To assess the likely effects of “terminator” technologies on the societies and economies of developing countries, one needs first to understand the roles played by intellectual-property rights (IPRs) in those countries. Accordingly, this memorandum is divided into two parts. The first briefly reviews and evaluates the types of IPRs currently available for new plant varieties. The second evaluates the potential roles of “terminator” genes as supplements or substitutes for those IPRs.

It bears emphasis that this memorandum deals exclusively with the potential function of terminator technologies in the protection of intellectual property. Assessment of the health and ecological effects of that technology is left to other members of the Advisory Group.

I. Background

A. Legal Protection for New Plant Varieties

The character and amount of intellectual-property protection accorded genetically modified plants throughout the world are currently in flux. Broadly speaking, protection is most generous in the United States, is slightly less generous in other parts of the developed world, and is substantially less generous in most developing countries.

In the United States, new plant varieties created through genetic engineering are subject to protection under three statutory systems: the Plant Protection Act (covering asexually reproducing new plant varieties); the Plant Variety Protection Act (covering sexually reproducing new plant varieties); and the Patent Statute. The most generous of these three regimes is the last. Until the 1980s, it was not clear that the Patent Statute covered living things – and plants in particular. The Chakrabarty and Hibberd decisions removed the doubts on that score. Since then, the developers of new plant varieties – and specifically of new varieties created through genetic engineering – have relied whenever possible on patent law.\[2\]

The legal protections available to plants breeders in Europe resemble those available in the United States, but are somewhat less generous. Beginning in the 1940s, several European countries adopted special statutes providing protection for new plant varieties. The formation in 1961 of the Union pour la Protection des Obtentions Vegetales (UPOV) resulted in the repeal of these statutes and their replacement with a uniform system of “Breeders’ Rights.” The UPOV has been amended several times, and the contours of its successive iterations vary. The protections it provides to plant breeders roughly resemble patent law – with three significant exceptions. First, it provides no protection for novel methods of developing plants. Second, it provides less protection than patent law for “equivalent” plant varieties. Third, it permits member countries to provide an exemption for “farmer's rights”; in other words, farmers may be allowed to reuse seeds produced by protected crops.\[3\]

The 1973 European Patent Convention is less hospitable to the protection of plants than the American patent statute. Article 53(b) provides that “European patents shall not be granted... [for] plant or animal varieties or essentially biological processes for the production of plants or animals....” The judicial construction of this provision has varied considerably over time (sometimes permitting, sometime forbidding, the patenting of plants that do not meet the technical definition of a “variety”).\[4\] At present, it is more difficult for breeders to avail themselves of European patent protection than
to obtain American patent protection.

Until quite recently, most countries in the developing world lacked any intellectual-property systems applicable to genetically altered plants. Pressure exerted by TRIPS (the 1994 GATT Agreement on Trade-Related Aspects of Intellectual Property Rights) is gradually changing that situation. Article 27 of TRIPS imposes on all members of the World Trade Organization (currently 134 nations) an obligation to “provide for the protection of plant varieties either by patents or by an effective sui generis system or by any combination thereof.”[5] The most important template for “an effective sui generis system” has been the UPOV (discussed above). Compliance by developing countries with their obligations under TRIPS has been slow and uneven – for reasons aptly summarized by Prof. Johnson Ekpere at the recent Global Conference on Biotechnology.[6] In many developing countries, the politicians who negotiated and signed the Agreement are no longer in power. Establishing systems of the sort required by TRIPS will be costly. Finally, the benefits conferred upon developing countries of a vigorous intellectual-property regime are far from obvious. These circumstances make it likely that many developing countries will fail to meet their obligation under TRIPS to comply with article 27 by January 1, 2000. Even those countries that do meet the formal deadline may fail to provide effective enforcement of the new provisions. Whether threats of trade sanctions by the United States will be sufficient to overcome their reluctance to comply with the Agreement remains to be seen.[7] The bottom line is that we can expect that the levels of effective intellectual-property protection for genetically modified plants will remain lower – and perhaps dramatically lower – in developing countries than in the United States and Europe for some time to come.

