

# Staff Papers Series

Staff Paper P91-26

June 1991

## USING NATURE AS BOTH MENTOR AND MODEL: ANIMAL WELFARE RESEARCH AND DEVELOPMENT IN SUSTAINABLE SWINE PRODUCTION

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IN SUSTAINABLE SWINE PRODUCTION

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## USING NATURE AS BOTH MENTOR AND MODEL: ANIMAL WELFARE RESEARCH AND DEVELOPMENT IN SUSTAINABLE SWINE PRODUCTION\*

"The greatest calling of the farmer is to leave those gifts [of nature on which agriculture depends - soil, water, plants, and animals, both wild and domestic] in better condition than when they were received. Such a responsible agriculture can only be achieved when nature is both mentor and model, and when natural systems are the standard against which success is measured.... Farm animals often contribute to ecologically sound agricultural systems and they deserve humane care."

-- Asilomar Declaration on Sustainable Agriculture, 1990.

### Introduction: Sustainability Issues in Animal Culture.

Until quite recently, animal culture largely has been left out of discussions about sustainable agriculture. These have tended to focus on cropping practices and their effects on soil and water. Two recent journal articles have helped to rectify that omission (Baker, et al. 1990; Beauchamp, 1989). In extension presentations and farm magazines, Honeyman (1990; McMahon 1990) has drawn a connection between swine production and the sustainability of farming systems and Zartman (1990) has described intensive rotational grazing of dairy cattle. Fox (1988) was the first to describe a philosophy of **humane** sustainability.

Animal culture has significant effects on sustainability of both natural and agricultural systems; on surface water and groundwater quality; on the welfare of production animals; and on human welfare, including the well-being of producers, consumers, and agricultural workers. In these respects, animal culture as it is practiced today, presents both advantages and disadvantages. Once we have identified these, the question becomes "How can we maximize animal culture's contributions to the long-term sustainability of agriculture and both short- and long-term human needs, while minimizing

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\* Paper presented May 12, 1991 at the "Varieties of Sustainability" Conference cosponsored by the Agroecology Program, University of California, Santa Cruz and Agriculture and Human Values Society, University of Florida, Gainesville, May 9-12, 1991, Asilomar Conference Center, Monterrey, California.

those effects that might jeopardize human and animal welfare and the ability of animal culture to sustain itself?" As the title of this paper and its placement in a session on "Humane Sustainable Agriculture" imply, one answer may lie in research and development of more humane animal production systems, i.e., systems that specifically include, as an important design parameter, provision for the welfare of the animals.

Following a brief discussion of the role of animal culture in sustainable agricultural systems, this paper will suggest that research and development of animal production systems, using "nature as both mentor and model," can lead to a more humane, sustainable animal culture and, in turn, to more sustainable agricultural systems. Two diverse approaches to designing production technologies with the objective of improving the welfare of animals will be described -- a conventional approach and one which I will describe as "using nature as both mentor and model" -- and their respective contributions to animal welfare and sustainability will be discussed.

#### Advantages of Animal Culture with respect to Sustainability

Although livestock agriculture is not necessary for soil sustainability, some do believe that a biological or ecological agriculture system should include animal culture (Beauchamp 1990). Baker, et al. (1990) point out that sustainable farming methods use the natural animal-plant interrelationships to improve the ecological, biological, and socioeconomic viability of farms and, ultimately, of agriculture as a whole.

As per Baker, et al. (1990), since the basic resources in an agroecosystem<sup>1</sup> are air, solar radiation (energy), water, and land, the sustainability of the system depends on the

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<sup>1</sup> The interaction of animals and plants with the nonliving parts of the environment, such as soil and climate, creates an ecosystem. If the ecosystem involves primarily domesticated animals and plants under human management or direction, it is called an agroecosystem (Baker, et al. 1990).

efficiency of processes within the system and the steps taken to replace losses from the system. The natural processes whereby carbon, nitrogen, water, and minerals are cycled and recycled are important factors contributing to the system's sustainability. These natural cycles are generally more complete and effective when both animals and plants are included in the system (Baker, et al. 1990). For example, grazing, lactating cows return to the soil 75 percent of the nitrogen and 90 percent of the minerals they consume. Baker, et al. (1990) also cite research showing that a mix of herbivores, having a variety of dietary requirements and preferences, in a diverse ecosystem increases biological efficiency because it uses the plant biomass more uniformly than a single animal species.

It has been estimated that when soils are brought into agricultural production, biological processes occur such that there is a net loss of organic matter to about 50 percent before a new organic matter content equilibrium is reached (Beauchamp 1990). Livestock manures supply both nutrients and organic matter to the soil and both are major determinants of soil productivity. Combined with plant organic matter in the form of straw bedding, livestock manure adds not only nutrients but tilth to the soil and can improve soil structure. Agroecosystems including pasture have been shown to increase soil organic matter content and nitrogen content (Beauchamp 1990) and lessen biocide input requirements on the farm as animals eating the weeds often are controlling insect populations simultaneously (Baker, et al. 1990). When well-managed (optimally rotated and not overstocked), pasture has one-fifth the runoff of cropland. Hence, water quality degradation often is reduced in areas where carefully managed pasture systems predominate over concentrated feedlot or confinement operations.

Forage crops are more conserving of soil (prevent erosion) than the grain crops generally grown for non-ruminants and for human food (Beauchamp 1990). However, sows

(non-ruminants) can be fed diets with 90 percent forage and will do well (Honeyman, cited in McMahon 1990). Growing/finishing pigs can grow well with 10 to 20 percent forage diets. Thus, forage crops can supplement swine feed rations and pasture systems for swine can be effective seasonal alternatives to controlled environment housing in some climates.

Livestock production also can provide for economic sustainability of farming operations by reducing reliance on off-farm fertilizer inputs, increasing labor efficiency by providing on-farm employment during the winter months, and reducing risk through enterprise diversification (Honeyman 1990; Baker, et al. 1990).

Preliminary results from a recent survey conducted by the University of Minnesota's Center for Rural Social Development, on behalf of a statewide sustainable agriculture working group, appear to have confirmed the importance of livestock to sustainable farming operations (Virginia Juffer, personal communication). The results indicated that farming operations which had both livestock and crop enterprises met more sustainability criteria than those which had only crop enterprises. (However, for hog farms, the study found statistically significant inverse relationships between the numbers of sows owned and the farm's sustainability index and between market hogs sold and the farm's sustainability index. This appears to indicate that, as hog enterprises became larger beyond some point relative to the size of the farm operation as a whole, they met fewer sustainability criteria (Minnesota Center for Survey Research 1990; Center for Rural Social Development 1991).)

