

Knocking Out Pain in Livestock: Can Technology Succeed Where Morality has Stalled?

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Abstract Though the vegetarian movement sparked by Peter Singer's book *Animal Liberation* has achieved some success, there is more animal suffering caused today due to factory farming than there was when the book was originally written. In this paper, I argue that there may be a technological solution to the problem of animal suffering in intensive factory farming operations. In particular, I suggest that recent research indicates that we may be very close to, if not already at, the point where we can genetically engineer factory-farmed livestock with a reduced or completely eliminated capacity to suffer. In as much as animal suffering is the principal concern that motivates the animal welfare movement, this development should be of central interest to its adherents. Moreover, I will argue that all people concerned with animal welfare should agree that we ought to replace the animals currently used in factory farming with animals whose ability to suffer is diminished if we are able to do so.

Keywords Nonhuman animals · Animal neuroethics · Genetic engineering · Pain · Suffering · Bioethics

Introduction

Peter Singer's philosophy-infused popular book *Animal Liberation* [1] has been credited with jump-starting the animal liberation movement in the United States. Singer argued, among other things, that people have an ethical obligation to become vegetarians given the intense suffering that is caused by modern factory farming conditions. Since 1975, the animal liberation movement has been successful in many respects, with estimates that over 4.7 million people are now vegetarian [2] and many new legal restrictions in place that dictate how people may treat other animals. Nonetheless, there is inarguably more suffering today as a result of factory farming than there was when the book was written, as per capita meat consumption in the United States has risen from 190 lbs/person in 1975 to 222 lbs/person in 2007 [3, 4] and the population itself has increased.

Given that the animal liberation movement's growth has failed to outpace increases in human population and per capita meat consumption, those who are concerned with the reduction of unnecessary suffering of animals may need to consider additional approaches. In this paper, I argue that there might be a technological solution to the problem of animal suffering in intensive factory farming operations. In particular, I suggest that recent research indicates that we may be very close to, if not already at, the point where we can genetically engineer factory-farmed

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Reducing Unnecessary Suffering

Singer's argument against eating meat is often erroneously described by popular critics as an argument for "animal rights," but in actuality is based on consequentialist principles¹ [5]. In *Practical Ethics*, where he more fully develops his position, Singer argues for the principle of equal consideration of interests which states that we ought to "give equal weight in our moral deliberations to the like interests of all those affected by our actions," ([6] p. 19). As Singer suggests, one way of understanding this principle provides a good reason to adopt a utilitarian position: since each interest is treated the same regardless of *whom* the interest belongs to, a natural suggestion for determining the optimal ethical choice would be to ascertain the choice most likely to maximize the satisfaction of the interests of all those affected ([6] p. 12).² Since an interest in avoiding a life of suffering is presumably stronger than an interest in a particular gustatory preference, it follows

¹ Singer did often talk of "animal rights" in *Animal Liberation*, but as a utilitarian he is in fact committed to a position that is opposed to the existence of rights as they are commonly construed in ethics. He explicitly states this position in *Practical Ethics* [6].

² Though this is one way of interpreting the implications of the principle of equal consideration of interests, it is by no means the only way (as Singer recognizes). Kantian theories and strict animal rights theories can also endorse the principle. As David Degrazia writes, "when seen from the proper perspective, utilitarianism and animal-rights views appear far more alike than different. Crucially, both extend to animals a *principle of equal consideration*. Any such principle requires that we (in some significant way) give equal moral weight to comparable interests, regardless of who has those interests" ([8] p. 112, emphasis in original).

on this account that we should choose not to eat meat that comes from factory farms where animals endure a substantial amount of suffering.