B. The Merits and Demerits of IPRs in Plants

The standard justification for intellectual-property protection for new plant varieties is that same as the standard justification for intellectual property in general: Knowledge of how to produce and replicate superior plant varieties is a classic “public good.” Unlike most goods and services, it can be used and enjoyed by unlimited numbers of persons without being "used up." Partly as a consequence, denying access to such knowledge to persons who have not paid for the right to enjoy it is impracticable. These conditions create a risk that new plant varieties that would be worth more to consumers than the costs of creating them will not be created because the monetary incentives for doing so are inadequate. Intellectual property protection mitigates this source of economic inefficiency. By forbidding the nonpermissive replication of new plant varieties, the law increases the incentives for firms in the private sector to develop and market those varieties.

It has long been recognized, however, that pursuit of this strategy has three potential drawbacks. First, by deliberately conferring monopoly power upon the creator of the new plant variety, intellectual property rights foster “deadweight losses.” Consumers (i.e., farmers) who value the seeds of the new plant variety at more than the marginal cost of producing them but less than the monopoly price charged by the patent owner will not buy them. The net result, in economic terms, is a sacrifice of the consumer surplus that would have been reaped by the excluded consumers had the variety been made available to them at its marginal cost. This effect is traditionally represented graphically as follows:
Rectangle 1 represents the profit enjoyed by the owner of the intellectual property as a result of being empowered to engage in monopoly pricing. (It is this profit that provides the incentive to develop the plant variety.) Triangle 2 represents the consumer surplus reaped by farmers (and consumers of their crops) who are able and willing to purchase the seeds of the new plant variety at the monopoly price. Triangle 3 represents the social loss with which we are presently concerned – the consumer surplus that would have been reaped by consumers represented by the line FH, which is sacrificed because those consumers have been “priced out of the market.” The human reality that lies behind this triangle may be as mild as a foregone opportunity to taste an especially delicious variety of fruit or as severe as the starvation of impoverished persons deprived of access to a new, more productive or more disease-resistant strain of rice.

The second of the familiar drawbacks of intellectual property protection – in general and for new plant varieties in particular – is commonly known as “rent dissipation.” The lucrative prize of patent protection, in combination with the “winner-take-all” regime that characterizes most intellectual-property systems, tends to attract an inefficiently large number of private firms into the race to develop new varieties. The result is a waste of scientific and social resources. Scholars continue to debate the relative merits of alternative techniques of mitigating such “rent dissipation.” No one, however, suggests that it is possible to eliminate this effect altogether.[8]

Third, intellectual-property regimes tend to foster the concentration of economic power and to exacerbate disparities of wealth among the nations of the world. Both of these tendencies are evident in the context of genetically modified plants. Considerable consolidation among the firms that supply seeds worldwide has occurred since patent-protected innovations became important.[9] In addition, almost all of the relevant plant patents are now held by firms located in developed areas of the world, resulting in a flow of revenue from the poorest to the richest countries.[10]

Do the benefits of intellectual property protection justify incurring the drawbacks associated with it? In other words, do the socially valuable incentive effects of IPRs more than offset (a) the associated deadweight losses through monopoly pricing, (b) welfare losses through rent dissipation, and (c) the injuries associated with oligopolistic industrial structures and increased inequality of wealth? With respect to many fields of technology, the answer is not clear; scholars continue to debate the question whether, on balance, we would be better off without any IPRs at all. With respect
to biotechnology, however, there is general agreement that IPRs are essential to the industry.[11] Anecdotal evidence suggests that this overall judgment concerning the importance of IPRs to the biotechnology industry as a whole holds true with respect to the more specific issue of genetically modified crops. In the absence of intellectual-property protection (for example, in most developing countries), private-sector firms have been highly reluctant to invest significant resources in developing new varieties of self-pollinating plants. The only major exception to this pattern has involved crops (such as corn and maize) that lend themselves to improvement through hybridization. The fact that such hybrids are only highly productive in the first generation, combined with the ability of private firms to keep secret the highly refined stocks from which the hybrids are produced, has created a kind of “natural” intellectual-property protection sufficient to attract investors and stimulate innovation. But self-pollinating crops (such as rice or wheat) that do not lend themselves to this breeding and marketing strategy have traditionally not attracted significant private investment in creating superior varieties.[12]

