16

In Vitro Meat

What Are the Moral Issues?

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Looking back in human history, there was a time when hunting was the most common method for getting meat to eat. Gradually, agriculture was established and with this the domestication of animals. Hunting was no longer necessary in agricultural areas but could be used as a complementary way of obtaining meat. Of course, in populated and industrialized areas, there are no longer many wild animals to hunt. Where there are big animals, like the moose in Sweden, hunting is strictly regulated to keep the stock sustainable and to hinder overpopulation. Even if it is popular to hunt moose in the northern part of Sweden, the meat gleaned from this activity is a very small part of Swedish meat consumption.

In fisheries, we are now witnessing the first steps toward something similar to the human use of domestic animals. Still, "hunting" is the predominant mode of obtaining fish, and ever more effective fishing fleets threaten to wipe out many of the most popular fish stocks.

If hunting animals for meat was the first stage, and slaughtering domestic animals the second, it is now time to move on to the third stage in meat production. With progress in tissue engineering and cell culturing, it is now possible to grow animal cells and tissues in bioreactors. Although the technology is at a very early stage and there are many hurdles to overcome, such technology for large-scale production is on its way. Producing meat in this way will constitute a radically new version of meat production, namely meat produced in vitro without any animals being slaughtered.

A living animal does many more things than just grow—at least that is how we wish to see the lives of domestic animals. But from a food-production point of view, much of the energy that goes into a living animal is "wasted." The inputs include

not just the feed but also fossil fuel and other resources (Horrigan, Lawrence, and Walker 2002). Even though there is no full-scale in vitro meat bioreactor in operation today, it is an acceptable guess that the output-to-input energy ratio will be more favorable than in conventional meat production (a guess that must of course be verified). If this guess comes true, the result will be less impact on the environment.

In this chapter, we discuss ethical issues related to in vitro meat technology. We contrast this with the "old" meat technology, claiming that the new technology may actually contribute to solving some pressing problems caused by conventional meat technology. We end by briefly outlining the new problems that emerge with the application of in vitro meat technology. But before we turn to these and other issues, let's make a short visit to the future.

SCHOOL TRIP TO THE MEAT PLANT OF THE FUTURE

It is a gray and chilly day, someday in the future. A school bus stops in front of a low building on the outskirts of the city, and children get out to tour a meat plant—this is one of the educational activities for schoolchildren sponsored by the in vitro meat company. The ten-year-olds have learned some basic cooking in school, and now it is time to see where their food comes from. On this day, meat is the topic. Inside the building, the director of the meat plant greets them in front of a large metallic container.

"Welcome to the city's meat plant," the director begins. "What you see here is the very heart of the process, namely, our bioreactor. We have no animals here. This is meat without animals."

A schoolchild raises his hand: "Is it really true that once upon a time they made meat from dead animals? That's what mother says. When she was young she never wanted to eat meat."

"Yes, but that was a long time ago," says the director. "At that time there was something called slaughterhouses, where animals were killed. But that does not exist any longer. Instead, we take tiny cells from animals and these are cultured and grow in the bioreactor." The director points to the container. "In the old days, animals were kept inside big buildings before they were brought to slaughter. We had to import food for them and the animals emitted large amounts of greenhouse gases."

The director tells the children that there were many reasons to start in vitro meat production. "One problem was the environmental impact of all the animals kept for meat production. Vast resources were needed to breed the animals indoors. Our animal cells here do not need so much. As meat production increased around the world when formerly poor countries grew more affluent, it would have required enormous numbers of animals kept indoors to supply all that meat; or

many forests would have been cut down to obtain more pasture. Advances in medicine are another reason why in vitro meat production took off. Scientists learned how to grow human organs from human cells. If you can grow a human organ, a muscle for example, to be implanted and function in the human body, it was easy to make the leap to growing animal organs for eating. The muscle to be implanted must function; it must be connected to tendons, blood vessels, and nerves. A muscle for eating does not need to be able to contract. It is much easier to produce."