My primary strategy in this paper will be to argue that replacing current livestock with genetically modified livestock who have a reduced capacity to suffer would lead to better consequences than maintaining the status quo: specifically, it would lead to a world in which there is much less unnecessary suffering. Hence, my argument will be directly relevant to utilitarian (or, more broadly, consequentialist) positions such as Singer's. However, as John Rawls notes, in discussing the prime theoretical competition to consequentialist theories, "deontological theories are defined as non-teleological ones, *not* as views that characterize the rightness of institutions and acts independently from their consequences. *All* ethical doctrines worth our attention take consequences into account in judging rightness. One which did not would simply be irrational, crazy," ([7] p. 30, emphasis mine).³ If we agree with this statement from Rawls, and if we think that unnecessary suffering is among the kind of consequences that need to be taken into account, then my argument should provide reasons to favor genetically engineering livestock on any ethical theory, "worth our attention." Of course, on consequentialist theories the fact that a position produces better consequences provides not just reasons but *overriding* reasons to favor that position, whereas nonconsequentialist theories might have other considerations that "trump" the fact that better consequences will be produced. Thus, I aim to show not only that genetically engineering livestock will produce a world with better consequences, but also that doing so will not introduce any new "wrongs" into the world that will be offensive to other ethical theories.

Though the following argument may initially seem counterintuitive for most people who call themselves animal welfare advocates, I will argue that anyone who thinks consequences matter in our ethical choices should take the argument very seriously and, indeed, should ultimately evaluate it based on the strength of the empirical assertions that it is based upon.

³ Thanks to an anonymous reviewer for suggesting that I include this quote.

Knocking Out Pain

Pain researchers have demonstrated, using a variety of techniques, that pain can be dissociated into at least two distinct dimensions, which correspond to activation in different areas of the brain [9–12]. The sensory dimension of pain constitutes a pain's intensity, localization, and quality (whether it is sharp, dull, burning, etc.) and is associated with activation in the primary and secondary somatosensory cortex. The affective dimension of pain in humans is equated with the unpleasantness of the pain, or "how much one *minds* the pain," and this pathway is associated most strongly with activation in the anterior cingulate cortex and the insula cortex.⁴

A 1997 study by Rainville et al. [12] demonstrated that the affective dimension of pain could be modulated independently of the sensory dimension, and that the resulting variation between the two dimensions corresponded to activation in the associated areas. A lesion to the primary somatosensory cortex in a case study by Ploner et al. [13] resulted in a patient who reported a vague feeling of unpleasantness but lacked the ability to describe the location and quality of the pain. Conversely, lesions to the anterior cingulate result in patients who claim to still feel the pain but no longer find it unpleasant ([14,15]).

Several authors have argued that the affective dimension of pain is the relevant dimension for what we would call suffering [9,16,17]. To see why one might think so, consider that patients given morphine experience similar effects as those with anterior cingulate lesions, reporting that they still feel pain but no longer mind it as much. This is consistent with

⁴ There is fMRI data that shows anterior cingulate involvement in other cognitive operations such as attention shifting and error-detection. Some have suggested that activation of the anterior cingulate during pain may merely be a result of these other operations. However, considering that the relationship between the anterior cingulate and the affective dimension of pain has been established using not only fMRI studies, but also lesion studies [14], single-cell recordings in humans that identified nociceptive-specific neurons [19], and behavioral responses to the localized injection of excitatory and inhibitory neurotransmitters [20], this suggestion is not very convincing without further support. At the very least, some story is owed by proponents of such a view about why people with lesions to the anterior cingulate report that they still feel pain but no longer mind it as much, as well as an explanation of why their story is not compatible with a view that the anterior cingulate plays a crucial role in the affective dimension of pain.

the fact that the affective pain pathway contains more opiate receptors than the sensory pathway [18]. We give patients morphine in order to prevent suffering, even though they still experience the sensory dimensions of pain. To claim that the sensory dimension of pain is part of suffering, or that the affective dimension of pain is not constitutive of suffering, is to deny the first person reports of the patients themselves.

