COMMENTARY

Genetic Engineering, Welfare, and Accountability

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Implications of genetic engineering for animal welfare are changing rapidly and need to be reviewed regularly. They include the welfare problems associated with techniques used to achieve genetic changes, which are similar to problems of other experimental approaches; these should be considered carefully, especially where techniques are used on a routine basis. When it comes to the genetic modifications themselves, some are detrimental to welfare, some are neutral, and some are beneficial; these results include direct effects of the intended change, side effects, and indirect effects. Currently, the two main applications are modification of farm animals for biomedical products—which appears to be largely neutral for welfare—and modification of mice as models for human disease, which results in suffering, often severe suffering. Beneficial applications are rare and still experimental or theoretical. The situation is similar with regard to the use of recombinant hormones and viruses; use of recombinant vaccines has potential for improving welfare, but may raise other ethical problems.

Although few, if any, of these concerns are specific to genetic engineering, various factors combine to suggest that particular safeguards are needed in this field. These include the facts that changes can be produced rapidly and repeatedly, and that one of the driving forces behind genetic engineering is commercial exploitation of technology. In general, ethical evaluation still is done on a case-by-case basis, using the limited criteria seen as directly relevant to each case, rather than on a broader framework. There also is little public accountability, whereby the public can have confidence that such evaluation is being carried out properly. Calls for advisory "watchdog" committees to consider ethical questions on the use of animals are endorsed by this article. Furthermore, it is essential for public confidence in the safeguarding of animal welfare that the procedures of such committees should be well-publicized.

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Work on genetic engineering is increasing exponentially (Cameron, Harvey, & Onions, 1994; Pursel & Rexroad, 1993; Robinson & McEvoy, 1993; Soulsby, 1997), and ethical concerns need to be considered carefully and repeatedly, because scientific developments are so rapid that their implications change on a time scale of months rather than years. This article is concerned mainly with implications for animal welfare (a term that I use synonymously with "well-being"). Some of the conclusions will have general relevance to the ethics of genetic engineering, and these conclusions will be compared to those of previous reviews of the field, but it would be beyond the scope of the article to review comprehensively the methods or justification for all work in progress in this expanding field.

Most ethical evaluations have considered the broader field of biotechnology (Grandin, 1991; Mepham, 1993; Morton, James, & Roberts, 1993). Two particularly systematic evaluations may illustrate this: a workshop on "Biotechnology and Animal Welfare," financed by the Organization for Economic Cooperation and Development (Raichon, Demeyer, Blokhuis, & Wierenga, 1993), and a committee set up by the U.K. Government to consider "Ethical Implications of Emerging Technologies in the Breeding of Farm Animals" (Banner Committee, 1995). The Banner Committee listed a number of techniques beyond the scope of this review—artificial insemination, superovulation and synchronization of oestrus, embryo transfer, in vitro fertilization, and semen and embryo sexing—as well as cloning and genetic modification.

There are two points to make here about the drawing of boundaries. First, although the emphasis is on new techniques, we should not assume that the status quo is an ethically acceptable or neutral ground. Indeed, there is no status quo—selective breeding continues on most of the animals with which we are concerned, and welfare problems have resulted and continue to result from the increasingly sophisticated methods used. Examples of such welfare issues in farm animals are the physical problems associated with rapid growth in broilers and turkeys, the hunger and frustration of feeding behavior caused by food restriction of broiler parents and sows, and the calving difficulties of double-muscled cattle. The ethics of such "traditional" methods are increasingly called into question. Second, however, concern over new breeding technologies primarily is caused by the fact that such effects may be more rapid and intense than ever before. In particular, genetic modification has vastly more potential than do other techniques to produce sudden change in characteristics relevant to welfare. It is more akin to mutation than to recombination of genes already present. For this reason, this article will concentrate on the effects of genetic modification and only consider other techniques where necessary.

Objection is sometimes made to the term "genetic engineering," because "engineering" is not an accurate description of the procedure. However, "genetic modification" does not convey the extent of manipulation involved (as distinct from "selective breeding," for example). It also applies more to the result than to the attempt (which may be unsuccessful). The two terms will be used here as alternatives.
This article concentrates on genetic modification of animals, as distinct from modification of hormones and vaccines that are then used on animals, although it will also mention the latter where relevant. Some work on genetic modification has relatively little effect on animal welfare. Other work has the potential for improving some aspects of welfare. Some, however, have deleterious effects; some of these problems may decrease as processes are refined from the experimental stage to the stage of exploitation, but others may increase as processes are used on a larger scale. I will start by considering the manipulation involved in achieving genetic modification.