The schoolchildren move on to an exhibition hall where they see advertisements from the beginning of in vitro meat production. "It was difficult in the beginning," the director explains. "People were very skeptical and regarded in vitro meat as unnatural. At the start, it was also about the same price as natural meat. It was not like today, when in vitro meat is cheap. Shops were afraid to sell the new meat. But then we came up with an idea of a campaign that changed everything. We called our product 'meat without suffering' and made a promotional movie showing pictures from slaughterhouses. We also described the process as good for the climate. Now there is only in vitro meat: And it tastes good too! All the indoor meat production has gone.

FOOD MATTERS

This future snapshot provides the context for discussing various issues that arise when considering in vitro meat. First, most broadly, we turn to food ethics, a field that has grown out of the sphere of traditional ethics. Early on, medical ethics appeared. More recently, we have seen bioethics, animal ethics, research ethics, and even space ethics (Williamson 2003). Now we have an upsurge of interest in what is often called food ethics.

food & religion

Food ethics has a long history, mostly connected to religion. Many religions have explicit dietary rules that believers must follow. Some foods are deemed unclean and not fit for eating; there are rules for how food should be prepared and sometimes also for when eating various kinds of food is appropriate. These kinds of rules continue to play a large role for many people today.

From a secular perspective, there is what may be called a lifestyle kind of food ethics, perhaps best summarized as "you are what you eat." In this view, food needs to be compatible with a person's basic values and life plans. Even people who do not reflect very much on food refuse to eat some kinds of food. In the Western world, we do not like to eat dogs and cats and other pet animals. Aspects of food production also play a role. Animal ethics has for a long time been at the center of the discussion of meat production. Other considerations in this kind of lifestyle food ethics are that food products be produced in a fair and just manner and traded in a nonexploitative way.

The present interest in food ethics can also be understood in relation to concerns about food safety and food quality. Since the outbreak of BSE—or mad cow disease—these issues have been in the forefront of public interest. There is intense public discussion about food quality and about supplements added to food. Much of this is related to health, but some groups focus on other issues. Such issues range from organic or natural farming in food production, concern over long-distance transportation, questions of waste, and also fair trade and justice for food producers. The recent increase in prices for basic food has also triggered a concern about food security: how will we feed the world and avoid famine and undernourishment?

Concern about climate change has also moved to the forefront of public attention. There is also competition for land with the recently booming demand for, and production of, biofuel from cultivated crops. This has triggered more discussion of food security and the morality of using valuable land to produce fuel for cars—mostly in the rich Western world—instead of food for a starving world population. In general, there is a need to produce enough food for a growing population on a diminishing amount of land.

In vitro meat is not only about technology and science. Will people eat in vitro meat? Will in vitro meat be considered "unnatural" and run into the same problems as genetically modified crops? The naturalness/unnaturalness issue will perhaps be rendered more difficult if animal cells used in bioreactors need to be genetically modified in some way to make them grow faster. Other important issues are the environmental impact of in vitro production compared to conventional meat production and, of course, the question of price.

In vitro meat is a technology that changes the moral landscape. This has happened before and will happen again.

TECHNOLOGY CREATES MORAL PROBLEMS . . .

It is no mystery why new technologies force us to increase our moral responsibilities. In the old days, when it was impossible to send food around the world to relieve famine in distant areas, there was no moral obligation to come forward with such support. It was simply impossible to do. There *was* a moral obligation to come forward and help your neighbors if you were in the lucky position of having excess food. Then, as now, it was not clear exactly how much you were obliged to do for your neighbors. However, before the advent of transport technology, there was no moral obligation to send food to distant countries. Such technology has since vastly widened our moral responsibility to distant persons, while the obligation to people in our neighborhoods has been there all the time.