We cannot, of course, ask nonhuman animals whether they find particular pains unpleasant. However, scientists have devised other methods for measuring the affective dimension of pain in nonhuman animals (for a more thorough discussion of how one can address the "problem of other minds," as it is known in philosophy, see recent papers by Farah [9] and Shriver [17]). One of the most common ways of measuring affective pain in nonhumans is the conditioned place preference (CPP) paradigm. On such a paradigm, animals are exposed to noxious stimuli in various conditions, and their location preferences before the exposure are compared to their preferences after exposure. For example, rats noxiously stimulated on hypersensitive paws while in a dark chamber will begin to develop a preference for a light chamber. However, when one lesions the anterior cingulate [21] or administers morphine to the rats [22], their preferences no longer change as a result of the noxious stimuli, even though the rats will still withdraw their paws during the stimulation. In a similar but slightly different CPP task, Johansen and Fields [20] found that microinjections of excitatory neurotransmitters into the anterior cingulate caused rats to develop an aversion for a particular location in the absence of noxious stimulation, but microinjection of inhibitory neurotransmitters into the anterior cingulate prevented the rats from developing an aversion even in the presence of noxious stimulation. Thus, similar dissociations in the pain pathways can be found in nonhuman animals as in humans.

In the last several years, scientists have made remarkable progress in starting to identify the mechanisms underlying the affective dimension of pain. Min Zhuo and colleagues have been at the forefront of identifying the cellular mechanisms of pain-related activity in the anterior cingulate. Long-term potentiation (LTP) is a process whereby the connections between two neurons are strengthened as a result of synchronized activity. Zhuo and colleagues have

found that injury and peripheral noxious stimulation can produce LTP in neurons in cortical layers II/III of the anterior cingulate [23] that mirrors LTP evoked by direct stimulation of brain slices of the cingulate [24]. They have identified several key features that are necessary for LTP to occur in the cingulate, including the presence of extracellular-regulated kinases [25], the mGluR1 subreceptor [26], and the presence of adenylyl cyclases AC1 and AC8 that respond to Ca^{2+} and lead to the production of the important secondary messenger cAMP [27]. Zhuo and colleagues have furthermore found that blocking these processes leave acute pain intact while reducing persistent and/or chronic pain symptoms. Thus, down to particular molecules in specific cell layers of a brain region, Zhuo and colleagues have identified crucial features underlying the affective dimension of pain.

This leads to the first experiment that suggests a possible genetic manipulation that would modulate the affective dimension of pain while leaving the sensory dimension relatively intact. Feng Wei et al. [27] were able to genetically knock out the enzymes AC1 and AC8 that play an important role in the cAMP pathway crucial for LTP in the anterior cingulate. Mice lacking these enzymes still showed normal acute responses to pain in tests such as the hot-plate test (where the temperature of the floor is gradually increased until a rat licks its paw, vocalizes, or attempts to escape, and the time before this occurs is measured), the tail-flick test (where temperature is increased until the rat flicks its tail), and mechanical withdrawal thresholds. However, in a formalin test, where formalin is injected into a paw and licking behavior is measured over the course of the next few hours, the mice showed greatly reduced licking behavior. Thus, selectively knocking out AC1 and AC8 reduced persistent pain behavior. Since AC1 and AC8 are expressed in other parts of the brain, these results alone might not be thought to show that anterior cingulate activity was necessarily playing a role. Importantly, however, the authors also found that a targeted injection into the anterior cingulate of Forskolin, a chemical that aids in the production of cAMP, completely restored persistent pain behaviors in the knockout mice.

Thus, one possibility would be to create knockouts of other mammals (cows and pigs for starters) lacking the AC1 and AC8 enzymes. Interfering with the

cAMP cycle in the brain reduces the affective dimension of chronic or persistent pain, rather than pain full stop, but this would still be an improvement over current circumstances. If we could eliminate the sensitization that occurs as a result of painful or traumatic experiences, the animals would still be better off than they are now.

One might question, however, whether the formalin test is an adequate method for measuring the affective dimension of pain. Several scholars have argued that operant learning measures such as conditioned place aversion are the best measurement for the affective dimension of pain, since many other behaviors that are measured can be spinally mediated [28]. However, other researchers coming from a very different direction than Min Zhou's lab found a different genetic manipulation that also looks promising. Zhou-Feng Chen and colleagues searched the Allen Brain Atlas to find genes that were highly expressed in the ACC but not other areas of the brain [29]. One strong candidate was the peptide P311. The researchers created knockout mice lacking the expression of P311 and found that heat and mechanical sensitivity were normal in the animals. However, they then performed a conditioned place aversion test on the animals and found that the knockouts no longer demonstrated the conditioned place aversion caused by formalin injections, in stark contrast to control rats. Thus, at first glance, it appears that knocking out P311 in mice strongly diminishes the affective dimension of pain while keeping acute responses intact.