So, despite the relative paucity of research being conducted in the U.S. to design more sustainable livestock systems, there exists a rather well-developed set of arguments to support the inclusion of thoughtfully practiced animal culture in a sustainable agroecosystem. As these are thoroughly discussed in the articles cited, they will not be described further here.

### Disadvantages of Animal Culture with respect to Sustainability

The current state of the art in animal culture does present sustainability problems, however. When humans intervene in the natural environment to redirect or curtail natural systems or natural processes, new interrelationships and new patterns of interdependence among species and/or between species and their environments result. In some cases, extinction rather than adaptation occurs.

Human intervention can result in dependence of natural processes on further human intervention (invention becomes the mother of necessity) and a loss of natural systems' "natural" sustainability. For example, indiscriminate hunting of predators can lead to overpopulation in the prey species, necessitating human management of prey species.

Domestication and selective breeding of animals to fit human wants have been conducted for many centuries. However, the decades since World War II have seen a great acceleration in genetically selecting for characteristics in animals that fit human wants.

Ekesbo (1988) argues

[a] study of what is known of the joint history of man and his farm animals shows that no other definable and limited period during the latest 10,000 years is characterized by such drastic changes in farm animal phenotypes and farm animal environments, including management, as the period since the 1950's.... A total analysis of [these] changes ... indicates a strong trend to replace the biology-based strategy of the traditional farmer with a technology-based strategy. In the former, technical aids like the saddle, the harness, the yoke, the stanchion or the pen were developed during many thousands of years of trial and error and were adapted to species-specific biological demands. In the latter, the animals are forced to adapt to the technical constraints of the different systems offered to farmers. This has led to an altered animal-disease panorama with an increase in the incidence of many diseases associated with environmental factors.

Agricultural research and development paths, particularly in the developed countries since the 1950's, have tended to emphasize technologies that reduce, inhibit, or circumscribe the natural capabilities of animals, in the interest of producing other efficiencies such as



increased growth rates, higher milk production, larger progeny, and higher ratios of lean to fat tissues. But these technical advances have also had their negative side effects. In some cases, an attendant result of the increasingly technological research focus has been to reduce animals' capacity to sustain themselves or their lines and to increase their dependence on further human interventions (See Ekesbo 1988; Pursel, et al. 1987; Halverson 1991, endnote 5). Van Putten (1988) has suggested our current efforts are reaching for points beyond the ability of animals to adapt.

For example, exogenous administration (injection) of porcine somatotrophin or of other "repartitioning agents" results in suppressed appetites in pigs and the redirection of nutrients to production of lean tissue over fat (Steele, et al. 1987). However, it also adversely affects the pig's ability to maintain homeostasis by means of its own mechanisms for thermal regulation (its skin, hair, metabolism, and subcutaneous fat), can cause other physiological problems, and is likely to necessitate softer flooring, closer human management, and higher energy (fuel) usage to maintain a narrower range of air temperatures in confinement buildings (Curtis 1987) than would be required if the animal were untreated. Transgenic pigs (gene transplantation, from other species, to insert characteristics desirable to humans such as leanness) have been produced by scientists, but the desired characteristics have been accompanied by renal disease, nervous system disorders, ulcers, and arthritis (Pursel, et al. 1989). Thus, it is true only theoretically that transferring specific genes transfers only the characteristics we want (Crabo 1991).

The economic effect of increasing animals' dependence on human interventions is to raise the overall levels of capital investment in facilities and equipment, increase farmers' reliance on off-farm variable inputs such as fuel, electricity and animal drugs, and increase the management time needed for maintaining physically healthy animals. For animal

"factories," having large capital investments, economies of scale can be maintained only at large output volumes, reinforcing the practice of keeping stocking densities high and space per animal unit low. In their turn, high stocking densities and restrictions of animals' movements cause stress and susceptibility to disease (Ludvigsen, et al. 1982, cited in Fox 1984; Tillon and Madec 1984; Curtis 1981), reinforcing the now routine practice of adding prophylactic doses of antibiotics to animal feeds (Ekesbo 1988). This in turn leads to attendant consumer health problems associated with drug residues in meat and milk and the growth of antibiotic resistant strains of bacteria. The latter can be harmful or even fatal to humans when the infecting strain of bacteria is resistant to treatment by antibiotics (Tauxe 1986; Cohen and Tauxe 1986).<sup>2</sup>

Scale economies contribute to increasing sizes of animal enterprises and the specialization of individual farming operations to a single animal enterprise.<sup>3</sup> With growth

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<sup>2</sup> It should be noted that there is disagreement between public health scientists (represented by the Centers for Disease Control, for example) and some agricultural scientists (represented by Council for Agricultural Science and Technology, for example) over the size of the threat to human health presented by antibiotic resistant bacteria and, indeed, over whether antibiotic resistance in salmonella organisms is engendered by agricultural use of antibiotics. Refereed articles reflecting the former point of view are cited in the text. The latter point of view can be found in Alternative Agriculture: The Scientists' Review, a compendium of responses by various agricultural scientists to the National Research Council Board on Agriculture report Alternative Agriculture, compiled by the Council for Agricultural Science and Technology (Council for Agricultural Science and Technology 1990).

<sup>3</sup> The tax policies that originally gave rise to these "factories" were not neutral with respect to their effects on substitution of capital for labor. Their effect was to subsidize capital at the expense of labor. Investment tax credits and full cost recovery in five years, allowed by the 1981 tax law, attracted outside investors and big corporations into the hog business and gave them a competitive edge over small and mid-sized farmers. Corporations such as Tyson Foods, which qualify as family farms according to law, were also able to take advantage of tax deferral programs targeted to small and mid-sized family farmers. In these cases, as long as investment in inventories of animals and feed remained constant or grew from year to year, income taxes could be deferred. A September 1986 article in the Arkansas Gazette reported that Tyson Foods, with annual sales of more than \$1 billion, deferred \$26 million or 75 percent of its tax bill in 1985 under this provision. Van Arsdall and

in scale and specialization of livestock enterprises, another source of enterprise diversity potentially is lost to independent, family-sized farm operations. This has already occurred in the broiler industry (Easterling, et al. 1985).