In sum, if our objective is to stimulate the development of new plant varieties through genetic engineering,[13] we should support the establishment and effective enforcement of an intellectual-property system – in developing countries as well as in developed countries. That general guideline, however, does not imply that we should apply automatically to genetically modified plants all aspects of the patent system currently in force in the United States. Strategic adjustments in the patent system – or the adoption of a *sui generis* form of plant protection (of the sort permitted by TRIPS) – may make it possible to reap the social and economic advantages of intellectual property while limiting the concomitant drawbacks.

II. "Terminator" Technology

Technology protection systems enable the developers of genetically modified plant varieties to alter the characteristics of the plants while they are growing. The best known of these systems -- popularly known as “terminator” genes -- render the seeds produced by genetically modified plants sterile. In other words, seeds containing the gene will produce only one generation of plants; farmers cannot, by saving the seeds generated by those plants, produce additional crops in future years.

The technology necessary to produce this effect is already sufficiently advanced to have garnered a patent in the United States. Less well developed but clearly foreseeable are so-called “second-generation” terminator technologies. These include systems that will make it possible for farmers, by applying innocuous but specific chemicals to genetically modified crops, to “turn on” and “turn off” their novel characteristics (such as resistance to specific insects). As yet, most of the debate surrounding “terminators” concerns first-generation technologies – and this memorandum will similarly concentrate on the basic form. However, is it worth bearing in mind that more sophisticated systems are already on the horizon.[14]

The most controversial of the potential functions of “terminator” genes is their capacity to serve as substitutes for IPRs. By incorporating “terminator” genes into their seeds, the developers of new plant varieties are able to prevent farmers from making “copies” of those seeds. To be sure, these genes do not prevent competitors from using genetic engineering to produce and then sell identical seeds. To shield the developers of new varieties from such competition, intellectual property law remains necessary. However, the most direct and widespread threat to the revenues of private firms developing new plant varieties – namely, the capacity of the farmers who buy the seeds to produce unlimited copies of the plants in question – is removed by the “terminator” technology.

In this respect, adoption of “terminator” technology to shield new plant varieties would precisely parallel recent changes in the ways in which informational products are marketed on the Internet. For centuries, the producers of informational products have relied primarily upon copyright law to shield their creations from unauthorized copying, thus enabling the producers to engage in monopolistic pricing strategies and earn enough income to cover their costs of creation. Three characteristics of the Internet, in combination, have undermined that traditional strategy. First, digital
copies of informational products can be copied and transmitted with remarkable ease. Second, it is difficult to trace the persons who, without permission, copy and transmit copyrighted materials on the Internet. Third, the strongly anarchic culture of the Internet increases the frequency of such unauthorized copying. In the mid-1990s, political leaders sympathetic with the plight of the producers of informational products attempted to meet this threat by tightening copyright law on both national and international levels. In the past few years, however, their reliance on the copyright system has diminished. A growing number of producers are now relying instead on either contracts or technological protections. Thus, for example, software manufacturers now commonly use “click-on licenses” to extract from their customers agreements not to engage in a variety of unauthorized uses of the products. Even more effective in protecting the economic interest of suppliers are the increasingly common forms of encryption – cryptolopes; trusted systems; serial copy management systems; the SDMI initiative, etc. Inexpensive and largely self-enforcing, these technological protections are rapidly becoming the preferred mode of shielding informational products.\[15\]

The marketing of genetically modified crops seems to be following a similar trajectory. The developers of new plant varieties continue to push hard for strengthened IPRs. In recent years, however, they have come to rely increasingly upon contracts to prevent unauthorized replication of their products. For example, Monsanto commonly insists that farmers agree not to reuse seed produced by its genetically modified crops.\[16\] In the future, “terminator” technology may provide the seed suppliers technological shields closely analogous to the encryption systems already being employed by software and entertainment suppliers.