Furthermore, P311 is likely to play a similar role in all mammals (Chen, personal communication), so one presumably could engineer other mammals that have a reduced affective dimension of pain while maintaining the sensory dimension of pain.⁵ Since it seems

⁵ Of course, the true degree of similarity of the role played by P311 in all mammals could only be fully determined through extensive empirical investigation. However, it would be relatively straightforward to test for the presence of P311 in other species and, if it were present, to subsequently develop P311 knockouts, given the sophistication of current molecular neuroscience practices. The main unknown would be whether the gene knockout would have similar effects in a different species, as there is at least some evidence that knockouts on "lower" animals don't always translate to similar effects on more complex species. This is also complicated by the fact that the gestation period is much longer for the relevant mammals compared to rats.

likely that the affective dimension of pain played some role in determining the evolutionary fitness of organisms, we might question whether knockout livestock could really survive up through the point where they are normally slaughtered. However, it appears that the experimental rats were able to survive without complication at least in their cages (Chen, personal communication). This would be a good model for sows or veal calves who spend most of their lives confined in small pens where they can't do much of anything that would injure or otherwise harm themselves.

Would eliminating the affective dimension of pain have any real beneficial effect for livestock? Sows and veal calves who spend much of their time unable to move can develop severe joint damage [30]. While there might be different estimates of how effective slaughter methods actually are, there is no doubt that things occasionally go wrong and animals are not immediately killed. In such cases, they are left instead to suffer extremely painful deaths. And even dairy cows, who might mistakenly be thought to have it relatively easy, are reported to show signs of distress after their calves are taken from them [31], which happens approximately once a year in order to keep them producing milk. Interestingly, studies have shown that that ablation of the anterior cingulate causes mother mammals to stop responding to the cries of their young, leading some researchers to suggest that the "neural alarm" system that underlies parental response was built off of the machinery for pain [32]. When considering such cases along with the massive scale of contemporary factory farming, eliminating the affective component of pain would almost certainly prevent a great deal of suffering. Thus, creating genetically engineered animals that lack the affective dimension of pain has the potential to eliminate a great amount of suffering.

More research clearly remains to be done, and it is possible both that the knockouts I have described do not completely eliminate the affective dimension of pain and that such techniques cannot be extended to other mammals. However, I think the evidence provided thus far along with recent dramatic advances in molecular neurobiology suggests that even if we currently have not identified genes that can eliminate the negative affect of pain, we likely are very close to doing so. The understanding of the anterior cingulate and other parts of the affective pathway has increased

dramatically with the application of cellular neurobiological techniques in recent years, and if P311, AC1, or AC8 aren't helpful knockouts for this idea, something else on the horizon likely is.

A Potential Argument

I am now in a position to formulate an argument for the genetic engineering of animals reared in intensive factory farming environments:

- (1) We should prevent unnecessary suffering when possible.
- (2) Intensive factory farming is responsible for a considerable amount of unnecessary suffering.
- (3) Replacing the current animals used in factory farming with genetically engineered animals who lack the affective dimension of pain would decrease the amount of suffering caused by factory farms.
- (4) Not enough people are willing to become vegetarian to completely eliminate the suffering caused by intensive factory farming.
- (5) People would be willing to eat genetically engineered food if it meant they were no longer responsible for suffering and if it did not impose too much of a burden on their lives.
- (6) Animals can be genetically engineered and used in food production in a way that does not impose much of a burden on people's lives.
- (7) Given (2), (3), (4), (5), and (6), replacing current livestock with genetically engineered animals who lack the affective dimension of pain would prevent unnecessary suffering.

Conclusion From (1), and (7), we ought to replace current livestock with genetically engineered animals who lack the affective dimension of pain.

Several of these premises are empirical claims whose truth cannot be determined by armchair speculation alone. For example, any of the claims (3), (4), (5) and (6) could turn out to be false. Hence I am not trying to claim that the above argument is conclusive, but rather that the conclusion is likely enough that we should explore the empirical claims it is based upon in more detail. The rest of this article will be devoted to considering potential objections to this argument and to several of the premises.