Concentrating animals on limited land areas, as in large scale cattle feedlots, and poultry, swine, and dairy operations, can overload the soil with animal wastes causing reduction of plant growth due to toxic levels of soil nutrients, and contamination of surface and ground water (Baker, et al. 1990). Concentrated animal operations can also increase air pollution in the form of odor and gasses escaping from manure storage facilities (hydrogen sulfide gasses escaping from large scale, concentrated swine operations have been blamed for loss of forests in Europe).

Large, concentrated, total confinement operations also raise questions about the appropriate use of scarce natural resources and about the directions in which society wants to proceed with livestock agriculture. Economies of scale can be enhanced substantially when unpriced or cheaply priced common property resources are substituted for high priced factors of production such as labor. For example, it is estimated that one factory operation in the West, having bought up the water rights of its neighbors and substituting groundwater -- a common property resource -- for more highly priced labor, uses two and one half million gallons of fresh groundwater daily to flush the manure from its swine barns. On the ends of buildings large tanks fill with fresh groundwater and automatically trip to flush the barns several times a day. The supernatant is then pumped out through a center pivot irrigation system onto the surrounding agricultural land. Flushing with fresh groundwater

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Nelson (1985) point out that even if tax policies did influence large investors initially, once the large firms became established in hog production, size economies helped them grow. Rising opportunity costs of farm labor also have encouraged substitution of capital for labor in agricultural production.

is a common, labor-reducing method of cleaning animal housing facilities in capital-intensive, environmentally-controlled livestock operations (Hassebrook 1991).

A second plant which is anticipated to produce 300,000 market pigs and between 10,000 and 12,000 cattle, uses a similar flushing system with a state of the art effluent treatment plant resembling a small municipal sewage treatment facility (Smith 1991). The plant's operator describes the operation as an ecological loop. This is a newly operating facility with fairly elaborate state of the art manure management. Nevertheless, increases in nitrate concentration in the soils and groundwater supply serving the operation and neighboring farms and communities have been reported to be increasing since the facility opened (Marshall 1990; Business Farmer-Stockman 1991; Jackson 1991).

The internal environments of intensive, environmentally controlled, closed confinement hog houses contain hog dust composed of dander, fecal matter, and dust from bedding, together with bacteria, carbon monoxide, carbon dioxide, ammonia, and hydrogen sulfide. Preuschen (1974) found decreasing work capacity in swine confinement workers because they tended to spend longer periods indoors in swine houses with little or no compensatory time in open fields. Inhalation of dust and other particles in swine house air has led to losses in swine house workers' lung capacities, chronic bronchitis, organic toxic dust syndrome, and farmers' lung disease (Donham, et al. 1984; Rylander 1986; Brouwer, et al. 1986; Donham, et al. 1990). Similar effects are found on workers in dairy and in chicken operations (Marx, et al. 1990; Morris, et al. 1990). Accidental inhalation of toxic gasses during manure pit emptying has led to workers' deaths (Donham 1982, Donham, et al. 1982). Farmers and would-be rescuers have died when they came into contact with gasses emitted from indoor pits (St. Paul Pioneer Press 1989).

However, these "hidden" costs of production get little attention in the agricultural policy debates. It is worth quoting the remarks of Dr. Kelley Donham, University of Iowa, concerning his testimony before the Joint Economic Committee on this matter (Donham 1990):

In 1984, I had the opportunity to present testimony before the joint U.S. House and Senate Economic Committee on agricultural policy for the future. I was there to present views from the medical college. At that hearing, economists and agricultural scientists from all over the country were testifying. Their testimony revolved completely around production and commodity support price issues. My testimony took a road never travelled before in that group's mind. I said: 'You know, there has been a course of agricultural policy established that has been generated secondarily from our national economic policy. The results of that policy on agriculture have never before been anticipated, but have been recognized today by those of us who deal with sick or injured farmers every day. These results are the new and serious health hazards brought on by these policies to our farm families.'...

One example is respiratory disease among persons working in intensive livestock housing. The shift to intensive swine housing was driven by taxation policies, dictated by economic policy, to intensify and increase productivity in large scale farming.... The technology that resulted was the confinement method of livestock production.

Through our research, we have been able to document that a large percentage of people working in these facilities have respiratory health problems, perhaps as high as 70%.... We estimate that nearly 400,000 workers are exposed to this environment in the U.S.... A whole new set of health hazards has been introduced because economic policy dictated agricultural policy and resulted in technology that results in hazards to human health never before anticipated and only lately recognized....'

These observations neither [were] absorbed [by] nor penetrated the awareness of the hearing attendees. That realization was very disconcerting to me. We must make the connection between agricultural policy and health hazards, not only for the workers' benefit, but for the general environment, as well.

Carbon monoxide buildup inside controlled environment, intensive hog confinement buildings has caused stillbirths in swine (Carson, et al. 1980). Significant subclinical levels of respiratory disease in animals raised in indoor, intensive confinement environments have

been found at slaughter (Curtis, 1985). In intensive confinement environments which restrict movement and eliminate opportunity for social interaction, the distress experienced by animals may reduce their mental health and put welfare at risk (See discussion and references in Halverson 1991.).

Of all the food processing industries, meat products is the largest. The meatpacking sector has been characterized by shutdowns, bankruptcies, expansion, divestitures and acquisitions, increased concentration, and excess capacity (Gallo, et al. 1988; Hayenga and McDaniel 1987). Through these structural changes, plants have become updated, larger, and more efficient. Efficiency improvements imply plants process larger numbers of animals in the same period of time as before the technological improvements were made. Yet, the high capital investments entailed in modernization demand a large volume and steady flow of hog inputs to the pork production process. There is considerable evidence that efficiency and cost savings in meatpacking, particularly in slaughter plants, have been achieved at the expense of packing house worker safety and long-term worker health (U.S. Congress 1988; Institute of Southern Studies 1989). Pearce and Reif (1990) found increased risk of several cancers in slaughterplant workers and meat cutters, as well as in farmers.