Technology & new moral questions

Another example is organ transplantation. In former times, it was not possible to move one kidney from a living person to another. This is possible today. Hence, a new moral question has emerged: should I give my kidney to someone

in desperate need of one? As most of us have two functioning kidneys, we have the possibility of giving one of our two kidneys to someone with end-stage kidney disease. This is a moral question created by the development of modern medicine. It is a question too seldom asked. Most of us tend to shy away from the fact that modern medical technology has expanded what we can do for our fellow beings. It is not just time and property that may be shared with others; even parts of our bodies may be of value for others in distress. Organ transplantation, especially from living donors, generates further moral problems formerly unknown. Should human organs always be given freely with no financial reward? Or can there be a scheme for paying volunteers who are willing to part with one kidney (Omar et al. 2008)? Whatever your view on these issues, the questions are all created by a new technology.

Another example involves human embryos. With the advent of in vitro fertilization, and in particular of human embryonic stem cell technologies, human embryos can be used as a resource to produce potentially medically valuable stem cell lines. This immediately prompted a moral issue: is it right to destroy human embryos in order to produce human embryonic stem cell lines? Whatever your position, the very question did not exist before the technology did. Technology can create moral problems.

. . . BUT IT MAY ALSO SOLVE OLD MORAL PROBLEMS—AND CREATE NEW ONES

Sometimes technological development may partly solve some moral problems. For example, recent development of induced pluripotent stem cells seems to do away with the issue of harvesting stem cells from human embryos. If differentiated adult stem cells can be reversed and turned into more primitive stem cells, ultimately the embryo may no longer be necessary (Persson and Welin 2008, 137).

Let's return to the question of kidney donation: should I volunteer to give my kidney to someone in need? If tissue engineering can produce human organs for transplantation, there will no longer be any need for me to volunteer. If organs can be grown outside the human body from donated cells or from stem cells, then the issue of giving my kidney is no longer pressing. There may be better alternatives.

Such a development is not without drawbacks. First of all, the possibility of engineering organs will in the long run likely be quite expensive. Today, organs are free—except on the black market and a few other places—but the surgery is expensive. The volume of organ transplantation is restricted because of lack of organs. This is particularly true of organs that cannot be obtained from living donors. If organs can be grown in laboratories, the sheer amount of possible transplantation

would be astonishing. Why wait until you have a serious heart failure? Better to get a new heart in time. Savings would result in such a case because there would be no need for expensive advanced heart surgery. But the increase in transplantation that would come with increased supply would probably be quite expensive to society overall. National health care systems—such as in Sweden and most of Europe—would likely need to ration transplant procedures.

Similar problems would appear if regenerative medicine succeeds. Such procedures will likely prolong life. It is difficult to know how much the average life span might be extended, but it will come with costs: the actual cost of supporting an ageing population and the less tangible cost of what a changing proportion of old people to young will mean for our societies. Shifting age demographics are already a global issue, though seldom discussed. In the affluent world there is a (slightly diminishing) ageing population with vast resources at their disposal, while in the developing countries we find a much younger population with far fewer resources.

IN VITRO MEAT: THE TECHNOLOGY

What is the present status of in vitro meat technology and what can we expect in the near future?

The main idea is to select suitable cells from animals and make them proliferate in vitro with the help of a growth medium and a bioreactor. Stem cells are the only cell type that can naturally give rise to the large numbers of cells needed to generate sufficient quantities of meat to make this a viable process. The source of the stem cells remains open at the moment. While embryonic stem cells were first thought to be the only alternative, these have been superceded by the use of skeletal muscle progenitor cells and mesenchymal stem cells: cells that are easier to isolate from animals and that still maintain high proliferation rates. Attention has now turned to induced pluripotent stem cells, in which a mature animal's skin cell can be transformed to an embryonic stem cell simply by turning on only three or four genes (Holden and Vogel 2008). This can be done without genetically modifying the cells themselves (Zhou et al. 2009), and although additional verification from the scientific community is needed, the process paves the way for non-genetically modified in vitro meat.