Bruising

In considering possible objections to my view, I turn first to points brought up in the work of Temple Grandin. Grandin has frequently emphasized the fact that animals treated well in slaughterhouses have fewer bruises, which in turn leads to better meat quality [33]. Thus, in some situations, it would appear that welfare considerations and economic considerations converge to recommend the humane treatment of livestock. However, if the ability of animals to feel pain is diminished, it seems likely that such animals might not respond to normal noxious stimulation and hence would be more likely to acquire bruises that ultimately diminish the quality of the meat, threatening the extent to which we can switch to genetically modified animals without imposing a burden on consumers.

This objection might be somewhat mitigated by the fact that the proposed gene knockouts do not eliminate pain altogether. Rather, they eliminate selective features of the pain. The knockout in the Wei et al. study [27] eliminated the signs of chronic pain while leaving acute pain features intact. Similarly, the study by Chen and colleagues [29] knocked out conditioned place preference, believed by many to be the best measure of the affective component of pain, but left in place normal acute responses to noxious stimulation. Thus, the appeal of such selective knockouts is that the resulting animals might be able to show normal guarding behavior in a range of situations despite lacking the phenomenological feeling of suffering.

However, since the affective dimension of pain is involved in some kinds of behavioral responses, we should still expect there to be situations where the knockout animals are more likely to be bruised. In particular, the conditioned place preference task is in part a measurement of the animals' ability to learn to avoid noxious stimulation, so knockout animals might be less likely to learn to avoid harmful features of the environment if parts of the affective pain pathway are blocked. It is hard to know in advance how significant this problem would be, but it may turn out that additional precautions would have to be taken to ensure that the animals are not able to harm themselves. This presumably could lead to additional costs, and such costs could influence the viability of this solution.

On the other hand, Grandin has also emphasized that increased stress in livestock can decrease meat quality. If there is a correlation between the degree of suffering in animals and the corresponding amount of stress, then knocking out the affective dimension of pain could actually increase the meat quality. Though it would be hard to know before knockout animals are actually produced, it could turn out that creating animals who do not suffer as much would result in higher quality meat.

Pure Vegetarianism Advocacy vs. a Mixed Strategy

Many of the people who have been invested in the fight against factory farms from an animal welfare perspective (myself included) would probably say that, in an ideal world, it would be preferable that people refrain from eating factory-farmed meat entirely rather than switching to genetically engineered meat that does not suffer as much. In fact, there are plenty of other reasons independent of animal welfare concerns to want to do away with intensive livestock operations, including potential health risks to humans and damage to the environment.⁶ My argument is not an argument against vegetarianism; it is simply an argument that *if* we are going to eat meat from factory farms, the animals that provide that meat should be engineered to have a reduced capacity to suffer. Nevertheless, one might still argue against it by claiming that the best way to truly reduce suffering is to advocate purely for vegetarianism. Thus, the strength of my argument crucially depends upon the claim that it is more likely that people would be willing to eat GM livestock than to give up meat entirely, and that making such a switch would result in a diminishment of suffering that made up for the other costs.

This claim can be attacked from two directions. First, one might argue that despite the increase in meat consumption, we are in fact moving towards a world where people will eventually give up the consumption of factory-farmed meat. There seems to

⁶ Unfortunately, I do not have the space to address these possibilities here, but I do note that any full consideration of the consequences would need to take their potential implications very seriously.

be a lot of anecdotal evidence that could lend vague support for such a view. In my own experience, there certainly are far more vegetarian options available at restaurants now than there were in the late eighties and early nineties. The fact that human beings exist who don't eat meat is not quite as shocking or subversive an idea as it used to be, even in areas far removed from urban centers. And, as noted at the beginning of the paper, there appears to be a growing number of people who choose not to eat meat. These claims are all interesting, but ultimately amount to little more than a hope that some more serious mindset change will occur in the future. As long as factory farming is the primary source of meat, the measure of total meat consumption is ultimately the closest measure of total animal suffering, and as long as meat consumption is steadily increasing, I see no reason to trust to hope that people's minds will radically change in the near future.^{7, 8}