TECHNIQUES

The procedures involved in genetic engineering can themselves cause welfare problems irrespective of the nature of the intended modification, including problems for animals kept in reserve but not used and those on whom the techniques are unsuccessful. Some of these problems are associated with husbandry and handling and are similar to those of any other manipulative experimental work. They can be divided into three categories that act separately and in combination: human contact (including unpredictability), social conditions (particularly isolation), and physical conditions (especially barren surroundings and diets that can be consumed rapidly). In some countries, such problems are being considered more now than in the past, under the general licensing procedures for experimental work, but considerable room for improvement remains (Appleby, 1995). One particularly promising finding with potential to reduce the ill effects of forcible restraint in many species is that animals can be trained to enter restraining devices—voluntarily and repeatedly—for procedures (Grandin, 1986, 1989), including blood withdrawal (and, hence, potentially also for injection of anaesthetic).

As noted, this field is constantly changing. However, the main techniques currently used are pronuclear injection, retroviral infection, and introduction of embryonic stem cells in blastocysts. These techniques involve a number of procedures on a number of animals. For example, Hubrecht (1995) reported the following welfare issues associated with pronuclear injection in mice: hormone injection (to stimulate superovulation), mating (while still only 3 to 4 weeks old) and euthanasia of mother (to obtain the fertilized eggs, into which DNA is then injected), sterilization of males (who mate with foster mothers to produce pseudopregnancy), insertion of embryos into foster mothers (done under anaesthetic), and mortality of offspring and ear punching or tail tip removal of offspring (to distinguish transgenics). Other techniques, including cloning, produce and copy genetically modified organisms (Wilmut, Schnieke, McWhir, Kind, & Campbell, 1997) and produce embryos by transferring the nucleus of one cell into another without a nucleus. Embryos resulting from nuclear transfer have a high rate of mortality, and at least some have been unusually large, so there may be welfare problems for both the offspring and the mother around the time of birth.
With some applications, techniques are only used a limited number of times, because once genetically modified lines are established, they breed true. With others—for example, research into embryonic development using transgenic mutants (McNeish, Scott, & Potter, 1988)—techniques are used repeatedly. With such routine techniques it is important that the precise methods and their implications for welfare should not be taken for granted.

For some applications in which the changes produced are themselves neutral for welfare, the effects of techniques may be the most important welfare consideration. None is specific to genetic engineering, so in this respect they are not a cause for special concern. However, this conclusion must be considered against a background in which the justification of all animal experimentation is increasingly questioned, with growing pressure for the three “Rs” of reduction, refinement, and replacement.

EFFECTS OF GENETIC MODIFICATION

If genetic modification is successful, it will result in changes to the physiology and perhaps the physical structure of an animal. Many of these changes will have direct implications for welfare—intended or unintended. Modification is likely to have indirect effects, with the animal being treated in ways that are different from normal husbandry. In this section I consider the types of effects that are possible; in the next section I discuss the extent to which they actually occur.

Direct

No effects. Some modifications appear to have no direct implications for welfare. An example is transgenic sheep who have the gene for human α-1-antitrypsin (Carver et al., 1993), a protein of medical value for treating emphysema. The gene is expressed only in the lactating mammary gland, and the protein is expressed in the milk. No ill effects are apparent, although complete verification is still in progress (Hughes, Hughes, Waddington, & Appleby, 1996).

Planned effects. Some changes may be described as specifically intended to impact welfare. The main potential positive effect considered is increased disease resistance in farm animals, such as genetic engineering of antibiotics and vaccines to improve efficacy and specificity (Robinson & McEvoy, 1993). Benefits to welfare potentially could include measures to reduce or prevent other specific welfare problems, such as leg disorders in turkeys. However, the only improvements to welfare likely to be implemented on a voluntary basis are profitable ones.
Intentional negative effects on welfare exist in cases in which transgenics are used to study disease, particularly as models for similar conditions in humans. Mice are most commonly used, for example, with increased susceptibility to cancer (Cameron et al., 1994); animals used as models include the so-called Oncomouse. But livestock such as pigs also are studied (Petters, 1994). The appropriateness of the model is the major issue (Poole, 1995). Welfare problems also are integral to the application of genetic engineering to pest control.