The energy needed to produce in vitro meat consists mainly of nutrients to grow the cells plus what it takes to operate the bioreactor at controlled levels of temperature, humidity, gas atmosphere, and sterility. Stimulation (electrical, mechanical, physical, and biochemical) will likely be needed to get cells to grow into something that resembles muscle tissue as rapidly as possible (Dennis et al. 2009). There will be emissions and waste products from the cells to deal with, but the gases that

result can rather easily be captured and controlled. Sterile, deionized water is a key component in this process, which is important to keep in mind when considering future scenarios of climate change and water shortage.

The first successful in vitro meat will likely be in the form of minced meat, which could be further processed into hamburgers, sausages, and so on. Cells grown on porous microbeads suspended in the growth liquid in large bioreactors are expected to offer higher cell yields, and cells plus microbeads could easily be harvested and processed further as a minced meat equivalent. This is not a new concept—microcarriers are used for culturing animal cells to produce insulin and vaccines—and this has already been applied to skeletal muscle cells, although not with meat in mind (Bardouille et al. 2001).

Later on, the idea is to produce the "real" thing: meat filets comparable to their natural counterparts. Today we can grow skeletal muscle tissue in vitro having dimensions up to only a few millimeters (Dennis et al. 2009; Powell et al. 2002), mainly because current approaches lack the internal plumbing system we have in our bodies, namely blood vessels. Cells need fresh oxygen and nutrients continuously, and the waste products need to be removed. Currently, cells are grown on three-dimensional porous structures (e.g., fibers, gels, foams) (Beier et al. 2009), often in the presence of flowing growth media, to allow for transport of nutrients and waste, especially for the cells located at the interior of the structures. Interestingly, the shape of these porous structures will dictate the shape of the cultured in vitro meat filet. There is still a long way to go, but we believe that in vitro meat technology will profit from the intense interest in developing medical-tissue-engineering applications to produce vascularized human tissues and organs for transplantation (see, e.g., Scime, Caron, and Grenier 2009). Such organs for transplantation need to be fully functional. In that sense, in vitro meat has a simpler task. Such an animal organ need not be functional; it is enough if it is edible.

Benjaminson and colleagues (2002) were the first to report successfully cultured in vitro meat using skeletal muscle explants from goldfish. Their study is one of only a few scientific publications on in vitro meat to date (see also Edelman et al. 2005), and unfortunately their approach yielded insufficient quantities of newly generated meat mass. NASA, in the United States, supported this and other research in the interest of developing a sustainable food source for long-distance space travel. New Harvest (www.new-harvest.org), a nonprofit research organization founded 2004, also supports the development of competitive in vitro meat products. Furthermore, in 2008 PETA (People for the Ethical Treatment of Animals) announced a prize for the first research group able to produce a commercially available in vitro meat product.

The ultimate goal is to produce all varieties of meat now obtainable from animals. It is not yet clear precisely how in vitro meat will compare to conventional

meat production in terms of environmental costs, though the thought is that in vitro meat will have a lighter environmental load. The picture will become increasingly clear as bioreactor design improves, the right cell source is found, the most effective nutrition is established, and appropriate methods for handling the culturing process are determined.

Because we do not need to kill animals to produce in vitro meat, and if in vitro meat diminishes environmental impact, then this technology may indeed solve a moral problem. We may be able to enjoy meat eating while being good (or at least better) to the environment and reducing animal suffering.

