# Future Impact of New Science and Emerging Technologies on Animal Well-Being

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## Introduction

Earlier presentations at this conference have detailed the events leading to domestication of animals by humans and have described the characteristics, largely behavioral, that encouraged animals to be domesticated (see Curtis and Siegel).

For thousands of years, changes in domestic plants and animals were gradual and depended almost entirely on attempts to select superior individuals while applying little selection pressure. Most progress was made in the species that had the widest variety in uses (and which had been domesticated the longest)—the dog.

In colonial and frontier America, almost every family produced its own food, or at least the major part of it. A few chickens supplied eggs and meat. Not many eggs, because hens weren't as productive as they are now, and not much meat, either, because chicks (which came at the expense of eggs) had to avoid disease and predators and literally had to scratch for food to live long enough to fill the family skillet or pot. The cow calved in the spring and, if the family was lucky enough, gave a modicum of milk that the family shared with the calf until fall. In between milkings, many of the cows pulled a plow or wagon.

Both the farm family and its animals had to share home-grown crops of marginal quality or to forage for food provided by nature. Indeed, the family larder probably contained more game, as a source of protein, than home-grown food.

Well into the 20th century, agricultural labor was supplied by men and animals. Indeed, the largest program in fledgling departments of animal husbandry was generally the (draft) horse program, and plowing a straight furrow was considered an indispensable agricultural skill. Farm size was limited to the number of acres that could be handled by the farmer and his animals, and productivity per farm was low. Entering the last half of the 19th century, 80 percent of the population lived on farms. By the 1920s, each farmer produced enough food to supply the family and four others.

## The Mechanical Revolution

The mechanical revolution changed the basic nature of farms. Each farmer could farm more acres with a tractor, reducing the need for draft animals and farm labor. Workers no longer needed to raise food were free to fuel the industrial revolution with their efforts and ideas, in turn further reducing the need for on- and off-farm drudgery and diminishing the need for animals for work and transportation.

The discovery of hybrid corn, the introduction of soybeans to the United States, and the realization that processing byproducts (e.g., sugar beet pulp and cottonseed oil meal or cake) could be used as animal feed allowed farmers to market animals faster on fewer acres.

Because people increasingly demanded a steady supply of products of uniform quality, the food industry changed. Supermarkets, providing advantages in choice, product freshness, and price, supplanted general stores, butcher shops, and fish markets. Regulations designed to assure food safety that required modern equipment and the need for efficient production speeded the demise of family packing houses, small creameries, and neighborhood delivery of dairy products. Commerce grew in size and integration, and standardization and specialization were fostered on the farm and by packers and distributors.

As time passed, the industrial revolution provided urban jobs for many of our country's citizens. Industry gave us stoves and iceboxes, railroads and telegraphs, automobiles and airplanes; it also gave us better and larger tractors and harvesters. Farm productivity—of both plants and animals—increased to feed a growing urban population. By mid-century, each farmer fed 40 to 50 additional people.

## The Chemical Revolution

The industrial revolution in agriculture was followed by the chemical revolution. By removing the need for mechanical weeding and cultivation and reducing the competition from weeds, by reducing the need for crop rotation and for forage production, by reducing the need for animals to consume forages and produce manure, the chemical revolution enhanced specialized agriculture and encouraged larger, more efficient agricultural units.

Changing demands of consumers and changing abilities of farmers resulted in the production of more grains and oil crops and fewer grasses. The increase in low-cost, concentrated feeds, coupled with improved preventive veterinary medicine, led to larger flocks and herds, to feedlots and confinement systems, to reduced per-animal labor and capital costs, to an entirely new form of animal "husbandry."

Today, each farmer provides food for 125 people at home and abroad, and about two percent of Americans are involved in on-farm production of it.

# The Biological Revolution

Around 10,000 years ago humans first domesticated the ancestor to today's dog. Until a millennium ago the dog didn't change much. Then, people began breeding dogs for specific purposes—as hunters, herders, and defenders. During the last century, they embraced the concept of dogs as pets. From then until now we've developed the Great Dane and the Chihuahua, the Pekinese and the St. Bernard, and scores of other widely divergent breeds.

Similarly, we began 300 years ago differentiating between meat and milk in cattle. The British Isles, for example, can be considered the home of both the Jersey and the Angus.