In all phases and types of the increasingly industrialized modern agriculture, adverse effects on the health and safety of the people engaged in agriculture indicate that production efficiencies are being gained at the expense of both human and animal welfare. (See special issues of American Journal of Industrial Medicine, Volume 10 (1986) No. 3 and Vol. 18 (1990), No's. 2, 3, and 4, for articles specifically relating to agricultural occupational health and safety.)

## The Meaning of "Using Nature as Both Mentor and Model"

"Using nature as both mentor and model" to design sustainable agricultural enterprises and systems describes an orientation to research, technology development, and farming practice that takes special note of the ability of natural systems to grow and sustain themselves over long periods of time without human intervention. In these systems, through the process of natural selection, plant and animal species have adapted to their surroundings and have coevolved with other species in the environment.

This orientation does not imply that we should opt for nature over agriculture (i.e., revert to hunter-gatherer societies) or make a value assumption (although there is a normative aspect to the sustainability concept) that whatever exists in nature is what ought to be in agriculture (e.g., all production animals should be allowed to run wild outdoors). Nature and agriculture have very different purposes and sometimes, of necessity, these are at odds with each other (See Diagram 1, Maxwell). Rather, this orientation suggests that natural systems and their capability to renew themselves over time hold lessons for us as we grapple with questions about the long-term sustainability of the natural resource base that supports agriculture and about man's relationship to the natural environment and other species, including farm animals.

A good deal of humankind's recent history and, particularly, the history of Western industrialized nations, has been characterized by a massive effort to achieve human independence from nature and human mastery over natural processes. Parallel effort has been applied to establishing the philosophical underpinnings to justify this human effort, in particular, to achieve some type of philosophical or spiritual validation of the rights humans claim for themselves with respect to nature. For example, his place at the head of the natural order has been suggested by some to be what gives man predominance over and

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COMPARISON OF SYSTEMS

	<u>AGRICULTURAL</u>	<u>NATURAL</u>
Optimizes:	Yield	Reproductive Success
Time Scale:	Periodic	Consistent Yield
Varieties:	Monoculture	Mixed Species
Relation to other species:	Coevolution Minimized	Coevolution Occurs
Persistence:	No Succession	Succession
Species characteristics:	Artificial selection for characteristics pleasing/useful to humans	Natural selection, or survival of the fittest
Treatment of biomass:	Biomass Removal	Recycling
Diversity:	Low Diversity	High Diversity

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Diagram 1. Characteristics of Natural versus Agricultural Systems, a Comparison (adapted from Bruce Maxwell, Department of Agronomy, University of Minnesota).

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rights with respect to other species and the natural environment. Callan (1970) has described how men overcame the initial shock of Darwin's theory, and its implications that man is a part of the natural, evolutionary "process," by fashioning from it the notion of "human progress." According to the notion of "progress," man might have been part of the evolutionary "process," but he was, nevertheless, at the top of the ladder, and his progress could be measured by the distance he was able to put between himself and whoever was on the next rung down. Eventually, human progress came to be signified, not only by man's distance from other species, but by his difference from them, and by the degree of



control he could gain over natural proceedings and the extent to which he could exert a causal influence on their outcomes. In this regard, Rachels (1990:52), also, has described how, following the publication of Darwin's Origin of Species, thinkers in the Western tradition "strove to find ways to except human beings from the laws they now admitted must govern the rest of nature," or, in Lorenz's words (1987:18), to find evidence of purposefulness or predetermination "which allows man to appear as if, from the very beginning, he had been the goal of the world of evolution."

For others, a strong belief in God-given "dominion" over the earth and its non-human inhabitants (Genesis 1:28) justifies man's use of animals and the natural environment in whatever ways suit man's purpose. According to this belief, animals and nature were created solely for the use and sustenance of man, who remains apart from and above them. This also seems to be an important part of U.S. agricultural philosophy (e.g., see Oppedal 1988; Johnson 1989). Fox (1988), however, has noted, with respect to the concept of "dominion," that the root verb of the word "dominion," as used in the first chapter of Genesis, is the Hebrew word "yorade," which means "to step down" or "to come down to." While human superiority with respect to the rest of creation, including other animals, is thus acknowledged in the Judaeo-Christian ethic, in this interpretation dominion is meant to be exercised not in the spirit of domination but in the spirit of empathy.

To suggest that natural systems can be the standard against which success in achieving the goals of sustainability is measured, then, presents an alternative to the traditional notions of progress and dominion, based in a recognition of human interdependence with (not independence from) natural systems. It is based in the view that man has needs with respect to (rather than rights over) the natural environment, natural processes, and other species. With respect to man's relation to the natural

environment, the objective of this vision of agriculture is, in the words of the 1990 Asilomar Declaration, to "foster an ethic of land stewardship and humaneness in the treatment of animals" -- both wild and domestic -- that is based in "humility" rather than in human pride of place above the natural order.

To suggest that natural systems can be the standard against which success is measured is to suggest that by studying the ecology of natural systems, that is, the interrelationships of living things, including humans, with their environment, we can understand more fully how to research and develop farming technologies and practices that will be sustainable for the long run. By designing the production environment to fit the needs of the animal, compatible with its (often species-specific) behaviors, instead of redesigning the animal to fit the mechanical needs of our systems, it may be possible to create a welfare-improving, more "natural" production environment and more sustainable agricultural systems.

#### Animal Welfare and Agricultural Production<sup>4</sup>

The welfare of an individual (human or non-human) is defined to be "its state as regards its attempts to cope with its environment" (Broom 1988). It is important to note that welfare concerns the individual and not populations of individuals. Animal welfare relates specifically to the well-being of individual animals.

When we speak of an ideal level of animal welfare, this is defined to be "a state of complete physical and mental health in which the animal is in harmony with its environment" (Wood-Gush 1983). This implies that there are two critical components of

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<sup>4</sup> For a broader discussion of animal welfare and agriculture, see Halverson (1991) and the references cited in it, from which this discussion is taken. Also see Fox (1984).

animal welfare: basic physiological health, hygiene, and comfort of the animal and mental, or psychological, health of the animal. Taken together, these two components define the "quality of life" or level of welfare the animal experiences.

Welfare, then, exists on a continuum from very good to very poor (Baxter 1983). It can be assessed scientifically (Broom 1988) and this assessment can be conducted independently of any value judgement regarding what level of welfare should exist. The question that must be asked after the assessment has taken place is the moral choice: "How poor must the welfare be before people consider it to be intolerable?"