ENVIRONMENTAL, BIODIVERSITY, AND LAND-USE ISSUES IN CONVENTIONAL MEAT PRODUCTION

There is wide consensus that human activity is affecting the global climate and our ecosystems. This includes activities such as burning fossil fuels and also agricultural production. It is not just that we may run out of coal and oil in the future, but use of fossil fuels also produces greenhouse gases that tend to increase global temperature. The system of meat production based on grain and soybeans—especially if they are grown on open, newly deforested land—emits a considerable amount greenhouse gases. Studies of the environmental impact of the life cycle of conventional meat production (i.e., agriculture, slaughter, retailing, household use, waste management, and transport at all stages) suggest that the greatest impact comes from the agricultural portion of meat production. The Food and Agriculture Organization of the United Nations reported in 2006 that worldwide livestock activities contribute approximately 18 percent of the anthropogenically emitted greenhouse gases and 65 percent of anthropogenic nitrous oxide (Steinfeld et al. 2006). Moreover, a slaughtered animal contains many more parts than just the edible ones and needs energy input just to live. A conservative estimate is that about 80 percent of the energy input in animal farming is lost. The edible parts of a pig or chicken amount to 70 percent of the animal, while for a cow the amount is 50 percent (LivsmedelsSverige 2009). The rest is used as fodder or is considered waste, which requires waste management. One way to reduce greenhouse gas emissions is by reducing agriculture-related emissions. Using the European Commission's integrated product policy framework, Eder and colleagues (2008) showed that the aggregate environmental impact of meat and dairy product production can be reduced by only 20 percent. For associated greenhouse gases, the improvement potential is about 25 percent. For further reductions, a totally new kind of production is required; maybe that will be in vitro meat production.

reducing environmental impact

Conventional intensive meat production, as all agriculture, puts pressure on land use, whether production is indoors or free range. When animals are raised indoors, substantial input of food is needed. This demand for food for animals

(but also for direct consumption) has led to an increase in soybean production. Indoor meat production in combination with free-range meat production exerts additional pressure. For example, in Latin America pastures for cattle grazing have been converted to soybean fields and the cattle have been moved deep into the Amazon (Rother 2003). This threatens biodiversity and also diminishes the rain forest's capacity to absorb carbon dioxide.

Another worldwide problem is the growth of cities, which often takes place on good and fertile land and which may affect the global food supply (Ananthaswamy 2002). The increase in human population and the expansion of agricultural land for growing plants and for pasture will also involve more and more of the planet's land. There is simply no free space left.

ANIMAL ETHICS

There is general consensus that animal suffering is an evil thing and should be avoided as much as possible (DeGrazia 1996). In particular, present-day slaughterhouse practices evoke negative reactions among the public (Eisnitz 2006). There is also a discussion in the European Union about reducing the transportation of animals to be slaughtered. This can be seen as an attempt to avoid (unnecessary) animal suffering.

The views among philosophers and ethicists are divided when it comes to animal slaughter. Painful killing is generally considered unacceptable, but there is intense debate about (painless) killing of (merely sentient) animals who do not have clear sense of a future (McMahan 2002). An important distinction is made by some between persons (human beings and sometimes higher apes) and "mere" sentient animals (Cavalieri and Singer 1994). For persons, we have stricter ethics. Most people find it morally acceptable to kill an intensely suffering animal "for it owns sake," while this is considered morally outrageous if applied to persons.

Not all ethicists concur with this distinction between an ethics for persons and another ethics for merely sentient beings. For a dissenting view, see Regan (1983), who claims that most animals should be treated as persons and be viewed as having rights akin to those that humans have. This is also an idea held by many animal rights groups.

Animal suffering in instances other than slaughter is also an issue. As discussed above, animal husbandry and meat production cause large emissions of greenhouse gases. The easiest way to control these emissions would be to keep animals indoors and capture the gases before they escape into the atmosphere. However, many consider that such lives indoors are not good for animals. Modern factory-like animal production has serious drawbacks regarding animal welfare and animal suffering (Singer 1979). Most animal ethicists believe that an animal life outdoors, grazing freely, is much preferable. This would also give animals the possibility of a more

natural life. But the outdoor grazing makes it impossible to control the emission of greenhouse gases.

WHY NOT GO VEGETARIAN?