Would the use of this new technology as a substitute or supplement for intellectual-property protection be socially desirable? In particular, would it be good for developing countries? No simple answer to that question is apparent. Rather, the technology would have some substantial social advantages, but also some substantial drawbacks. These are sketched below.

A. Advantages

1. The most obvious benefit of the new technology is that it would enable the developers of new plant varieties to make a profit selling seeds in countries that currently lack intellectual-property protections for plants. Opportunities for such profits should encourage biotechnology firms to develop plant varieties suitable for cultivation in developing countries and then to make those varieties available to farmers. If, as some observers believe, innovations in biotechnology are essential to fuel a second “Green Revolution” – which, in turn, is essential to stave off the looming crisis in world food production – terminator technology might well facilitate an increase in the quality and quantity of food available to the world’s poorest people.

2. “Terminator” technology is more than a potential substitute for IPRs; from the standpoint of the private firms, it is even better than IPRs. It is plainly superior (from the firms’ standpoint) to “sui generis” plant-protection statutes styled on the UPOV, for the obvious reason that it overrides the traditional entitlement of farmers to reuse seeds produced by protected plant varieties. For two, less obvious reasons, it is also superior (again, from the firms’ standpoint) to patent protection. First, although license agreements can enable patentees to forbid farmers to reuse seeds, those license restrictions are notoriously difficult to enforce, even in the United States, where respect for patents is reasonably strong and where enforcement mechanisms are reasonably efficient. In developing countries, the practical impediments to effective enforcement of restrictive licenses are much more severe.\[17\] By contrast, “terminator” technology makes it simply impossible for farmers to reuse the seeds. Second, patent law in many countries limits in various ways (e.g., through the “patent misuse” doctrine) the kinds of license agreements that patentees may extract from their customers. By employing “terminator” technology, the firms can escape those restrictions. These two differences suggest that the incentive effects of terminator technology will be even stronger than that of IPRs. (Whether they give rise to unacceptable adverse side-effects will be considered below.)

3. By discouraging arbitrage, “terminator” technology increases the ability of seed suppliers to
engage in price discrimination and other forms of precise marketing. To be sure, the technology does not eliminate arbitrage altogether; farmers who bought seeds at low prices could, instead of planting them, resell them to other farmers able and willing to spend more. But plainly, it would prevent farmers from selling to their neighbors seeds produced by first-generation crops. Enhancement of the suppliers’ ability to engage in price discrimination would, in turn, have two predictable effects. First, it would increase the suppliers’ potential profits. Second, it would enable and encourage the suppliers to make seeds available at lower prices to poorer farmers, thus reducing the welfare losses associated with monopoly pricing. These effects are traditionally represented graphically as follows:

![Figure 2: Economic Impact of Partial Price Discrimination](image)

The essence of so-called partial price discrimination is the strategy of dividing the pool of potential customers into segments and then charging the members of each subgroup what they are able and willing to spend. For example, on the simplified assumptions embodied in Figure 2, the seed supplier would charge the relatively wealthy and/or efficient farmers represented by line 0-U price p, charge the less wealthy farmers represented by line U-V price q, charge farmers V-W price r, charge farmers W-X price s, and charge farmers X-Y price t. By adopting this strategy, the supplier would be able to increase its profits substantially. (Contrast the size of zone 1 in Figure 2 with the size of zone 1 in Figure 1, above.) At the same time, the set of farmers “priced out of the market” would shrink. (Contrast the size of zone 3 in Figure 2 with the size of zone 3 in Figure 1, above.) Both of these effects represent improvements over monopoly pricing in the absence of price discrimination.[18] (Whether price discrimination also has unacceptable adverse side-effects, we will also consider below.)