**Effects of other changes.** Other modifications have effects on welfare that cannot be considered side effects because they are the direct result of the intended change. Transgenics, in which normal immunology or development is disrupted and then studied for insight into the normal processes, come into this category. For example, the Legless mouse, used in embryological and genetic research, has major limb and craniofacial abnormalities and dies within 24 hours of birth (McNeish et al., 1988).

This category also would include production of pharmaceuticals in the milk of farm animals resulting in deleterious effects, or genetic engineering to increase production (analogous to selective breeding causing rapid growth and double muscling). A relevant comparison, not involving genetic modification of animals, is the use of genetically synthesized bovine somatotropin (BST) to enhance the milk production of dairy cows. This extends the already prolonged energy deficit in high-yielding cows, which is neutral for welfare if other aspects of management are good, but deleterious (e.g., resulting in increased mastitis) if they are not (Dell’Orto et al., 1993; Grandin, 1991; Willeberg, 1993).

**Side effects.** These have probably received more attention than any other effects. Thus the “Beltsville transgenic pig” with enhanced growth hormone production had severe arthritis (Pursel et al., 1989), and sheep transgenic for growth hormone genes never attained puberty and died before 1 year of age (Nancarrow et al., 1991). Robinson and McEvoy (1993) stated that, “In many instances, the site and time of expression of the transferred genes still lack the degree of specificity required and lead to deleterious side effects” (p. 348).

Work continues to reduce these side effects, but there may be some that cannot be prevented; an analogy from traditional breeding is the increased fearfulness of double-muscled cattle (Holmes, Robinson, & Ashmore, 1972). Loew (1994) made the trenchant point that in new work, “unanticipated results, like those ... described in swine by Pursel et al. (1989), are, as it were, to be anticipated” (p. 4). In the case of Loew’s specific example, however, the results of Pursel et al. should have been anticipated. It was already known that high concentrations of growth hormone in pigs (achieved by injection) caused liver and kidney degeneration, oedema, and arthritis (Machlin, 1972).
Finally, some effects arise first as side effects but then become subjects for study. An example of this are Legless mice (McNeish et al., 1988).

Indirect

**Husbandry and related effects.** As an indirect result of genetic engineering, many animals are kept or treated in ways that have other implications for welfare. Transgenics are valuable and their health tends to be looked after particularly well, although as with other experimental animals they are often kept in isolation. In addition, because of the importance of hygiene, transgenics usually are kept in barren conditions, although this may not be necessary (Appleby, 1995). By contrast, one concern that has been raised about the work on disease resistance is that if such resistance is achieved, animals may be stocked at higher densities (Fox, 1992). This also would apply to animals treated with vaccines improved by genetic engineering.

Another indirect effect resulting from the synthesis of growth hormones by genetic engineering is increased frequency of injections. In addition to the injections themselves, which may be daily, there also are problems with injection site abscesses (Effertz, 1990; Straw, 1986). To alleviate injection site distress, implants sometimes are used. But while there is work in progress to develop a long-lasting implant, the existing implants only last 2 weeks and have to be injected with a thick needle. These problems have been used to argue in favor of genetic modification of cattle as a better method of raising BST levels, but this argument ignores the harmful long-term effects of BST discussed previously, which are associated with poor management, and the side effects of high growth hormone during early development—still unsolved in any species.

Numbers of animals kept for different uses will change as a consequence of genetic engineering. Some uses will be more efficient and need fewer animals, whereas other new uses will increase numbers. The number of animals used in transgenic research currently is increasing rapidly. There is no simple correlation between the number of animals involved and the importance of their welfare, but there probably is a consensus that some association does exist.

