is not a serious issue.

It bears pointing out that patents cannot prevent plants and animals from reproducing. Humans already exert a great deal of control over reproduction of plants and animals in agriculture without patents, and patents in the GE field do not inherently enhance this type of control.

Most experts agree that the patent system is similar to, or at least compatible with, historical agricultural practices.

Q 28: When a patent is granted on the basis of a GE organism being novel and not occurring in nature, how can the intellectual property right (IPR) holders then seek to escape the responsibility of consequences of releasing the organisms? How can they treat the issue of biosafety as unnecessary?

All parties using a technology are responsible for damage caused by its use. This is just as true of GE organisms as it is for automobiles.

A related question is one of regulatory treatment. When regulatory agencies evaluate new GE organisms, the organisms are classified as either "substantially equivalent" to their conventional counterparts or "not substantially equivalent" to their conventional counterparts and then regulated accordingly. That is, if a GE tomato is found to be substantially equivalent to conventionally bred tomatoes, the GE tomatoes are not typically subjected to more stringent regulatory controls.

Critics often ask, "If a GE organism is substantially equivalent to its conventional counterpart," how can IPR be granted?" Such a question stems from a common misunderstanding of the concept of substantial equivalence. Substantial equivalence is a legal concept (not a scientific one), used in evaluating the risks of a GE organism relative to the risks of non-GE organisms. If the GE tomato is found to have the same nutritional and compositional make-up of the conventional variety, and is found to have no new toxins or allergens, it is deemed to be substantially equivalent in all relevant aspects pertaining to health and safety. It is also important to note, that a determination that a GE organism is substantially equivalent can be made only after the relevant scientific testing for safety has been conducted.

The best way to avoid any damage that GE organisms might cause, and the responsibility that would entail, is to be sensitive to biosafety issues and conduct thorough evaluations. That is why there are regulatory agencies in place. That is why there are regulations governing the early stages of development of these crops. That is why large amounts of data have to be compiled to obtain regulatory approvals. No one treats this issue lightly. However, we can be assured that when genetically engineered crops go through the safety evaluations and are approved for release, all issues of safety have been addressed.

Q 29: Won't IPR put restrictions on creativity of nature (i.e., inherent to living systems that reproduce and multiply in self-organized freedom) by shifting common rights and excluding intellectual commons' knowledge, ideas and innovations? Apart from corporate control over minds, IPR may become intellectual theft or bio-piracy?

No patent can prevent nature from doing what she pleases. No patent allows anyone to exert control over minds. Common knowledge is not patentable. That is why applicants have to demonstrate that their inventions are distinct from the "prior art" and "not obvious".

Intellectual property rights free man's creativity and give him protection for the fruits of his creativity. Plant Variety Acts and similar statutes do not allow people to claim intellectual property rights on plant varieties or "things of nature". Nature's creativity is protected alongside man's creativity.

"Bio-piracy" is a relatively recent concept, referring to the act of gaining intellectual property protection for someone else's invention, or for something that is already commonly known or used. However, intellectual property rights usually are denied for such things. The recent revocation of the neem oil patent is a classical example.

Q 30: Doesn't the emergence of GE threaten to change the meaning and value of biodiversity from life-support base for poor communities to raw-material base for private corporations?

Much historical evidence shows that poor communities are exceptionally good at destroying biodiversity without the aid of genetic engineering. Poor communities grow cash crops for sale because they cannot otherwise afford to produce or purchase goods and services not available through traditional agriculture and animal husbandry.

The key issue is that private corporations and public research institutions have developed products that would enormously help developing countries increase their sustainable agriculture programs. GM seeds are one such product, helping increase yields and generate crops on lands that were once unsuitable for agriculture or where crops would often suffer from terrible pest damage.

Corporations and communities alike have a long history of viewing biodiversity as a raw material. Biotechnology does not itself do anything to change this. How we use technology is the issue.

Q 31: Is there any possible benefits of the so-called "Terminator technology"? Or is it simply a means to exercise control over farmers' right to grow their own seed?

The most obvious benefit of the "Terminator" technology is to ensure that the rights of plant breeders are protected. Meanwhile, farmers will always have the right to grow and their own seed. Growing someone else's seed is another thing entirely.

The fundamental right rests with the producers of GE seed to be compensated for their inventions. In most cases, farmers are purchasing the enhancement just as much as they purchase fertilizer or other inputs that help them grow more or better crops.

When farmers buy GM seeds, it is common practice for them to make a promise to only use that seed one time, just as purchasers of computer software make an implied promise not to make duplications of their software. Saving seed from the harvest is a violation of the farmers' promise. Terminator technology would only enforce the obligations on potential cheaters, while sparing everyone the cost and aggravation of going to court.

The other obvious benefit is to allay the fears of those who believe that genes from modified crops will 'escape' into the environment and create 'superweeds.' Since the seeds produced by any plant with the "Terminator" gene will not germinate, any crosses between crops and weedy relatives would have no impact on the environment.



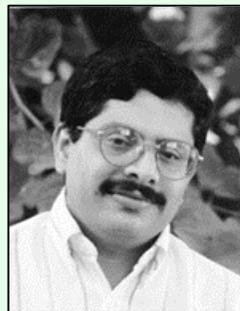
<http://www.agbioworld.org/>

AgBioWorld is devoted to bringing information about technological advances in agriculture to the developing world. Our members include scientists, physicians, professors and others who believe that recent developments in plant science, such as biotechnology, can and should be used to increase crop yields, grow more nutritious plants and reduce dependence on chemicals in order to alleviate hunger and to help preserve the environment.

AgBioWorld seeks to provide information to scientists, policymakers, journalists and the general public on the relevance of agricultural biotechnology to sustainable development. To get our message across, we are collecting the signatures of people who agree that these new tools should be used to help safeguard food security.

This site is sponsored and maintained by Professor C.S. Prakash, Director of the Center for Plant Biotechnology Research at Tuskegee University and a member of the newly-formed USDA Advisory Committee on Agricultural Biotechnology. <http://www.agbioworld.org/usda.html>

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