Animals try to cope with their environments, first of all, by means of behaviors. Every animal has a motivational system that consists of both learned and inherited behaviors and governs its interaction with the environment. Being able to affect its environment in ways that satisfy its needs is an important aspect of the mental health of an animal (Stolba 1981, 1982; Dantzer, Mormede, and Henry 1983a; Wiepkema 1983; Kilgour 1983).

Compatible with the animal's motivational system is its physiology. Physiology includes body characteristics which are genetic in origin, and the internal mechanisms by which an animal achieves homeostasis, or physiological harmony with its environment. All animals, human and nonhuman, have these characteristics -- motivation and structure -- which complement each other.

When behaviors fail to achieve harmony with the environment (adjust environmental conditions to suit the animal's needs), this implies a loss of the animal's control over its environment (Dantzer, Mormede, and Henry 1983a). Internal mechanisms of adaptation take over (to adapt the animal to the conditions of the environment). Sows in gestation crates, for example, where they have no behavioral control over their surroundings, may

engage in redirected and/or stereotypical behaviors such as incessant barbiting (biting the bars of the crate). Wiepkema, et al. (1984) have shown that performance of stereotypical behaviors coincides with the release of endorphins in the brain. Endorphin release during stereotyped behaviors is indicative of efforts to cope with extreme stress (See also further discussion in Halverson 1991). Repeated loss of control has been shown to lead to a condition called "learned helplessness" (Dantzer, Mormede, and Henry 1983b; Fox 1984). In tethered sows, this condition has been indicated by what has been called "mourning behavior," where the sow sits perfectly still, with head down or leaning on the stall, and eyes tightly closed (Sambraus and Schunke 1982, cited in Scottish Farm Buildings Investigation Unit 1986). When the internal mechanisms also fail to adapt the animal to its environment, the animal sickens and dies (Kilgour 1983). It should be noted, however, that the animal's welfare would have been affected long before things reached this stage.

The study of animal welfare is the study of animals' well-being relative to their interactions and attempts to cope with their environments. Animals exert control over their surroundings by means of their behaviors. The motivational system of an animal is made up of both learned and inherited (evolutionary) behaviors. In order to understand the animals' interrelationships with their environments, both learned and inherited behaviors must be studied. Therefore, in trying to design a welfare-compatible production environment, an understanding of an animal's behaviors vis a vis a semi-natural environment (one similar to that with which its species coevolved) is as important as understanding its behaviors in the production environment (to which it has been consigned for human use).

Modern livestock housing in commercial agricultural production is intended to enable animals to achieve near-optimum performance in growth, productivity, and

reproductivity (Hahn 1982). Theoretically, if the animal does not have to search for food, defend self and offspring from predators, and use calories to adjust to cold temperatures, it will direct those energies to growth and reproductive performance.

By providing adequate food and water, warmth and shelter, modern intensive confinement production methods have succeeded in significantly limiting some of these natural stressors. But they often fail to consider the motivational systems of the particular animal species (its genotype) for which the buildings are intended (Stolba 1981, 1982; Ekesbo 1988:96). That is, they do not allow the performance of many normal behaviors, such as walking or turning around, or behaviors that animals may be very highly motivated to perform, such as dustbathing (self-grooming) by chickens, isolation and nest building by sows about to farrow, or play and self-grooming by veal calves.

Moreover, over time, during the course of natural selection, animals developed means of coping with natural stressors such as temperature changes, fighting, avoiding or fending off predators, and searching for food. The production environment, however, may contain new and strange stressors against which animals' inherited behaviors are ineffectual and with which, if management is poor and inconsistent, animals also may not be able to learn to cope effectively (Ekesbo 1988). Ekesbo (1988:96) and Stolba (1981) both point out that the notion that instinctive behaviors, have been bred out of domestic livestock by modern genetics is not correct:

Despite the changes in phenotype related to production traits, ethological studies do not imply that the genotypes of the animals has changed much regarding species-specific behavioral qualities (Ekesbo 1988).

Ethology, or the study of animal behavior, helps to provide an understanding of the significance of animals' behavior with respect to their environments so that we may design production systems that are sustainable because they are compatible with the animals'

expectations of their environments.

[E]thology covers many approaches to the study of animal behaviour which are connected by one unifying concept: all behaviour must be considered in relation to the ecology and evolutionary history of the species under investigation. This may seem to some to put domesticated animals beyond the scope of classical ethology, but while domestication has involved some behavioural changes, we shall see that much of the behaviour of our species of farm livestock differs little from that of their putative ancestors (Wood-Gush 1983).

Systems of production that provide for both the mental and physical health of farm animals attempt to reduce the distress of intensive production by employing facility designs and management that not only promote good physical health and hygiene but allow animals to exercise control over key stimuli in their environments and to achieve harmony with their environments, including associates, through their behaviors. Instead of designing systems to which the animals bear the full burden of adapting, systems are designed to give the animals some control so they can be occupied in arranging aspects of their environment and also can achieve a high degree of success in making their environment meet their expectations.

### Toward a New Vision for Animal Culture.

What exactly are we talking about when we discuss a "humane, sustainable agriculture?" In general, we are humane to others when we consider sympathetically their welfare or well-being in any decisions or actions we take that may affect them. The American Heritage Dictionary defines humane to mean "characterized by kindness, mercy, or compassion." Webster's Ninth New Collegiate Dictionary defines humane to mean "marked by compassion, sympathy, or consideration for other human beings or animals."

Animal culture can be humane from the perspectives of persons who depend on it for their livelihoods, from the perspectives of those who depend on it as a source of safe

and nutritious food and other products, from the perspectives of other species it touches, that is, the wildlife surrounding or coinhabiting the farm operation, and from the perspectives of the animals used in production.

It is generally clear to us what we mean when we say the business of agriculture should be humane to and enhance the welfare of people. We would like farmers and farmworkers to be able to engage in farming without experiencing debilitating financial distress and without endangering the safety or lives of themselves and their families. We would like the individuals who slaughter and process animals and animal products to work in safe conditions that put reasonable demands on them. (For example, we don't want them to lose fingers or hands because the lines have been accelerated to increase rate of output, or to develop carpal tunnel syndrome from repeating the same hand motions for the same tasks continuously during the workday. More philosophically, we don't want them to become dehumanized in the process of doing their jobs and lose their capacity to recognize and alleviate suffering in the animals they are slaughtering and processing.) And, we would like consumers to have a reliable source of safe, nutritious food, regardless of their ability to pay. (This is one rationale behind government support of agricultural production -- it is more acceptable to spread cost of food production over a broad base of taxpayers rather than to have food priced beyond the reach of poor consumers.)