**Effects on attitudes.** Modification of animals is likely to affect attitudes toward them and therefore other aspects of their treatment; it also may alter attitudes toward and treatment of other groups of animals. This applies both to people who have direct influence over animals (such as breeders and producers) and to the public. Attitudes may be affected by new uses of animals (e.g., as models for human disease or as suppliers of organs for xenografting) and by changes in their legal status (such as whether particular types of animal can be patented).
CATEGORIES OF ANIMALS

Farm Animals Used for Agricultural Products

To date, the main attempts to change production characteristics of farm animals by genetic engineering have been insertion into pigs and sheep of genes for growth hormone and insertion into salmon of genes that activate growth hormone production (Powers, Gonzalez-Villasenor, Zhang, Chen, & Dunham, 1991). Salmon modified in this way are now undergoing commercial trials. Jamieson and Seidel (1992) suggested that one possible benefit of biotechnology would be more efficient production leading to the use of fewer animals. In fact, there seems to have been little consideration of whether such animals growing faster or further would be more efficient economically in terms of food conversion. Smith, Meuwissen and Gibson (1987) pointed out that transgenes would need to improve economic performance by 5% to 10% to be useful, because they would take several generations to introduce and, meanwhile, the performance of other stock could be improved by normal breeding methods.

Attempts to increase growth have had gross side effects, as described previously, but investigations are continuing into whether the worst of these problems can be prevented. For example, it may be possible to have a gene present but “silent” during early development, then expressed later. Grandin (1991, citing Rudman et al., 1990) points out that in elderly humans, injection of growth hormone may have positive effects, increasing lean body mass, decreasing fat, and increasing bone density.

Cloning by nuclear transfer (Wilmut et al., 1997) may be used in the future to speed the process of introducing transgenes into breeding stock. It also may be used to copy particularly productive animals. This might seem to give a relative advantage for welfare, because although cloning is associated with welfare problems, these are probably less severe than those of other currently available procedures such as manipulation of growth hormone. However, this does not mean that cloning is justifiable. Furthermore, improvements in other lines will continue, so such clones are unlikely to be the most productive animals for long.

A cause for concern is that if future work produces changes with side effects less obviously unacceptable—similar to those that have been produced by selective breeding—there will be commercial pressure for these to be tolerated. This is the case with the use of BST to enhance milk production of dairy cows, which is practiced in the United States but banned in the European Community. In its effects on welfare (neutral with good management, deleterious with poor), this practice is comparable to other management techniques (such as housing design and feeding regimes) intended to increase the profitability of production. This does not justify it, of course. The question also has been raised as to whether these other techniques are justified (Webster, 1994).
Some changes in production characteristics being investigated or sought are likely to be neutral or positive for welfare. Work in the Netherlands has produced Herman the transgenic bull, whose female progeny are intended to produce milk containing the human protein lactoferrin. This would have the dual effect of making it more suitable for human consumption (particularly for babies and patients on antibiotics) and reducing the risk of mastitis in the cows (Krimpenfort et al., 1991; van Reenen & Blokhuis, 1993). Another area of interest is the possibility of producing hens and cows who only have female offspring—for egg production and milk production, respectively—obviating the need for killing male chicks or rearing unwanted male calves.

Optimism about the prospects for increasing disease resistance in farm animals (Robinson & McEvoy, 1993) appears to have abated recently. Some of the approaches being investigated were unsuccessful or restricted to very specific experimental circumstances. In addition, the technology mostly concerns single genes, whereas the pathogens concerned are complex, and it is increasingly recognized that any increase in resistance might only be temporary given the likelihood of change in the pathogens (J. Clark, personal communication, 1996). There are examples of long-term resistance of certain species to certain diseases—for example, N’dama cattle to trypanosomiasis (Murray et al., 1991)—suggesting that if multiple gene technology becomes possible in the future, some permanent change may be achieved.

However, there are other ethical issues here. Some of the diseases prevalent in current production systems have been exacerbated by intensive selection for production and by the techniques used in those systems, such as mastitis in dairy cows. Unless genetic modification of dairy cows for resistance to mastitis (McEvoy, Robinson, & Sreenan, 1992) reduced incidence of the disease to what it was before the increased production, it could be argued that it would be more appropriate to reverse the changes that have caused the problem. This is particularly true if there are other ill effects of increased production on welfare that these techniques help to perpetuate. Similarly, modifying the animals to prevent disease may increase the tendency to keep animals in poor conditions (such as high stocking density, as mentioned above), having other disadvantages for their welfare.

