Ethics and Biotechnology – Identifying Issues in the Face of Uncertainties

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Introduction

The aim of this paper is to delineate ethical issues raised by applications of recombinant DNA technology in agriculture. Agricultural products created by genetically altering living organisms using recombinant DNA technology have begun to penetrate the commercial marketplace. In the United States, the Flavr Savr Tomato and genetically modified cow hormone are on the market. This commercialization comes after two decades of research and development marked by intense controversy. Strong resistance that has slowed the entry into the marketplace of genetically modified products continues. Even in the United States where the Clinton administration supports the loosening of government restrictions on the introduction of new genetically altered agricultural products, controversy continues within the scientific community and among consumers. And applications of this new biotechnology on a large-scale are not yet a reality.

Proponents and opponents of rapid, large-scale commercialization often seem to agree in expecting from this technology a radical transformation of agriculture. The proponents anticipate beneficial new products, easier and more effective weed and pest control, improved production, and significant economic boosts to national economies. Opponents, mindful of unanticipated harmful consequences from earlier technological transformations in agriculture, such as the use of chemical herbicides and pesticides, project much darker scenarios of the future.

In the discussion which follows, my aim is to move away from polarization, from visions of future unalloyed benefits or grim scenarios of the harms from science and technology out of control. Rather, I will use a selective survey of developments in genetic modification of plants and animals in agriculture to identify some important ethical issues. These are issues about what conduct is right or wrong according to standards of our common morality, about consequences of conduct for the welfare of humans, animals, and the environment, and about responsibilities of individuals. Suggestions of appropriate responses to ethical issues will be framed in light of the significant scientific uncertainties that remain, notwithstanding the impressive accomplishments of molecular biology.

A persistent question that becomes entangled with ethical issues is whether genetic modification using recombinant DNA technology marks a radical departure from past methods, a revolution. Some scientists stress that the technology is a continuation from 'classical' biotechnology, from processes of fermentation such as those long used to produce beer and cheese. Looking back at past practices of breeding plants and animals, some biologists are impressed by the continuity from those practices to the new processes for transferring genes to new organisms. In the debate about the risks from genetic modification using recombinant DNA, proponents of rapid increase of the use of this technology like to emphasize the continuities. Placing the new techniques in historical context in this way tends to diminish the specter of unintended, harmful consequences.

Yet other biologists, looking backward, see the ability to move genetic material from one organism into a totally different organism as a unique departure from the past, warranting concern (Pimentel et al 1989, p. 606). In the past, this genetic transfer was possible only between related species or, in some instances, between domesticated and wild versions of the same species. Of course, opponents of rapid development stress discontinuities and the harms that can come from bold departures. Whether or not there is a radical break with the past, it has to be conceded that living organisms are less predictable than mechanical systems.

The term 'genetic engineering' is often used as a synonym for genetic modification of plants and animals using recombinant DNA technology. This is not a neutral term, but serves rhetorically to convey a generally positive image, for it associates what are sometimes highly experimental, unsystematic, trial and error procedures with established practices of engineering. Engineers consciously manage the risks of technological advance in systematic ways, using certain heuristics such as safety factors, and generally making only incremental changes. Because a great deal is at stake with respect to embracing the new capacities introduced by recombinant DNA technology, the choice of terminology assumes importance and merits attention.

For an idea of how one scientist views the stakes, consider a statement by Charles Hess made in autumn, 1993. Presenting himself as a candidate for election to the Board of Directors of the American Association for the Advancement of Science (AAAS), he wrote, 'The opposition of consumer and environmental groups to the use of recombinant DNA technology to improve plants and animals on the basis of perceived risks and ethical issues discourages research and threatens the commercialization of the new technology.'[1]

Hess seems to share the attitude of proponents who hold that attention to perceived risks and ethical issues gets in the way of realizing the beneficial potential of biotechnology. Often they express the fear that taking time to investigate the risks and address ethical issues will make it possible for other countries to gain a competitive edge from earlier entry in the market. They apparently take it for granted that if we just forge ahead with intensified research and commercialization, all will be well.