4. In two related respects, the use of “terminator” technology has additional potential benefits. First, it would eliminate inefficient and inequitable cross-subsidies of long-term users by short-term users of new plant varieties. Suppose farmer A wishes to use a new variety of genetically altered rice for one year, while farmer B wishes to use it for 10 years. In the absence of “terminator” technology, it will be difficult for the supplier to differentiate among the two farmers. Consequently, they will pay the same price for the seed. Farmer B will then reuse seed from his first crop in subsequent years, while farmer A will not. The net effect is that Farmer A will pay the same amount for one year’s crop as Farmer B pays for 10. Such a situation both is unfair and distorts their incentives to use new varieties. “Terminator” technology, by contrast, would enable the supplier to lower its prices drastically, but then charge farmers each year. The beneficial result is that Farmer B would pay 10 times as much as Farmer A. The second, related effect is that the use of “terminator” technology would provide farmers optimal incentives to
experiment with new varieties. In the absence of the technology (or of effectively enforced IPRs), farmers have a strong incentive to stick with the first generation of genetically improved plants they purchase – because they can reuse the seeds produced by the first generation for free. If better varieties become available later, farmers will be reluctant to buy them. This distortion of their incentives would be eliminated if they had to pay for new seeds each year.

B. Disadvantages

1. The potential disadvantage of “terminator” technology that looms largest in contemporary debate is the danger that farmers will become dependent on Western biotechnology companies for their supplies of seeds. The companies, it is feared, will then take advantage of that situation to charge farmers exorbitant prices. The net effects will be further to impoverish farmers in the developing world – and to increase the regrettable flow of revenues from developing countries to the developed world.

2. A more subtle variation on this theme is the risk that the biotechnology companies will use their economic leverage to trap farmers in a cycle of economic dependency analogous to the “crop lien” system that prevailed in the American South in the late nineteenth century. In some areas, poor farmers may be unable to pay for the seeds at the start of the growing season. The seed companies will thus be tempted to provide the farmers the seeds they need in exchange for a promise to pay the companies higher prices at the time of harvest – a promise the farmers will likely have trouble keeping. After a few repetitions of this arrangement, farmers would find themselves hopelessly in debt.

Defenders of the technology protest that farmers are not as vulnerable as either of these scenarios would suggest. After all, they are not forced to use the new plant varieties. Only if the new varieties are dramatically superior to existing varieties will they purchase the new seeds. And, if the companies are foolish enough to raise the prices of the new seeds to exorbitant levels, the farmers can easily switch back to the traditional varieties.

Various circumstances suggest that these responses are not wholly persuasive and that the dangers highlighted by the critics are real. First, most arrangements between seed suppliers and farmers in developing countries will involve extreme inequalities of information and bargaining power. Those conditions make it likely that the farmers will enter into deals that are not in their long-term best interest. Second, it is far from clear that seeds from the traditional nonproprietary plant varieties will remain available to the farmers indefinitely. Widespread usage of superior, proprietary, genetically engineered varieties might in one way or another “drive out” the older types. Stocks of the older seeds might be abandoned – or might lose their fertility; farmers who produce for the market might find that customers now expect products of the new types; and so forth. If this occurred, then the economic power of the seed companies would increase dramatically.

C. What Is to Be Done?

The substantial potential benefits of terminator technology, outlined in section II.A., above, suggest that it would be unfortunate if the seed companies were compelled – either through legal prohibitions or popular opinion – to eschew use of it altogether. On the other hand, developing countries would be wise to regulate its usage so as to avoid the dangers sketched in section II.B. How? Set forth below are a few possibilities.

1. Manipulation of the rules of patent law is an unpromising way of seeking to prevent the technology from being used in exploitative ways. If anything, denying a patent to this technology – thus enabling many biotechnology companies (rather than just one) to use it in marketing their genetically altered seeds – would increase rather than decrease the dangers associated with it.

2. More promising would be mandatory disclosure rules – analogous to those imposed on all
residential mortgage transactions in the United States. Sellers of genetically altered seeds containing “terminator” genes would be required to explain to each customer the implications of the new technology – and, in particular, the fact that the customer would need to purchase new seeds each year. This strategy could go some distance toward reducing the information asymmetries between sellers and buyers, but would likely not eliminate altogether the risks catalogued in section II.B.