Farm Animals Used for Biomedical Products

Of all areas of work on genetic engineering, this one currently has the most commercial potential. As with animal production, the welfare issues are not wholly new: Some farm animals already are used for biomedical products with welfare problems resulting. For example, in North America, many thousands of mares, whose urine is used to produce estrogen, are kept in stalls too small for them to turn around.
The area of work that has received most attention is modification of sheep or goats to produce pharmaceuticals in their milk for human medical use, which will be cheaper and safer than those from alternative sources (such as human blood). The changes being made—or at least, those being publicized—appear to be neutral for welfare. Loew (1994) asked, “What possible harm to man or beast can arise from a minor change in the composition of goat’s milk such that it becomes a cost-effective source of a valuable pharmaceutical?” (p. 4). Yet vigilance is necessary, because certain genes may not be expressed solely in the mammary gland and because the milk–blood barrier is not complete; therefore, some compounds can be expected to affect the lactating female. There is interest in the use of this approach to obtain erythropoietin, which regulates erythrocyte production and can be used to treat renal disease (Eschbach, Egrie, Downing, Browne, & Adamson, 1987). Yet human or monkey erythropoietin has severe or fatal effects when systemic in mice (Semenza, Traystman, Gearhart, & Antonarakis, 1989; Villeval, Metcalf, & Johnson, 1992). Even if expression of the regulating gene is restricted to lactation, it cannot be assumed that the compound will not “leak back” into the blood.

Another major area of activity is the modification of pigs to allow their organs—heart, kidney, or pancreas—to be transplanted into humans (Fabre, 1995; McCurry et al., 1995). This is known as xenografting or xenotransplantation. One approach is insertion of a gene for human complement regulators into the pig genome; this gene will label the surface of pig cells so that hyperacute rejection does not occur when they are transplanted (White & Wallwork, 1993). Although there are other ethical issues involved (Nuffield Council on Bioethics, 1996), there is no reason to believe that the welfare of a pig with such a gene will be compromised in any direct way.

As with farm animals used for agricultural products, cloning may be used to copy animals who are particularly appropriate for pharmaceutical production or xenotransplantation. Again, this is likely to involve welfare problems, but these may be less severe than those caused by repetition of the procedures that are otherwise necessary to produce such animals.

Laboratory Animals

Most lines of research still are at the exploratory stage, so in that sense, all animals involved are “laboratory animals,” but the term is used here to mean animals—primarily mice—on whom work is being done without immediate application in that species. Indeed, much of this work is not applied, but pure science, although potential application may still be given as partial justification, particularly if there are implications for their welfare.

Many procedures carried out on laboratory animals are disturbing. As indicated previously, some involve intentional production of major welfare problems, as in the Oncomouse, and others require tolerance of such problems, as with the Legless mouse. As one other illustration, the abstract of one paper (Villeval et al., 1992) states that:
Murine bone marrow cells, infected with a retroviral vector ... carrying a monkey erythropoietin cDNA, were transplanted into lethally irradiated syngeneic recipients to study the effect of erythropoietin production by hemopoietic cells.... In transplanted mice, the hematocrit was elevated (90 ± 5%) and the mice died at a mean of 71 days after transplantation. (p. 107)

The issues are complex: One point that was made in the public discussion of the Oncomouse (in relation to whether it could be patented) was that in a particular study, use of such a strain would make it possible to use considerably fewer experimental animals. On the other hand, the increasing availability of varied transgenics is rapidly increasing the number of experiments and the number of experimental animals experiencing severe suffering (Day, 1995).

A major intention in the production of such animals is prevention or cure of human or animal diseases, but there is necessarily variation in the applicability of such work. Thus, Cameron et al. (1994) list the following areas of investigation: gene regulation and development, host–pathogen interactions, immunology research, and oncology research. Of these, the first is probably further from application than the others, yet mice studied for this reason probably suffer just as much. This issue becomes relevant when regulatory bodies decide whether particular research proposals are to be allowed. Laws in the United Kingdom and United States, for example, require consideration of both the likely effects on the animals involved and the likely benefits (Brooman & Legge, 1997). However, assessment of the balance between these is difficult. Poole (1995) pointed out that animal models of human diseases are sometimes inappropriate—even if the symptoms are similar there may be very different causes and etiology, and diseases also may exist in combinations with other pathologies that do not occur in humans.

The issue of patenting mostly has been concerned with this group of animals. Patenting of a whole animal (such as the Oncomouse) is permitted in the United States (O’Connor, 1993), but it still is being debated in the European Union, whereas patenting of DNA sequences is permitted in both places. Although patenting does not in itself confer any right to use animals or to condone suffering, it is relevant to welfare for at least three reasons. First, experiments on animals who are restricted by patenting are likely to be done in reputable laboratories, whereas those on animals not so restricted may be carried out in conditions that are less than ideal. Second, however, the patenting process is very slow; during that process, secrecy is maintained. This hinders full consideration of the ethics of the work concerned, especially open debate. Third, the question of patenting emphasizes the commercial factors involved in the exploitation of transgenics.