We have had ample experience of undesirable consequences from moving full-speed ahead with new technologies in the face of perceived risks and ethical concerns. We know that unacceptable harms to people and the environment, large economic loss, and insurmountable public resistance can result. We do not need to repeat past errors. We have to look ahead, prepared to investigate the potential for undesirable outcomes and to consider whether and when they are justifiable.

The areas of ethical concern include implications of the new biotechnology for our attitudes toward other living things and ourselves; impacts on the health and safety of humans, animals, and the environment; social and economic consequences; and implications for the responsibility of scientists. The ultimate aim is to manage further development taking adequate care to avoid unacceptable harms we can identify in advance. We are awash in predictions; what we need is

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[1] This statement appeared on the ballot for the 1993 annual election of the American Association for the Advancement of Science.

information on which to base predictions so as to be able to devise appropriate controls and choose appropriate directions for further research and development.

Current Developments and Associated Ethical Issues

In agriculture, biotechnology development encompasses the creation of new production processes, plant products, animals, and fish. To bring out ethical issues I will describe some selected, currently prominent areas of development, considering plants first and then animals. The final section will address responsibilities of scientists since their choices of projects for research and development are critical to development of biotechnology using recombinant DNA.

Plants

Many observers judge that the new biotechnologies will have their greatest impact on plants (Busch et al 1991, p. 6). The potential benefits which have been emphasized include higher yields, enhanced nutritional value from crops, reductions in pesticide and fertilizer use, and improved control of soil and water pollutants (Pimentel et al 1989, p. 606). Developments to date concentrate on modification of specific plant characteristics such as resistance to weeds, to pests, to herbicides, and to insecticides; tolerance of stress; and nutritional content. Scientists have come up with an array of techniques for transferring genes to commercially valuable crops and have produced transgenic plants in more than three dozen species.

We have had little experience in nature with genetically modified organisms and there is therefore a diversity of views about the risks. Nevertheless, analysts have identified risks associated with different genetic transformation options. Consider, for example, herbicide resistance. Weed control is a dominant objective and much of the biotechnological research in agriculture centers on herbicide tolerance. This development represents a reversal of the traditional approach to weeding which starts with the seed that has desirable traits and looks for chemicals or agricultural practices to get rid of everything else.[2] The approach ushered in by recent biotechnological developments is to start with the chemicals and then manipulate the seeds. The first step was to identify the genes that allow certain herbicide resistant weeds to survive even when particular toxins are present. The next step was to transfer those genes to crop plants. Experimenters have succeeded in transferring those genes from the weedy species in which they naturally occur to tomatoes, tobacco, and petunias. An impetus to adopting this strategy is the development of the new generation of chemical herbicides, including glyphosate, that seems to be far safer for humans and the environment than the older herbicides (Comstock 1989, p. 264).

The broadest ethical questions that arise center on the propriety of crossing unrelated plant species. What may underlie is a global ethical concern relating to the welfare of living things and focused on maintaining the integrity of traditional plant species. Often, on religious or theological grounds, observers question the human presumption in manipulating living species in these new ways. In the views of some, there is a natural order of species in the universe and it is under threat from the use of the new recombinant DNA techniques. Perhaps more often the underlying concern is not global, but relates to the welfare of animals, especially humans. To allow meddling with species in the plant world using recombinant DNA techniques is, in the eyes of some, to open the way to using such techniques for tampering with species of animals and to genetic manipulation of humans.

To biologists and philosophers of biology the concept of species is problematic. There has been extended discussion about whether a species is itself an individual. The definition of a species is a debated issue.[3] An established test for demarcating a species, drawn from the case of the mule, is whether interbreeding yields sterile offspring. However, the farther down the phylogenetic tree, the less well that test works as a criterion. Furthermore, there were techniques in use before the

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2 This account is based on Gary Comstock´s discussion in Comstock 1989.

3 A useful entry to the literature can be found in the chapter titled "Species" in Rosenberg 1985. There is a brief bibliography. See also Ereshefsky 1992 and Ruse 1987.

development of the new biotechnology that modified the genetic endowments of plants to produce new hybrids.[4]

Nevertheless, the use of the new techniques of biotechnology represents, for some individuals and cultures, a threat to deeply held views about the universe and the place of living things within it. In responding to such reactions, we have to consider what the general imperative to respect other persons requires. Different perspectives of different parties have to be recognized and not dismissed. It is well to remember that riding roughshod over traditional beliefs or world views integral to self-perception violate the requirement of respect and can produce powerful resistance.