3. More promising would be price controls. A developing country could permit the sale and use within its jurisdiction of seeds containing “terminator” genes, but only on the condition that the seller not exceed price ceilings set by an administrative tribunal. American copyright law (although not patent law) contains many such arrangements. Generally speaking, they work well in balancing the interests of innovators and consumers. A similar strategy could enable developing countries simultaneously to create incentives for the development of new plant varieties while curbing exploitative use of the resultant economic levers.

4. Finally, more elaborate regulatory mechanisms might be effective. For example, a developing country could permit the sale and use within its jurisdiction of seeds containing the terminator gene, but only on the condition that each seller agree in all future years to continue to provide the seeds to the original purchasers at the same price (adjusted for inflation). Under such an arrangement, the seller could charge a higher price to new customers, but not to existing customers.[23] Such a system would shield farmers from many of the exploitative tactics predicted by the critics of the technology.

It is impossible, without knowing a good deal more about the economic and social conditions in a specific country, to determine which regulatory apparatus would work best. But the general idea should be clear enough: A sensible response to the advent of terminator technology would permit – but regulate – its use.

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[5] TRIPS article 27(3)(b). For explications of the provision, see Klaus Bosselmann, “Plants and Politics: The International Legal Regime Concerning Biotechnology and Biodiversity,” Colorado Journal of International
For the purposes of this memorandum, I have put that fundamental various impacts are examined in greater detail in Fisher, "Property and Contract on the Internet," supra note 15. Their own. The strategy described in the text has substantially reduced the consumer surplus enjoyed by wealthy and eager buyers (near the Y axis), but has made the product available to a much larger set of consumers, who are now enjoying surpluses of aggregate consumer welfare. Notice that adoption of the pricing strategy described in the text has substantially reduced the consumer surplus enjoyed by wealthy and eager buyers (near the Y axis), but has made the product available to a much larger set of consumers, who are now enjoying surpluses of their own. Whether total consumer surplus has increased or decreased is impossible to determine. See W. KIP VISCUSI, ECONOMICS OF REGULATION AND ANTITRUST 279-83 (1992); Michael J. Meurer, "Price Discrimination, Personal Use and Piracy: Copyright Protection of Digital Works," Buffalo Law Review 45 (1997): 845, 897-98. These various impacts are examined in greater detail in Fisher, "Property and Contract on the Internet," supra note 15.

Such a situation would involve an enormous change in current practices. Presently, 80% of the crops in the USA are genetically modified, with the percentage growing. The use of genetically modified crops has increased consumer surplus for consumers who can afford them, but has decreased consumer surplus for those who cannot. This is because the pricing strategy described in the text has made the product available to a much larger set of consumers, who are now enjoying surpluses of aggregate consumer welfare. Notice that adoption of the pricing strategy described in the text has substantially reduced the consumer surplus enjoyed by wealthy and eager buyers (near the Y axis), but has made the product available to a much larger set of consumers, who are now enjoying surpluses of their own. Whether total consumer surplus has increased or decreased is impossible to determine. See W. KIP VISCUSI, ECONOMICS OF REGULATION AND ANTITRUST 279-83 (1992); Michael J. Meurer, "Price Discrimination, Personal Use and Piracy: Copyright Protection of Digital Works," Buffalo Law Review 45 (1997): 845, 897-98. These various impacts are examined in greater detail in Fisher, "Property and Contract on the Internet," supra note 15.
developing world are grown each year from saved seed. Approximately 1.4 billion people depend for their primary food sources upon crops grown in this fashion. See Reungchai Tansakul & Peter Burt, “People power vs the gene giants,” Bangkok Post (August 1, 1999); Anbarasan, supra note 17.


[21] Plainly, this scenario would only apply to farmers who plan to sell at least some of their crops. Subsistence farmers would thus be immune to this particular threat.


[23] This arrangement would closely resemble so-called “second-generation” residential rent-control statutes in the United States.