It is important to note that more transgenic laboratory animals are being produced and are suffering than are needed, even for the experiments being carried out, because breeders often keep animals in stock to anticipate demand. It is clear that animals should be bred only for firm orders rather than always being available.
Other Animals

Little or no work is being done on genetic modification of sporting animals, companion animals, zoo animals, wild animals, or "pests." In due course, if techniques such as improvement in disease resistance are successful in farm animals, they also may be applied in other groups.

Genetic engineering is being applied to vaccines and viruses to be used in wild animals who are dangerous or inconvenient to humans. The question of pest control is, of course, a complex one, and there may be both advantages and disadvantages for animals in new approaches. Recombinant vaccines against rabies are being used in foxes, raccoons, and skunks (Wandeler, 1991) and are beneficial to those species insofar as they reduce other control measures directed against them. On the other hand, genetic engineering is being used to introduce an immunocontraceptive effect to viruses that will then induce sterility in such pests as foxes and rabbits (Ellis, 1995). It is intended to use the myxoma virus for rabbits, which will limit disease in rabbits because many are now immune to myxomatosis and will simply become sterile.

DRIVING FORCE

One of the issues arising from this discussion is the question of why the work is being done at all. There are three main answers to this question.

First there is the scientific interest. This is a major motivation of most scientists in the field, and the main outcome so far has been an increase in scientific knowledge.

Second, there is the potential for commercial exploitation of the results. For example, changes to farming practice do not lead to increased profits for farmers in the long term because price competition continually and unevenly pares these to the minimum. Indeed, one factor contributing to the ban of BST injection by various countries was that it is likely to cause unemployment among farmers. Yet recombinant BST has been produced by commercial companies and is bought by farmers—with potential problems for the welfare of their cattle—because it gives them a short-term advantage in economic competition. Commercial interests also affect the expression of scientific interest, because this sort of work is expensive and funding—even for otherwise independent scientists—is increasingly targeted at work with commercial potential.

Third, there is perceived to be a genuine need for some areas of work. This is most clear with use of animals for biomedical products. Xenografting of hearts, for example, is being investigated partly because there are thousands of people who could benefit from heart transplants, yet there is a shortage of human hearts for transplanting. But even this line of investigation is affected by commercial factors: The financial support for the xenografting project in Cambridge, United Kingdom,
is coming from the drug companies that make the immunosuppressants, which will be needed daily after the transplant operation for the rest of a patient’s life (White, 1995). Innovators should be able to profit from their work. However, where technological advances are driven by financial incentive, there also should be a rational assessment of whether such advances are actually needed.

PUBLIC PERCEPTION

How can the public contribute to the assessment of need and justification for genetic engineering? Public attitudes are rarely focused: It takes the combination of a number of factors before there is mass interest and action, as recently seen in the United Kingdom in relation to calf transport. So the main factor that is relevant is the behavior of individuals, in two ways. One of these is the willingness of individual people to use the products.

In relation to agricultural products, it often has been pointed out that the majority of people are willfully ignorant: Most people do not know that “Farm Fresh Eggs” come from battery cages, because they do not think about it, because they do not want to think about it. Lobby groups in this area want battery eggs labeled as such and would want meat from genetically modified animals labeled as such (although it is difficult to see how such labeling could incorporate adequate, balanced information). It is likely that many people would avoid such products, although a possible counterexample is provided by genetically modified Flavr-Savr Tomatoes: When products incorporating these in the United States were labeled “Product of Genetic Engineering,” sales increased. Furthermore, a finding at a “Consensus Conference on Plant Biotechnology” in the United Kingdom (BBSRC, 1995) is instructive here: In response to questions from the media at the end of the conference, 14 of the lay panel of 16, by then quite well-educated about biotechnology, said that they would eat tomatoes that were genetically engineered. Unfortunately, they were not asked the same question at the start of the conference, but it seems probable that fewer would have held that position.

People’s willingness to buy food from genetically modified animals will be affected by various factors, including the group of animals concerned. For example, genetically modified fish may be more acceptable than mammals or birds. Perception of the animals’ welfare also will be important and will be affected by the information available.