The safety of the final product is a major ethical concern. Will there be adverse effects from herbicide resistant plants on humans or livestock? What about the impact on the environment? There is considerable documented evidence to show that small genetic differences involving a single gene can be ecologically significant (Pimentel et al 1989, p. 607). The risks that have become salient have to do with effects on agricultural practices rather than direct effects of crops on humans. Producing herbicide resistant crops confers the advantage of expanding the array of herbicide types for weed control. But there is a danger that increasing the number of herbicide resistant crops will encourage wider herbicide use and in that way contribute to environmental problems. Moreover, genetically modified crops resistant to major herbicides could become weeds or cross with weedy relatives and spread herbicide resistance into weed species. These outcomes spell indirect adverse effects for humans.

However, we must take note of uncertainties here. A genetically modified organism may be genetically unstable. On the one hand, the modified organism, with its additional genetic baggage, may be at a disadvantage in competition with the unaltered organism in its native habitat. The likelihood is that instability will result in shutting out the modified organism. On the other hand, natural selection might favor the additional genes, making it possible for the organism to become a pest. We have seen such outcomes in the United States with accidentally introduced species.

[4]At the IIT colloquium discussion of an earlier version of this paper, Warren Schmaus made these points compelling.

impacts of introducing genetically engineered herbicide resistant crops. What will be the effects on rural income levels and distributions? Technological advances often bring disproportionate disadvantages to farmers with moderate and small-scale farms. This consideration of justice applies with force in third world countries. Another dimension of this issue of social and economic consequences has to do with predicted impacts on the structure of agriculture. One prospect is increased concentration of economic power in the large chemical firms that invest in genetically contrived herbicide resistant crops, firms such as DuPont and Monsanto. Will this new technology strengthen their hold over the industry eventuating in inflated prices that farmers have to pay for seeds and chemicals and ultimately in higher prices for consumers (Comstock 1989, p. 265)?

For better estimates of consequences, further scientific investigation is needed. Adverse effects can be acceptable in some circumstances, when they are viewed in light of broader societal goals, the benefits that accrue, and the distribution of harms and benefits. A burden of justification falls on those who would introduce innovations bringing foreseeable adverse effects; they must show that the costs are necessary and outweighed by the benefits.

Animals

For enhancing livestock production, the means are to be better diagnostic products, vaccines, growth promotors, and manipulation of the animal genome in order to bring out desired traits. Genetically manufactured vaccines and growth hormones are already in use. The section that follows will look at a growth promotor and transgenic animals.

Consider bovine growth hormone (bGH), recently approved for use in the United States, as already noted. The genetically contrived hormone is intended to increase muscle growth and reduce fat production without compromising nutritional value (Comstock 1988, p. 38). Studies evaluating the use of bGH indicate that in certain climates, with proper management, there is an increase in milk production and feed efficiency (Comstock 1988, p. 38). This means that some farmers will be able to produce more milk from fewer cows while using less labor. In dairy operations with large herds, farmers can remove less productive cows, increase the feed of the remaining ones, and get the same amount of milk (Comstock 1988, p. 36). As farmers save costs, consumers, especially poorer consumers, are expected to benefit from lowered prices.[5]

Members of the public raise questions about the quality and safety of milk produced with the use of bGH. Where there is an overproduction of milk, as in the state of Wisconsin in the United States, dairy owners and cattle farmers fear losses from larger surpluses, consequent dropping of prices, and further reduction of dairy farms, especially small and moderate-size farms. In 1986 in Wisconsin, farm and environmental organizations, including the Wisconsin Farmers Union and the Secretary of State of Wisconsin, formed a coalition in opposition to the use of bGH. Two ethical concerns emerged in their opposition effort. One is that the use of bGH constitutes 'inhumane' treatment of cows. The other is that the use of bGH threatens to displace a disproportionate number of disadvantaged farmers. The claim is that the impact will not be random but will be felt primarily by small and medium sized farmers in the later stages of their careers, those with small herds or high debt loads, and without highly mechanized and intensively managed operations (Comstock 1988, p. 37).