With respect to our treatment of animals, in general, humaneness means taking the individual animal's welfare, defined as both mental and physical well-being, into account while it is under our control and care.

### Two Approaches to Design of More Humane Production Environments

There are two basic research approaches that can be taken when modifying the production environment for the purpose of improving animal welfare (Stolba 1981; S.H.

Baxter 1983:51). As we shall see, the two approaches have very different results with respect to the actual welfare parameters considered and incorporated into the production system and with respect to animal culture's contributions to sustainability.

The first of the two approaches takes the existing technology and makes minor modifications: for example, enlarging battery cages by a few inches for laying hens or adding a few inches to the back of a farrowing crate to accommodate longer sows or adding movable sides to a gestation crate so a sow can turn around. In this case, a single component of the system is modified. The objective is to meet one or more welfare criteria, while preserving the integrity of the existing system.

The second approach is the one I will describe as "using nature as both mentor and model," is one in which designers go back to first principles of the animal's relationship to its natural environment to identify key environmental stimuli, and behaviors with respect to them, that appear to have meaning and importance for the animal (Stolba 1981). Ethograms and sociograms for the pigs in the semi-natural environment are constructed from these observations and used to design an experimental production unit with all of the key stimuli present in one form or other. Slowly, stimuli are removed and the production environment is simplified to a point where it appears from animals' behaviors, to continue to satisfy a high level of welfare, while also maintaining a high level of productivity. In this case it is the system as a whole that is redesigned. The objective is to modify the system subject to providing a high level of welfare for the animals.

To illustrate the difference in the two approaches, I've selected two recent examples of production technologies designed for the specific purpose of improving sow welfare. The two approaches differ in terms of their implications for welfare and for sustainability.



The technology corresponding to the first approach is a turnaround crate system. This is a modified crate for housing gestating sows. Unlike the "stationary" crate system, where sows cannot turn around but must face in one direction for the entire gestation period (111-115 days), the crates in a turnaround crate system have side panels that swing from hinged ends at the front of each crate so that sows in crates adjacent to each other can turn around one at a time by moving temporarily one or both of the side panel(s) into the adjacent sow's (or sows') crate(s). The modified gestation crate fits easily into a conventional production system without special adjustments to the system.

The second approach is illustrated by a system developed in Sweden, in a cooperative arrangement between the Swedish University of Agricultural Sciences at Skara and a farm family producing feeder pigs. In this system, gestating sows are group-housed and free to move about in a large, straw-bedded pen, with individual feeding stations. The farrowing room also is large and straw-bedded, with individual cubicles for nesting provided during the first week of the farrowing-nursing period. In this case, the system is redesigned.

#### **Approach One: Make Small Modifications to Existing Technology**

The description of the design method for the turnaround crate is taken from McFarland, et al. (1988); Curtis, et al. (1989); and Curtis (1990). The designers first modified stationary crates, by making an outline on the floor of an ordinary gestation crate, and then getting down on all fours and trying to turn around in the space in order to decide on a general shape for the modified crate. The shape chosen was based on the designers' experience and on the dimensions of the original crates, and then the crate was tested with live sows. Crates of two different widths with one end flared were tested in one experiment. In the second experiment, crates of two different lengths with both ends flared were tested and sows' behaviors were compared to those of sows housed in ordinary

gestation crates of two different lengths. The designers observed that sows would turn around frequently in the crates that flared at one or both ends to permit them the opportunity. Thus, some movement was allowed the sow without sacrificing much floor space in the barn.

The next step was to modify the side panels dividing adjacent crates from each other so that they could be swung sideways. Since the flared ends were then unnecessary, the floor pattern was the same as that of the ordinary gestation crates, and a sow could turn around by moving toward the back of her crate and swinging the side panels into the two adjacent sows' spaces. The adjacent sows could turn around by swinging the panels into sow spaces adjacent to theirs. The designers' noted that sows appeared to be willing to accommodate a neighbor's desire to turn around by temporarily giving up some of their space. The new design eliminates the need for an alley in back of the crates. Since two rows of crates can be butted together at the backs, total floorspace requirement is reduced. This system has been promoted as a practical alternative to traditional production systems that contributes to the physical and psychological well-being of animals (Curtis 1990).

Since the turnaround crate technology changes nothing about the production system except to give the gestating sow the possibility of turning around, other aspects of the system and of the intensive, confinement production environment remain the same. No change occurs, for example, in the method of manure collection and disposal. Consequently, by itself, this system would not solve the problems facing concentrated livestock operations with respect to soil, ground and surface water contamination, odor, and air pollution. No reduction occurs in the stocking density and no additional modifications to the production facility are required to install the turnaround crate. Consequently, no reduction would be expected in use of subtherapeutic doses of antibiotics in the feed and

no particular change in air quality in the internal production environment would be anticipated. Occupational exposures to dust and gasses would not be expected to decrease with its adoption. Sows are still unable to perform "most of the major activities which make up [their] behavior," to paraphrase the Brambell Committee (see Appendix), so very important welfare requirements still will not be met with this technology's adoption. Finally, system productivity would not be expected to change from that of systems using stationary gestation crates.

#### Approach Two: Modifying the System<sup>5</sup> Basic Research

In 1983, two Pig Parks were set up outside Stockholm, at Tovetorp, by Per Jensen of the Swedish University of Agricultural Sciences (Jensen, 1986, 1988; Jensen, et al., 1987). These were similar to the Edinburgh Pig Park of Wood-Gush and Stolba (see Appendix). Jensen and his colleagues were interested in learning about the maternal behaviors of Swedish Landrace sows in an unconstrained, open environment. They wished to see if there would be anything in the sow-piglet relationship that might help them design a farrowing environment that can reduce the high piglet mortality of conventional systems.