The other way in which members of the public continue to have an important influence is in relation to safeguards. Safeguards are put in place by legislators, and legislators are influenced by public opinion. In North America and in many countries in Europe, members of the public who are concerned about animal welfare are more vocal than those who are not, joining humane societies, writing letters to the newspapers, and expressing strong views in opinion polls. This climate of opinion increases the pressure for ethical evaluation and for the control and legislation of genetic engineering, as discussed in the next two sections.
There is an increasing number of relevant books intended to be accessible to the general public (Fox, 1992; Reiss & Straughan, 1996; Rollin, 1995), but public perception will continue to be much more influenced by television and the newspapers, which vary considerably in their coverage.

ETHICAL EVALUATION

Many discussions and conferences on genetic engineering include consideration of ethics (Grandin, 1991; Jamieson & Seidel, 1992; Reiss, 1997; Thompson, 1993), particularly about implications for animal welfare. However, it sometimes seems that although concerns are noted, no action is taken on them: The dogs bark, but the caravan moves on. This impression could be created, for example, by the fact that the number of transgenic animals used each year continues to grow (Day, 1995). This raises the issue of accountability in the whole realm of genetic engineering.

Those most active in ethical evaluation of genetic engineering vary in their conclusions, from those generally opposed (Fox, 1989, 1992; Rifkin, 1985), through qualified opposition (Comstock, 1992) to qualified acceptance “informed by values of respect for animals, humans, nature, and risk and by notions of sustainability and awe at its potential” (Rollin, 1995, p. 214). What follows is inevitably a simplified version of such considerations.

There are three categories of ethical concerns about genetic engineering. First, applications have potential advantages and disadvantages to humans, consideration of which is what was meant in an earlier section by “a rational assessment of whether such advances are actually needed.” For example, the need for increased productivity of farm animals is highly questionable in developed countries (Sandøe, Holtug, & Simonsen, 1996). Production of hearts for transplantation is potentially beneficial, but it could also be argued that money should instead be spent on preventative health care. Second, many genetic modifications affect animal welfare. Third, various other issues are discussed as important in their own right. They include other consequential issues (e.g., possible effects on genetic diversity) and what are called “intrinsic objections,” (e.g., should we be manipulating animals in this way at all).

It may be argued that most or all such issues, if valid, actually fall into one or both of the first two categories. If they do not have any effect on human or animal welfare, not even a potential effect in the long term, it is difficult to imagine that they would be widely accepted as important. Rollin (1995) suggested that all cogent concerns about genetic engineering of animals come down to arguments about danger to humans, animals, or nature, although he did not discuss danger to nature in detail. Sandøe and Holtug (1993) perhaps went further in suggesting that animal welfare is the only ethically significant concern in this area, with all other concerns either being baseless or turning out really to be about animal welfare; however, the researchers may not have considered all the implications for human welfare. Others
have, though, placed more weight on intrinsic objections (Banner Committee, 1995; Reiss & Straughan, 1996). The Banner Committee, for example, rejected the idea that it is only the consequences of actions that are ethically important, in concluding that “harms of a certain degree and kind ought under no circumstances to be inflicted on an animal” (p. 1).

With respect to animal welfare, Rollin (1995) introduced the principle of conservation of welfare:

Any animals [who] are genetically engineered for human use or even for environmental benefit should be no worse off, in terms of suffering, after the new traits are introduced into the genome than the parent stock was prior to the insertion of the new genetic material. (p. 175)

Mepham (1993) took a different stance in considering together potential advantages and disadvantages to humans and animals. He provided a framework for cost–benefit analysis of the effects on the animals and on the different groups of people affected by the technology (e.g., farmers, consumers, and people in less developed countries)—although as with all cost–benefit analyses, there is no way of quantifying the relative weight to be placed on different factors. Either approach, though, brings us back to the question of how to assess effects on animals. Perhaps the most practical recommendations in this respect are those by Broom (1993). With reference to farm animals, he suggested that “carefully controlled studies using a wide range of welfare indicators are needed. These should be carried out for at least the total farm life of a breeding animal and for at least two generations.” However, Broom also pointed out that, “No such comprehensive studies … have been reported in the scientific literature to date.”