We must bear in mind that both the risks of inhumane treatment of animals and the disproportionate losses to already disadvantaged farmers are risks that are projected. In studies so far, when low dosages are carefully administered within one lactation cycle, animals do not seem to be adversely affected. The treatment under these test conditions seems no more inhumane than many other practices that are characteristic in modern dairy operations. However, in light of the rewards from administering the hormone more intensively, it is unlikely that all farmers will use bGH uniformly in the controlled style of university researchers. And we need to know more about how animals fare over the longer term, through repeated lactations.

When considering the displacement of labor as a result of new inventions, we have to be careful to target concerns appropriately. The introduction of new technologies always puts some workers out of business. There are pains for the displaced and societal costs involved,

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5 This entire discussion of bGH relies heavily on Gary Comstock 1988.

but sometimes these are acceptable when they are outweighed by the social benefits. We are appropriately concerned when new technologies displace workers unnecessarily, arbitrarily, unfairly, or without any redeeming social benefits.

Among those who study the decrease in small and moderate-size dairy farms, there is debate about the contribution that the use of bGH would make to that decline. Some have urged that bGH is 'size-neutral', that it can be used by farmers whether they have 'ten cows or a thousand'. Other analysts counter that even though the cost per dosage may be low, cost-effectiveness in using this product will depend upon the number of cows and upon significant managerial expertise (forage testing, ration balancing, and the like). That expertise tends to be associated with large-scale farming.[6]

Elimination of farmers with small to moderate holdings would not be arbitrary. But it is not clear whether it is necessary or whether the social benefits would outweigh the losses. It would be unjust if the costs of introducing bGH were born disproportionately by already disadvantaged farmers. When bGH is introduced to increase production where there is already an over-supply, the harms to farmers with small and moderate-size farms are harder to justify. Gary Comstock, a philosopher who has studied these debates and the associated uncertainties, suggests that for these problems we need the notion of 'potential future injustices'. The increasingly sophisticated studies of relevant economic impacts by social scientists should be examined in the light of this concept. For, as Comstock points out, if we have the power to prevent an injustice before the fact it is surely better than trying to remedy it after the fact (Comstock 1988, p. 42).

The creation of transgenic animals and fish deserves particular attention. Transgenic creatures are creatures which are fashioned by inserting into the creature's DNA a gene from an animal with which the transgenic creature's mother could not have bred naturally. The mouse has turned out to be the animal favored for these modifications. A great majority of transgenic animals are mice with genes taken from many different species, including humans (Comstock 1992, p. 3). The primary purpose for making transgenic mice is to improve medical understanding. Genetically fashioned creatures in agriculture include

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[6] This paragraph relies on an extended discussion in Comstock 1988, pp. 39-43.

creation of transgenic livestock is the desire to improve food production.

Some concerns that arise are familiar from the discussion about plants. In the eyes of many, to create transgenic creatures is to make artifacts of animals. Many observers fear a consequent and parallel modification of our perspectives on ourselves and other living creatures. The prospect is the engendering of a more casual attitude toward treating animals and humans as commodities. This is a concern that requires careful and sustained consideration. To make this concern compelling, it is necessary to articulate what it is about the creation of transgenic animals that goes beyond our already extensive manipulation and commodification of other creatures and human tissues and organs.

Allied to and sometimes driving the worries about creating transgenic animals is the concern referred to earlier, that there could be a slide toward genetic experimentation with human beings. Some envision the resurgence of eugenics equipped with more powerful tools and therefore more dangerous than in the past. These concerns have also been fueled by the project to map the human genome, but they take us beyond the scope of this paper which concentrates on agriculture.

Fears about harms from propagation of new creatures which can breed with existing species in an uncontained environment apply especially to transgenic fish. The farming of fish generates similar concerns, and problems in some places, and may provide information useful for anticipating harms from transgenic fish.