In this experiment, gilts, sows, and boars were released into two adjacent, semi-natural enclosures (17 and 32 acres, respectively) at the Tovetorp station. Their behaviors were observed over a three-year period from 1983-1987. Each of the two enclosures consisted of marshy areas, woods, a major water and wallowing source, other places for fresh water, and pasture-type areas. Wooden lean-to's had been built at a few sites in each enclosure. These lean-to's were bedded abundantly with straw and, from the first of

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<sup>5</sup> For a short history of the ethological approach to studying animal welfare and applying results to production system design, see Appendix.

November to the first of May, were opened for winter shelter. Altogether, 60 farrowings from 20 different sows were included in the analyses.

In September 1983, two groups of pigs, each comprised of two young gilts and one older sow, were released into the two respective enclosures. In February 1984, two adult boars were released, one into each of the two enclosures. All observations started from the first farrowing. Entrance of the boars was timed so that the first farrowing and, subsequently, most others would occur in the summer. However, winter farrowings did take place. In all, five farrowings occurred in summer 1984; 17 farrowings occurred in February, April, May, June, July, September, and October, 1985; 22 farrowings occurred in February, March, April, June, July, and October, 1986; and 16 farrowings occurred in January, February, June, and July, 1987.

In the winters, most sows used the lean-to's. Some, however, chose to isolate themselves in spite of the weather and built their nests some distance from the shelters. In general, sows that were more isolated, even in winter, had a lower litter loss (probably because the piglets didn't get trampled or squeezed by other sows farrowing close by).

New sows for the study were recruited from the litters born in the enclosures. New adult boars replaced the previous boars approximately once a year to minimize in-breeding. New recruitments were made on the principles that the groups should contain about 4 to 8 adult, reproducing sows; each sow should farrow three times before being removed from the enclosure; and, since most observations would take place in the summer sows should be timed to farrow then. Sows were marked with different colored ear tags to tell them apart. New-born litters were marked with small, different colored ear-marks shortly after birth. Each piglet's earmark color was the same as other piglets in its litter. There were two parts to the study: detailed, day-to-day behavioral observations and long-term (over the

length of the study) recordings. Jensen and his colleagues identified six different maternal behaviors of the sows:

- isolation from the rest of the animals and nest site seeking. This preceded farrowing by one or two days. Nest sites chosen usually afforded good horizontal and vertical protection. Sows collected nesting materials in a quantity inversely proportional to the degree of protection the nest site offered, indicating that the sows were capable of adapting their nest building behavior to the prevailing environmental conditions;
- nest building. This started five or ten hours before farrowing. Sows sometimes built "mock nests" which were simple nests compared to the nest they eventually used. It is unclear what purpose the mock nests served. They may have been constructed to throw predators off the track. Sometimes sows had to build new nests: one sow had built her first nest on an ant hill and later moved. In the winter months, sows gathered and used significantly more nest material. Quantity of nest material also correlated with the number of the farrowing, indicating that with experience, sows got better at the job. The researchers concluded that nestbuilding behaviors were under the control of both endogenous factors and environmental feedback;
- farrowing.
- nest occupation. Sows and piglets rarely left the nest the first few days after farrowing, and then only for short excursions. On average, the sow left the nest area and went to the daily feeding about the 7th day postpartum. Piglets followed to the daily feeding on about the 12th day postpartum. While in the nests, most of the pigs communicated with each other by nose to nose contact, except shortly before and during nursing, when a complex pattern of grunts occurred. During the few final days of nest occupation, sows and piglets spent longer times out of the nests and communicated by grunts. The farrowing nest was always used for night rest although it became less and less used by day. It continued to be a home base for the piglets, however, who frequently returned to the nest on their own during the day.
- nest abandonment and social integration into the herd. Average day postpartum for nest abandonment was about day 9. After leaving the nest, sows and piglets usually sought resting places closer and closer to the common group nest until all the nights were spent there. Social interaction among piglets during the second week occurred mostly among littermates. Thereafter piglets from other litters were the most common associates. The most frequent interactions were nose-to-nose contacts. Overt aggression among pigs in the newly mixing litters was rare.
- weaning. Average weaning age was 17.2 weeks. The sows terminated the sucklings.

Average litter size increased with litter number, and average between-litter interval was observed to decrease with increasing parity. The minimum time a sow was successfully

mated was eight days postpartum. Mortality was high, as would be expected in the "natural" state. On average, 36 percent of piglets died before three weeks of age, with a higher percentage of piglets dying when farrowing occurred from January to March.

#### Application: The Thorstensson Farm

The following system was built in part on knowledge gleaned from the Swedish Pig Park research. The designers' objectives were to provide a hospitable environment for the pigs using the Pig Park observations as a guide and, at the same time, to correct for environmental and behavioral factors that contributed to the high mortality in the "semi-natural" environment of the Park by making use of the pigs' behaviors, including those under control of "endogenous" factors such as maternal behaviors and the tendency of pigs to establish dominance orders in groups. So, it is not only a single piece of machinery or equipment that is modified; it is the entire system that has been designed around the animals' behaviors.

In this system, gestating sows are housed in a large, straw-filled room inside a mechanically ventilated, insulated, but unheated, building. Windows provide the inside of the building with natural light. Individual, automatic feeding stations are provided along the side of the room and elevated about one foot above the floor of the pen. Waterers are provided as well. Eighty-five sows are in the herd. Breeding is scheduled so that sows farrow and raise pigs to weaning in groups of 15 sows each. About a week away from their farrowing times, the 15 sows that are about to farrow are moved to an adjacent farrowing room that has several large bales of straw in the middle and individual pens or cubicles with removable fronts set up along the walls of the room. The removable fronts of the cubicles have doorways in them with high thresholds. On top of the threshold a roller is placed to protect the sow's udder as she goes in and out of the cubicle. Straw is present

in the cubicles as well as in the common area of the room.

The presence of the cubicles is meant to satisfy sows' preference for isolating themselves from the rest of the group at farrowing time to build nests for their piglets. Each sow chooses a cubicle and builds her nest in it using the straw already in the cubicles and the straw from the middle of the room. When a sow is about to farrow, the handler locks her in her cubicle. Once she has farrowed, the cubicle door is opened. While the sows can go in and out of the cubicles to socialize and eat, piglets are prevented from leaving their nests by the threshold. Similarly to their pattern in the Park, the sows do not leave the cubicles often the first week. This contributes to bonding between the mother and offspring. The bonding tends to prevent cross-suckling (piglets from other litters suckling the sow) when the cubicle front is finally removed after the first week to allow mixing of all the litters and sows. The sow pushes away piglets she does not recognize.