On the other hand, one might doubt whether people will really be willing to consume meat that comes from GM livestock. Worries about such meat being "unnatural" will likely carry more weight among the general population than they will with card-carrying utilitarians. However, as I argue below, I think there is a strong case to be made that the meat being consumed now is already unnatural. More importantly from a strategic perspective, is the fact that GM meat has a strong advantage over vegetarianism in that it is not directly opposed to the profit margins of large and powerful companies who have a proven ability to shape public discourse. Genetically

modifying organisms is not a continuous cost; once you've got a phenotype, you can continue to breed that phenotype. In fact, the ability to produce "pain-free" meat might even produce a market advantage for certain companies. The placation of companies that have spent the last several decades squeezing every drop of money out of their product at the expense of everything else is not usually something that most of us would see as a point in favor of a particular moral position, but it is something that needs to be considered if one is to take into account the constraints of the world that ultimately help to determine the consequences of our actions. In this case, I think it lends support to the idea that genetic modification might be a far more likely way to actually reduce suffering than waiting for people to change their culturally-reinforced eating habits.

The fact that it might be possible to convince the public to switch to GM livestock would also have its own disadvantages. Thus far, no genetically modified animals have ever been approved for use in commercial food production ([34] p. 207). The approval of affect-knockout animals could very likely open up the floodgates for GM animals. While the affect-knockout animals themselves may not be unhealthy or dangerous to the environment (as I argue below), future modifications very well might be. And once the gates are open, recent history suggests that it would be all too likely that corporations would start pushing for genetic modifications that maximized their profits, even if such changes came at the expense of human health, the environment, or the welfare of animals.

I think it is undoubtedly true that allowing GM livestock could increase the potential for future environmental or health risks. As for future modifications that actually impair animal welfare, the extent of the risk would depend in part on the scope of the original genetic modifications. The anterior cingulate is involved in a wide range of experiences associated with suffering, implicated in everything from social pain to anxiety to depression. If the activity diminished by the gene knockouts turns out to be activity that covers a wide range of things that might be described as "suffering," then the possibility of additional modifications causing more suffering will be greatly reduced. However, if in fact the anterior cingulate is only involved in the affective dimension of pain but negative affect from things like depression, anxiety, and fear are still fully present in the

⁷ California's voters recently voted in favor of increasing the space for chickens in egg-laying operations. This certainly is a promising development from an animal welfare standpoint, and perhaps a model that can be used to impact suffering more effectively than past efforts. However, one of the arguments used by egg producers was that this would drive up costs to the point where California egg producers could no longer compete with those from other states. It remains to be seen how willing people will be to pay more money as long as cheaper, factory-farmed options are available.

⁸ A somewhat related argument against my proposal would be to suggest that we grow all of our meat in culture as an alternative to factory farming. In fact, PETA has offered a million dollars to the first person who can create *in vitro* meat and bring it to market. It seems to me that *in vitro* meat would be preferable to pain affect knockouts because it would eliminate any uncertainty about whether suffering was taking place; however, it is not clear just how close we are to being able to actually grow meat in culture.

knockout animals, the risks of adverse effects of future modifications will be great. This would be compounded by the fact that negative affect knockouts could encourage people to be more careless or cruel in their interactions with the animals. In general, I think any decisions must be made to conform to what Bernie Rollin called the principal of the conservation of welfare, which states that, “genetically engineered animals should be no worse off than the parent stock would be if not so engineered, and ideally better off.” [35].

These are important concerns, and I will not pretend to know that all of these potential risks would be outweighed by the potential decrease of suffering caused by negative affect knockouts. This essay is intended only to argue that we ought to consider carefully the potential for genetically eliminating suffering. An applied ethics argument such as this will ultimately depend on the full range of consequences that might be thought to result from a given policy, and any full argument to this effect will extend far beyond the confines of this paper.