An important ethical concern relates to the suffering of animals produced as end-products and in the course of experimentation in medicine and agriculture. It is not evident that the new techniques of biotechnology introduce new ethical issues relating to the proper treatment of animals and the suffering of animals in experimentation. Rather, they seem to raise ethical issues in a new context. The question is whether we should create new tragic circumstances, bringing into existence animals that are to suffer in particular ways. The creation of transgenic animals may serve to kindle interest in ethical considerations regarding limits on experimentation with animals. Interestingly, sustained attention in recent years to limits on experimentation with humans may yield principles for defining boundaries on experimentation with animals. Over the last few decades, we have been identifying and putting into place constraints on experimentation with humans, for example, the should be the ethical constraints on manipulation of animals and how these are related to constraints on experimentation with humans. In the United States, federal regulations relating to the use of animals in research and the mandated creation of Animal Care and Use Committees in research institutions have made some progress in defining limits on experimentation with animals.

One approach to carrying over constraints from human experimentation to animals is offered by Gary Comstock (1992). He has tried to state what are the most fundamental prohibitions on experimentation with humans and to find a basis for transfer to some animals. This strategy requires that we first identify and make cogent the fundamental constraints on experimentation with humans. Next one shows that sentience and the possession of interests are the characteristics of animals that count for imposing similar ethical constraints on animal experimentation. It is then necessary to assess animals and fish to see whether they have these characteristics. Here is an area in which there might be further illumination from more concerted discussion which brings together scientists, physicians and veterinarians, ethics specialists, people from the various sectors of the agriculture industry, and members of the public.

Some have suggested that the intentional introduction of foreign plants and animals into the United States is a good model for predicting potential problems from introducing genetically modified organisms (Pimentel et al 1989, p. 608). If that is our model, we should be alerted to proceed with caution. Serious problems have resulted from introducing what were thought of as beneficial organisms. We need to consider that 11 of the 18 most serious weeds of the world are crops in other regions and notice that there are genetic similarities between many crops and weeds (Colwell et al 1985). Moreover, nine out of a total of twenty species of domestic animals introduced in the United States have become serious environmental pests (Pimentel et al 1989, p. 608). Though the foregoing model is debated, we have seen other grounds for proceeding with caution.

Almost all the harms surveyed are projected in hypothetical scenarios. Their hypothetical character forces us to recognize the very significant uncertainties associated with new genetic modification options in agriculture. Dealing with uncertainties demands that scientists and others are sensitive to ethical as well as technical aspects of situations featuring unknowns. The challenge is to make responsible judgements and recommendations where technical knowledge falls far short of being dispositive.

Responsibilities of Scientists

Those who design and carry out the research and implementation using the new techniques play a major role in generating products and processes that they agree will have significant impacts. It may be a loose use of the term 'scientist' to refer to all these agents as scientists, but it is convenient, and all are required to meet an appropriate standard of care. Scientists must, therefore, confront their responsibilities for the implications and consequences of their research and for the education of their students in their responsibilities as researchers.

The directions that scientists in biotechnology chose to pursue in their work help to determine agricultural practices and products. Research is, of course, driven by a number of factors; important among them are the interests and requirements of the public institutions and private corporations that provide the funding. But scientists do not passively respond to client demands. From social studies of science, we have learned that determination of the direction of research is an outcome of processes of negotiation, persuasion, and coercion (Busch et al 1991, p. 52). 'Scientists contribute to the scientific agenda-setting process and to the determination of products that emerge from scientific research,' (Busch et al 1991, p. 51). In the end, scientists have to make their own assessments of the relevance and feasibility of a line of research. Moreover, researchers control the supply of research when they are the only ones who fully understand how research can be brought to bear to respond to demands of clients (Busch et al 1991, p. 52).

Scientists, therefore, have some latitude for defining the research even in large, hierarchical organizations. As a first step, they have to become conscious of the part they play in producing certain knowledge and products and the uses to which they are put. It may be especially difficult for scientists in biotechnology to step back and reflect as required. That is because enormous amounts are made available for their efforts and they receive strong encouragement to move forward from government agencies and private companies. Moreover, when molecular genetics and plant breeding came together a little more than a decade ago, they attracted new players into the system of agricultural research and development. These include pharmaceutical and chemical companies, who, with their recently acquired seed companies, have become quite powerful agents. And they, like any clients with more wealth, power, status, and even ability to articulate their demands, attract researchers (Busch et al 1991, p. 54). The harnessing of research in biotechnology to the pursuit of corporate profits and market share adds to the difficulty, and the need, for scientists in companies and outside to be oriented toward socially and environmentally responsible biotechnology development.