Some studies indicate that it is environmentally friendly to reduce meat consumption and switch to eating vegetables and plants (Marlow et al. 2009). Why, then, should we be interested in introducing in vitro meat? The simple answer is that most people like to eat meat and will probably resist switching. It is already a disturbing fact that meat consumption increases with economic development (Worldwatch Institute 2006). While global meat production has more than doubled since 1970, the rate of increase in developing countries is higher; and the type of meat production that is increasing consists of confined and intensive meat production (Worldwatch Institute 2006).

That the public, to a large extent, prefers to remain meat eaters instead of turning to a vegetarian diet is a statement of fact. This does not answer normative questions, such as should we become vegetarians for the sake of the environment and animals? A simple answer would be perhaps that we should stop (or reduce) eating meat if this were the only way to avoid serious adverse effects to the environment and to animals. But in vitro meat offers an interesting way out of this problem. In vitro meat may "save animals and satisfy meat eaters" (Hopkins and Dacey 2008). Meat produced by in vitro technology does not involve animal suffering or the killing of animals. There is at least one source animal for the cells in the bioreactor, but the cells can in principle be obtained without killing the animal.

HOW TO CLASSIFY IN VITRO MEAT: IS IT NATURAL?

Will the consumer accept in vitro meat? There is to our knowledge no discussion of consumer preferences, with the exception of the Eurobarometer, the public opinion analysis arm of the European Commission (Eurobarometer 2006). Any public skepticism may partly be attributed to lack of knowledge—and at present there is very little knowledge about in vitro meat as a consumer product. However, it is far from certain that skepticism will melt away with more information. It is popular to claim that public skepticism is due to lack of knowledge, but this general thesis of knowledge deficit and the associated claim that the public would be more favorable if they were better informed does not hold up well in other technology areas (Persson and Welin 2008, 193).

The main issue for consumers concerning in vitro meat may very well be, is it natural or artificial? One answer is that in vitro meat is both natural (produced from real cells) and also artificial (grown and cultured through a tightly controlled

technological process). However, exactly the same can be said of much present-day intensive meat production: it is both natural and artificial. The really natural thing seems to be free-grazing animals living out in the countryside. Given the distinction between animal suffering (always bad) and the killing of animals (perhaps not always bad), free-grazing animals may be an acceptable source of meat for many consumers. But slaughterhouse practices seem to be a problem for much of the public. Most people (today) seem to want to eat meat from animals living as naturally as possible, but they do not like the way the animals are killed. In vitro meat does have a competitive edge, then, in avoiding the killing of animals.

Will people actually prefer to eat meat from animals that were once alive? Can we envisage a situation where the quality of in vitro meat is as good as ordinary meat and where people still prefer to have animals killed to get meat that was once alive? Even if we personally believe that it is pure superstition to believe that "once alive" confers some extra benefits to the eater, we cannot rule out that such an idea may take root.

Another question that may emerge connects to religious food ethics. Some religions have strict ideas about how animals for meat should be slaughtered. Only animals slaughtered in the appropriate way are allowed for meat consumption. How will these rules apply to in vitro meat? Will it be considered something other than meat in this religious sense, or will it be ruled out as not appropriately slaughtered? We are eagerly awaiting the first pronouncements from religious leaders.

That we can expect conceptual issues on how to classify in vitro meat to emerge illustrates how important classifications are to humans (Douglas 1996). This has been seen already in the debate around genetically modified food, where opponents claim that this is something radically new and unnatural, while proponents claim that genetic modifications are just a small extension of what nature does already.

CONCLUDING REMARKS

Are we moving into the third era of meat production? From hunting wild animals, to slaughtering domestic animals, and finally to producing in vitro meat? Our belief is that we are. It will take some time to get there, and it will take people quite some time to adjust. The main factor pushing development forward is the medical interest in tissue engineering. We also think that the emerging awareness of the earth's vulnerability and of the dreadful lives of the many animals kept for human consumption will move us in the direction of in vitro meat.

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