Deontological Considerations

As mentioned above, some ethical theorists might accept that this proposal would result in better consequences than the status quo but nevertheless find it unacceptable. One reason for taking such a position would be to believe that genetically engineering animals and using them in factory farms violates the animals’ rights. Tom Regan, for example, has argued that all sentient animals have a right to be treated with respect, and that when we fail to provide this respect by treating the animals as mere things, we have harmed them and thus are morally blameworthy. One can easily see how on such a view genetically modifying farm animals’ pain perception does not make the practice of meat consumption any more defensible. However, I think the differences between such views and what I am proposing become much less dramatic when we consider one of the central claims I am suggesting: namely, the claim that people are not in fact going to stop eating meat to a great enough extent to end factory farming. If this claim is true, then the question for animal rights proponents is not whether we will be violating animals’ rights, but rather whether we will be violating their rights *and*

causing suffering or just violating their rights. If this is the question, then I think even most rights theorists and deontologists more generally, will lack strong arguments against GM livestock, unless they believe there is something wrong with genetic modification in particular. I consider this suggestion below.

General Objections to Genetically Modified Foods

Finally, I turn to general arguments against genetically modified foods: arguments that I think are not particularly effective in this case. These arguments are that genetically modified foods (1) are unhealthy, (2) have the potential to seriously damage the natural environment, and (3), are unnatural.

The first argument does not seem especially promising. A classic example of the worry that a GM plant could be unexpectedly dangerous, the interpretation of which was later called into question, was an experiment that demonstrated that pollen from BT corn could kill the caterpillars that later turned into monarch butterflies. Since monarch butterfly populations had been rapidly shrinking, this finding was cause for great concern. However, while BT corn produces a protein cry1AB, which is not found in natural corn, the affective pain knockouts described above simply *remove* particular proteins that would otherwise be present. It is unlikely that the removal of a protein would result in anything toxic for consumption, for humans or for butterflies. Of course, we are complex organisms and it is better to err on the side of caution, so appropriate experiments could and surely would be conducted to see if the genetic modifications had any deleterious health affects, but *prima facie* there seems to be no reason to think that meat from affect-knockout animals would be any more unhealthy than regular meat.

Regarding (2), the claim that genetically modified foods have the potential to seriously damage the natural environment, one can easily see how an escaped GM plant that was resistant to insects could become a weed that interfered with a particular ecosystem. However, if anything, it seems that pain affect-knockout animals that escaped from the farm would be at a severe disadvantage to other organisms, given that they presumably would be lacking the capacity for certain forms of learning. Again, there is no particular reason to think that they would be any

more dangerous to the environment than regular livestock.

The most interesting argument of this set is the claim that GM organisms are unnatural. This can take either a religious form such as a claim that we are interfering with God's perfect creation or a secular claim that we are distorting the intrinsic value of the natural world. However, I think Peter Singer and Jim Mason [34] give the appropriate response to this claim when they write:

But it isn't easy to see why both the religious and non-religious forms of the argument should not also rule out the kind of selective breeding that has, over many thousands of generations, transformed wild animals into the familiar domestic animals we have today. Was it blasphemous for humans to transform Burmese jungle fowl into the modern chicken? If GM corn is "unnatural," so too is a turkey with a breast so large that it can only reproduce through artificial insemination. (pp. 210–11)

In other words, modern factory farming is already a practice that leads to humans consuming "unnatural" animals. I hasten to add only that we also feed most livestock "unnatural" diets, inject them with "unnatural" hormones, and keep them in "unnatural" environments. Thus, if genetically modifying livestock is truly blasphemous due to its unnaturalness, I'd wager that we were damned a long time ago.

Conclusion

In this paper, I have outlined research that suggests that we might not be far away from being able to genetically engineer animals with a reduced capacity to suffer. Depending on how much of the full range of suffering can be eliminated and a host of other complications, people who are concerned with eliminating unnecessary suffering ought to consider GM livestock a serious option. In some ways it would be very sad to see technology succeed where pure appeals to morality have not, but nevertheless those with a true desire to eliminate the suffering caused by human society must keep all options on the table.⁹

⁹ I'd like to thank Gary Varner and Clare Palmer for helpful comments. And special thanks to an anonymous reviewer for extremely insightful comments.

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