Advances in animal agriculture have been dramatic. Not only do we have low-cost feed, we've increased production—and quality—per animal *and* per unit of feed fed. In 1950, for example, a single dairy cow produced about 4,800 pounds of milk, compared with more than 14,500 pounds today. In 1950 it took 12 weeks to get a broiler to market; today it takes about seven weeks. In 1950 a hog carcass produced about 32 pounds of lard, while it produces less than 13 pounds today.

We've developed the technology and production techniques to improve the quality of many animal products. American farmers today are raising more pork, more chicken, more milk, more eggs on less feed—and with less fat—than ever before.

Productivity increases bring extra profits to early adopters of new technology and total production increases as others adopt the technology. As production increases, prices decrease; and the percentage decrease in price exceeds the percentage increase in production. Consumers ultimately benefit.

## *Genetic Selection*

Increased productivity of the dairy cow shows the results of applying science and technology in animal agriculture. A cow originally produced only enough milk to raise her calf. Humans learned long ago that milk is an excellent food, and throughout recorded history the dairy cow has been selected and developed to produce large quantities of milk.

Dairy cow improvements began in the United States in the mid-19th century. The first major steps were the importation of purebred cattle and the establishment of breed associations. Over the years, genetic improvement came from coordinated efforts in milk production, testing, and recording; reproductive physiology; artificial insemination; and statistical or quantitative genetics.

Reproductive efficiency is one of the most costly and production-limiting factors facing the livestock industry. Reproduction is influenced by genetics, management, nutrition, disease, and environmental factors. An important limiting factor in animal genetics is the time required to produce and evaluate each succeeding generation.

Classical selection and breeding programs based on physical traits—such as milk yield, weight at a given age, percentage of lean meat, backfat thickness, or egg production—are responsible for many of the advances in animal production over the past 50 years.

We've improved our dairy herds through artificial insemination breeding programs that use genetically superior bulls. Farmers will soon have the opportunity to exercise even more control over herd reproduction and genetics and over the health and milk-producing potential of their animals. For example, *in vitro* fertilization can improve conception rates and accelerate genetic gains, while sperm selection by sex may allow dairy farmers to select more females and beef breeders to select more males.

But genetic advances haven't been limited to dairy cows.

The U.S. cattle industry started over a century ago producing extremely lean beef with largely Longhorn-type cattle in extensive grazing systems. By the mid-20th century they were producing very fat beef from small-size English breeds. Now the trend has shifted back toward leaner beef. We're selecting large-framed, later maturing, exotic types of cattle. Consumer demand has accelerated this change and encouraged interest in many cattle breeds not formerly found in the United States.

A lot has happened with pork, too. Years of genetic selection produced dramatic changes and gave us the modern, lean hog. From 1950 to about 1970, we reduced fat in pigs through classical breeding. Now, genetics has given way to new options like nutrition, management, and endocrinology to further reduce fat.

The poultry industry has also changed remarkably in the past 40 years. Broiler and turkey breeders have bred birds that mature earlier, grow faster, and convert feed more efficiently. Reproductive efficiency, however, is being limited by egg production, fertility, and hatchability, which apparently have negative genetic correlation and have become important barriers to further improvements.

Because they respond differently to diet, male broilers are much more valuable. The sexing process, however, is costly, and sex selection of sperm is not yet available. One genetic alternative has been to produce fast-feathering males and slow-feathering females—but the individual chicks still have to be handled to examine their feathers. Researchers are examining a method of determining the sex of chicks by down color (probably not pink and blue) for virtually cost-free sex identification.

We've also seen a new emphasis on turkey, which may offer even better nutrition than chicken. To meet demand, producers have bred turkeys for larger and larger breasts. In fact, turkeys now have such large breasts they can't mate naturally—they can't get close enough together—so breeders have been forced to use artificial insemination. Now, they have the potential to use sperm selection as an additional tool for producing the preferred large male birds.

## *Metabolic Regulators*

Biotechnology refers to using living organisms or systems to produce useful substances or to using biological technologies to improve plants, animals, or processes. Although the word "biotechnology" is relatively new, using biological agents isn't. Yeasts, molds, and bacteria have been used for years to make fermented foods like beer, wine, and bread, and to preserve foods, such as by turning milk into cheese and yogurt. The newer technologies include the techniques of recombinant DNA, gene transfer, embryo manipulation and transfer, plant regeneration, tissue culture, monoclonal antibodies, and bioprocess engineering.

One current area of research is focusing on enhancing the rate and efficiency of meat production—increasing lean tissue and decreasing fat tissue with hormones and other compounds that alter metabolic pathways.