There have been concerted welfare assessments made on a lesser scale (Hughes et al., 1996; Phipps, 1989; van Reenen & Blokhuis, 1993), but too many new genetically modified organisms are being produced to do this systematically (H. Blokhuis, personal communication, August 1997). In these circumstances, the public is unlikely to have any confidence that such assessments will be applied wherever appropriate.

LEGISLATION AND CONTROL

Few of the welfare implications previously discussed are different in kind from those of other procedures such as selective breeding, so it might be argued that additional control is not needed. However, current legislation and welfare codes are not tackling existing problems successfully. For example, at a European symposium on poultry welfare, it was concluded (Appleby, Hughes, & Savory, 1994) that:
The growth rate of broilers and the concomitant food restriction of broiler breeders cause major welfare problems. These problems are getting worse with the continuing, intensive genetic selection for growth rate. Urgent consideration should be given to legislation against further selection for growth rate until or unless associated problems are solved. (p. 471)

Current legislation is likely to be even less adequate to deal with the rapid or unforeseen effects of other breeding technologies.

For adequate control of such technologies, particularly genetic modification, legislation is necessary to specify what is permitted rather than what is not. To obtain permission, proponents of a procedure should have to demonstrate one of two cases: The procedure may have no net deleterious effects on animal welfare; alternatively, benefits to humans may outweigh deleterious effects to animals (Mepham, 1993). Arguments for the latter case must be assessed by a properly constituted process such as that used by the U.K. Home Office under the Animals (Scientific Procedures) Act 1986 for licensing animal operations. Without such rigorous control, emerging breeding technologies are likely to cause more disadvantages than advantages for animal welfare.

In the United Kingdom, all genetic engineering must be done under the Animals (Scientific Procedures) Act (Hubrecht, 1995). The United Kingdom also has stringent regulations on potential release of genetically modified organisms, monitored by the Health and Safety Executive. The United States also has laws on care and use of laboratory animals, regulated by local committees. However, not all countries have similar legislation. In addition, it is unclear in the United Kingdom whether some procedures will, in due course, come to be regarded as routine rather than experimental and thus be excluded from the requirements of the Act. A major conclusion of this article is that the assessment involved in this legislation has another limitation—its low profile. There are some specific reasons for this, including the fact that animals or DNA sequences being considered may be subject to patent applications. However, this is an argument against patenting rather than for secrecy. The Banner Committee (1995) stated the position with regard to farm animals clearly when it said that

One unlooked-for consequence of the introduction of the emerging technologies can quite reasonably be anticipated—and that is the creation of public suspicion of farming, unless those who are engaged in the development and application of these technologies endeavour to be sensitive to public concerns, open to debate with interested parties and supportive of a reasonable system of regulation, provision of information and labelling. (p. 3)

It went on to recommend that “an advisory committee be created, whose remit should include a responsibility for broad ethical questions relating to current and future developments in the use of animals” (p. 3).
Such a committee was described in the press as "an ethical watchdog" (Coghlan, 1995). Similar committees already exist in several countries including the Netherlands (Brom & Schroten, 1993) and Denmark, and it is important that other countries establish committees of this nature. Rollin (1986, 1995) has long argued for such national committees with specific reference to the United States—committees supported by a major element of public involvement. At the least, it is essential for public confidence in the safeguarding of animal welfare that the procedures of such committees should be well-publicized.

CONCLUSIONS

Some genetic modifications of animals are detrimental for welfare, some are neutral, and some may be beneficial. The two main current applications are modification of farm animals for biomedical products, which appears to be largely neutral for welfare, and modification of mice as models for human disease, which results in suffering, often severe, of large numbers of animals.

Genetic modification has few effects on welfare that could not also be produced by selective breeding or other procedures. However, in no country does current legislation avoid welfare problems from selective breeding. Furthermore, the fact that changes can be produced rapidly and repeatedly by new technologies means that additional safeguards are needed. The same arguments apply to use of recombinant hormones, vaccines, and viruses.

Procedures for ethical evaluation of genetic technologies are in place in some countries, but need to be strengthened. Some countries have no such procedures, and procedures need to be established. Approaches for ethical evaluation have been proposed. Evaluation is, in general, done on a case-by-case basis and in secrecy. There is little public accountability, by which the public could have confidence that such evaluation is being carried out properly.

Calls for advisory "watchdog" committees to consider ethical questions on the use of animals are endorsed by this article. Furthermore, it is essential for public confidence in the safeguarding of animal welfare that the procedures of such committees be well-publicized.

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