In spite of the difficulties, scientists have to learn to view their work in the context of the values and goals that affect it and the ways it affects society. And they have to accept responsibility for contributing to foreseeable outcomes beyond the laboratory and the company. More self-consciousness, for example, about their role in creating technologies with consequences for the structure of the agriculture industry might have an impact on their work. It could be a stimulus to deriving scale-neutral agricultural products.

Scientists need to become attuned as well to the other ethical concerns identified above. These other concerns include attitudes of reverence toward other creatures and humans, the safety of the products for humans and livestock, ecological consequences, impacts on the environment, ethical constraints on experimentation with animals, and other socio-economic consequences, including impacts on third world countries. Scientists should not be contributing heedlessly to developments we might all eventually wish had been approached with more reflection and care.

We have examples of scientists, who, in contrast to Charles Hess quoted earlier, propose that we give ethical issues appropriate attention. Rita Colwell, who is President of the AAAS for 1995 and also President of the Biotechnology Institute of the University of Maryland, presented one of the leading addresses at the 1993 National Forum of Sigma Xi, the scientific honor society in the United States. Colwell identified some of the issues I have discussed and called for further attention to these ethical concerns (Sigma Xi Proceedings 1993, pp. 140-148).

What are some of the things that scientists can do to meet the expected standard of care? They can, as Jeffrey Burkhardt suggests, address the benefits and risks more openly.[7] They need to give more candid accounts to decision makers and the public about the dangers as well as the promises of the new biotechnologies. Instead of sidestepping critics, they can discuss and clarify what they know and indicate the limits of their knowledge. Within companies, they should not assume that there is an imperative to pursue any development that promises an increase in profits and market share. They have to take other social goods and goals into account.

I have emphasized uncertainties that are associated with the new biotechnologies; they require special attention from scientists. Some observers have contended that the management of uncertainty is critical to getting anything positive from biotechnology.[8] To manage the uncertainties in a disciplined way requires acknowledgement of some of the special difficulties in this area. First is the scanty knowledge base for anticipating consequences of using products of genetic modification on a very large scale in agricultural practice. We have limited experience on which to conjure up the widest possible range of unintended outcomes for investigation. Second, the knowledge required is quite distant from that of the molecular biologists who achieved control in the laboratory. These other areas of research have not been funded as generously. The major perceived risk with regard to crop plants, for example, is that they may turn out to be invasive and to overwhelm important crop plants and natural environments (Fincham and Ravetz 1991, p. 125). To learn how likely that is in specific cases and to assess the ecological and agronomic damage that might result, we need the help of biologists who study the relevant species and those who study genetic variation in relation to ecology (Fincham and Ravetz 1991, p. 125). Third, new kinds of endeavors different from traditional laboratory science are required. The development by scientists of routines for systematically considering uncertainties and for communicating about them, and for long-term monitoring is needed. An exceptional readiness on the part of scientists to make information public and clear is essential.

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7 For a useful discussion of this issue and of the socio-economic consequences see Burkhardt 1991.

8 This is a point made in a very useful introduction to ethical and technical dimensions of managing uncertainties in biotechnology in Fincham and Ravetz, pp. 29-142.

To conclude, neither blanket, undiscriminating discouragement nor across-the board promotion of research or commercialization programs is a desirable posture. The various players in this arena, scientists, universities, components of the agricultural industry, interest groups, the lay public, and government all have roles in shaping future developments. Moral responsibility in a sense articulated by the philosopher John Ladd applies to members of all these constituencies. Moral responsibility in this sense means that all have to look out for the impact of what they do on the welfare of others. Doubtless, some forms of legal control are needed. Yet, the high stakes in the outcomes of further developments require sustained attention to ethical issues – and caution.

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