Pharmaceutical companies are working on biological compounds, somatotropins and beta adrenergic agonists, for example, that partition energy away from fat and into muscle.

Somatotropins (growth hormones) may be the first products of biotechnology to significantly influence animal agriculture. Originally available only from pituitary glands of animals, somatotropin now can be produced in pure form and in large quantities at relatively low cost through recombinant DNA technology.

Recombinant somatotropins have impressive effects on growth, feed efficiency, and carcass composition in pigs and can dramatically increase milk production in dairy cattle. Multi-year tests of bovine somatotropin (BST) on tens of thousands of dairy cows have shown a 10- to 20-percent boost in milk production with a 10-percent reduction in feed consumed. Porcine somato tropin (PST) allows pigs to convert more feed into muscle and less into fat and improve feed efficiency as much as 20 percent.

Artificial insemination and frozen semen can be considered among the first developments in animal biotechnology. Since then, embryo manipulation (including embryo collection and transfer) has been used successfully with cattle. The process involves inducing superovulation and artificial insemination, with the resulting embryos implanted in surrogate mothers. During transfer, the embryos can be split, fused, sexed, or frozen. The success rate for splitting is excellent, and thousands of calves have been produced from split embryos. Embryo transfer techniques can be used to produce "litters" of calves from a single superior mother that would otherwise produce only one calf at a time.

Infectious diseases remain the leading cause of death and reduced productivity in domestic livestock. Biotechnology offers the potential to produce powerful vaccines for foot-and-mouth disease, scours, shipping fever, and other animal illnesses. Biotechnology has already led to a vaccine for pseudorabies, a herpes virus that infects cattle, pigs, and sheep, and causes estimated annual losses to the U.S. livestock industry of $30 to $50 million.

Along with superior vaccines, biotechnology techniques using monoclonal antibodies are being developed to detect animal diseases, estrus and pregnancy, and aflatoxin in livestock feed. Recombinant DNA can be used to make "probes" to diagnose disease, and monoclonal antibodies can be used to diagnose diseases, monitor drug efficacy, and develop therapeutic treatments and vaccines. We can already diagnose scours, pseudorabies, bluetongue, transmissible gastroenteritis, and several major poultry ailments. Monoclonal antibodies currently are available as therapeutic treatments against both calf and pig scours.

Researchers are currently investigating alternative uses for farm animals. Because mammals can efficiently convert feed sources into valuable proteins, scientists in the future may be able to develop animals that can produce high-value pharmaceutical or therapeutic products in their milk or blood.

Transgenic animals that produce these blood factors in their milk could be a viable and safe alternative production system. They may be more economical than microbial fermentation that is used for the large-scale production of human and animal vaccines, drugs, peptide hormones, monoclonal antibodies, and other high-value pharmaceutical products.

Although raising such animals would employ a relatively small number of farmers, it's an example of the potential opportunities that might come from biotechnological advances.

## Changing Animal Genetics

The precise "manipulation" of the genome portends greater changes than we can foresee or even imagine.

It's possible to modify the genotype of animals to improve disease resistance, stress tolerance, and growth performance. Inserting genes into embryos to produce transgenic animals that have desired characteristics may have real advantages over treating individual animals or traditional selection schemes.

Likely candidates for transfer included genes for disease resistance, efficient growth, and enhanced protein synthesis. Among the strains of commercially useful transgenic farm animals likely to emerge in the next few years are pigs with less fat, poultry resistant to avian influenza, sheep with wool that is easier to wash, and goats and dairy cattle that produce valuable pharmaceuticals in their milk.

## Changing Values

As agricultural efficiency has led to a remarkably safe, extensive, inexpensive food supply for this country, American citizens have been asking, "At what cost?" Increasing chemophobia, enhanced concern about quality of life for people and animals, and renewed preoccupation with the environment have become major public issues. The lack of food shortages for decades and the extended time since the population was familiar with farms have distorted images of agriculture. As a result of the mixture of fact, myth, and sensationalism prevalent in today's society, people have developed a remarkable ambivalence on a number of relevant topics.

- Polls reported in *Parents Magazine* and studies by Hoban and Kendall indicate that most Americans (80 to 85%) think animals have rights, while a similarly overwhelming group agrees that humans ought to be able to eat meat.

- Scientists are depicted in Saturday morning cartoons as "mad," with hair in disarray, laughing maniacally and working toward the goal of conquering the world and (more recently) destroying the envir-onment. On the other hand, the image of university scientists and medical and veterinary scientists is strongly positive. And people still look largely to science to solve today's problems.

- Industry is often depicted—frequently during this meeting—as uncaring, greedy, and cruel, with corporate profits driving all issues, including those of safety, health of people or animals, or moral turpitude. Anti-BST ads prepared by the "Pure Food Campaign" of the Rifkin Foundation on Economic Trends indicate that potential Food and Drug Administration (FDA) approval for the use of BST commercially is a result of FDA's "caving in to pressure from giant drug and chemical companies."

- The view of farmers is also varied. Seen as protectors of the land and the roots of most of our population, the family farmer is revered, if not respected. Seen as the source of contaminated and residue-filled products and environmental problems, the farmer is feared. But seen as the basis for sustainable, residue-free, often organic products, the farmer is considered the hope of those who would either return to the "good old days" or find a newer, safer agriculture for the future.

- Perhaps the greatest degree of ambivalence comes with discussion of our elected officials. Increasing cries for term limitations and public opinion polls that rank politicians very low are difficult to reconcile with the almost automatic reelection of incumbent legislators. Programs designed to reduce government spending or "pork barrel" projects are supported unless they have local effects.

Since polling alone cannot tell us what "the people" expect, it seems imperative that those involved with animal agriculture help address the issues involved in this conference.

Mensch suggests that it may be impossible to define animal well-being in a widely acceptable way. Although I understand her point, I submit that we must work toward that definition—even if it's only a working definition—as rapidly as possible.

To develop that definition, we need to use the science that we have without constantly lamenting the lack of science. We can then develop better scientific approaches to improving our knowledge.

Rollins suggests that "common sense" should be the basis for decisions on animal well-being and cites the story that engineers in the last century "proved" that bumblebees can't fly. But if common sense had always prevailed over science, over the audacious or the imaginative, we would be living in a world perceived as flat, seen as the axis around which the sun revolves, and devoid of heavier-than-air planes because common sense tells us they couldn't fly, either.

People's impressions regarding animal well-being are often more related to familiarity than to procedures. For example, a relatively large group insists that farm animals ought not be neutered sexually, even under anesthesia. Some argue that this deprives them of normal psychic functions, even if sexual activity is not permitted by management schemes. Others argue that sexual activity should be provided and that artificial insemination is "cruel" to males and females. There seems a consensus, however, and rules often exist to support it, that our closest animal friends—our pets—routinely should be neutered.

Even though science is incomplete, common sense is not enough, and public views are varied, definitions of animal well-being and regulations affecting animal agriculture will be forthcoming. In the absence of scientific, sensible, acceptable positions established by those who know the most about animal agriculture, decisions will be made by politics alone (see Baumgartner and Moseley).

Within this framework, we can also predict the fate of new biotechnologies as they are introduced into agriculture.

Data from Hoban and Kendall and my own biases suggest that products of biotechnology may be most acceptable to the public if they are perceived as economically advantageous, risk-free, environmentally benign (or advantageous), and not "playing God." Plant-to-plant transgenesis appears acceptable to the vast majority; animal-to-animal transfers are supported by fewer and opposed by more; and any combination involving humans or human genes is considered unacceptable (even though human genes are routinely transferred to bacteria to produce insulin and other medicinal products).

The effects of biotechnology on animal *well-being* appear less of an issue than the effects of management schemes. Given the opportunity to develop products of biotechnology that can enhance well-being, it would behoove us to fit such products into our management schemes.

## Conclusion

In the meantime, this conference on animal well-being suggests several steps, at least to me, to be taken in the short-run.

In my opinion, animal scientists and animal producers should work toward establishing definitions of well-being, using the best information we have available. Then we need to establish relevant science, to conduct relevant science, and to report science that addresses the issues.

We need to do what we can to learn what consumers think and know and don't know, what they respect or fear, and to develop our work efforts accordingly.

In the meantime, we must begin to develop guidelines describing appropriate husbandry factors in animal well-being and work to eliminate the inappropriate. (We can agree, for example, that there is no room in animal agriculture for animal abuse or physical neglect. We should not, then, tolerate such abuse or neglect or protect those responsible for it.)

When such reasonable guidelines are developed, we need to work with our many publics to assure that they are understood, accepted, and adopted as the bases for further study.

Then, when issues of the acceptability of biotechnology arise, we will be able better to address them.

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