Sows and litters are together in the straw-filled room for the next four weeks. In the fifth week, sows are removed from the farrowing room in order to wean the piglets. The piglets grow in the farrowing room until they are sold as fatteners. When they have been sold, the soiled straw is removed, the room is cleaned, and new straw is brought in for the next group of 15 sows.

The Thorstensson's have a solid manure system. The manure/straw mixture is spread on the Thorstensson's 250 acres and on 250 acres of nearby land. Antibiotics are administered only for therapeutic uses. However, overall incidence of disease is lower than in conventional systems. This is attributed to excellent air quality in the building due to low stocking density and air circulation, consistent and humane interaction between producers and pigs, the opportunity for exercise, and the presence of straw for warmth and occupation. The pigs dung in one place and do not soil the rest of the floorspace.

During their research on the maternal behaviors of sows, Jensen and Algers (1985) learned that there is intense communication between the sows and their piglets during suckling. The sow emits regular gruntings in a pattern that coordinates and regulates suckling behavior of the young. This pattern is disrupted by noise. Therefore, to ensure that there is no noise to disrupt the communications between sows and piglets, the air circulation in the mechanically ventilated facility is set at low wind speeds to keep noise at a very low level. Quiet at nursing time is also important so that piglets can hear the sows calling them to nurse and the sows can hear their piglets demanding food (nursing is initiated by either sows or piglets).<sup>6</sup> Keeping each litter together in the cubicles for the first week is also important to prevent competition by piglets from older litters for milk when the sow comes back to nurse.

The system is designed to make maximum use of the animals' behaviors and the husbandry and knowledge skills of the producers to improve management efficiency and productivity, as well as welfare of the animals. For example, in addition to facilitating sow-piglet communication by reducing noise levels, the stocking density in the pens is arranged to accommodate pigs' natural tendencies to establish a dominance order in groups. A dominance order can be achieved either by fighting or by avoidance of fighting. Fighting may be prevented by isolating animals in individual stalls. Alternatively, it can be prevented by giving each pig enough space so that pigs can face each other with sufficient

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<sup>6</sup> Sows have no reservoir in their udders for milk storage; instead the milk is ejected and accessible for only 20 seconds, after 60 seconds of intense piglet massaging of the udder, oxytocin release from the sow's pituitary to stimulate ejection, and 20-25 seconds of slow sucking at the udder. Following the milk ejection, piglets continue to massage the udder but this does not produce more milk. If piglets are absent at the time of milk ejection, or not in time, they miss a meal (Fraser, 1983/4; Jensen 1988). The first suckling days are decisive for piglet survival (piglet mortality is about 20 percent during this time). Survival depends on the amount of milk the piglets consume and amount of milk consumed depends on sow and piglet behavior (Castren, et al. 1989).



distance for the submissive pig to signal its submissiveness to the dominant pig by turning aside and avoiding a fight. A sufficient amount of unchopped, fresh straw in the group pen assures that pigs have something to do (root around in it, move it from place to place, make lying places, chew it) and don't fight out of boredom or irritation.

Day-to-day labor in the system consists of management to detect estrus and farrowing times, to detect problems with the pigs or the equipment, to add straw as needed, and to maintain human interaction with the pigs. About half the labor time is spent in interaction with the pigs. As the producers' knowledge and experience with their animals grow, so does their human capital of management skills and efficiency.

The Thorstensson system has been averaging 21.5 pigs weaned per sow per year (22.9 pigs born per sow per year) and feed conversion and growth rate are comparable to that in conventional systems. Conventional Swedish systems average about 18.5 pigs per sow per year. Top U.S. intensive confinement systems average between 20 and 22 pigs per sow per year.

### Conclusions

A primary motive of the type of ethological research represented by the Edinburgh and Swedish Pig Park studies is to ascertain the full behavioral repertoire of domesticated animals placed in "semi-natural" environments. A description of animals' behaviors occurring under natural conditions (i.e., using nature as mentor and model) makes it possible to produce models and ideas of how the behaviors are controlled. Predictions from the models can be tested in controlled experiments and the results can be used in the improvement of housing systems (Jensen 1988; Petersen, et al. 1990). The important element of interest for sustainability is that the ethological approach implies change, not just to a single piece of equipment or to a part of the operation, but to the entire system.

It implies a change in orientation from optimizing system productivity to optimizing animal productivity by meeting needs of animals that are not met in conventional systems.

Due to low stocking density and adequate ventilation, both the producers and the pigs enjoy good air quality in the facilities. Stress is minimized in the system so that disease incidence is low and antibiotics rarely need to be used for medication and are never used subtherapeutically. Manure is mixed with straw bedding, composted and spread on cropland, so air and water pollution are not a problem of this system and nutrients are cycled. Piglets mix with other piglets and sows, but only after a week in which they bond to their mother, reducing the possibility of cross suckling and competition from bigger pigs. Mixing with other piglets and sows helps them adjust when they are sold into other herds as fatteners and increases their chances of having "nonviolent" adjustments to new pigs which could cause stress (ethologists have speculated that the source of continuous aggressive behaviors in older pigs that fail to become socialized is the lack of opportunity to learn to defend themselves successfully against aggressors when young (van Putten 1989).) There is consistent, humane interaction between the producers and the pigs (a good relationship between producers or handlers and pigs has been shown to improve both welfare and productivity (Hemsworth and Barnett, 1987)).

In a well-designed, well-understood, and well-managed system, where animals have control over key aspects of their environments, animals' natural capabilities and inclinations, together with an informed understanding of them on the part of the animal handler, can substitute effectively for some of the labor, for some capital investments, and for some variable inputs such as fuel and routinely administered, subtherapeutic doses of antibiotics. Such systems require animal handlers -- farmers, veterinarians, or hired stockpersons -- to have a high level of management capability and knowledge of both the psychological and

physiological needs of the animals (Hemsworth and Barnett 1987; Seabrook 1980).

In traditional animal husbandry, in every culture, animal handlers gained knowledge of the biological and behavioral needs of their animals by observation and experience working with their animals. This "fund of 'silent' knowledge is comprised of knowledge of normal and abnormal behavior of several species of each age and sex of livestock" (Ekesbo 1988). Knowledge was passed from the old to the new generations of animal handlers with the result that the fund of "broad biological knowledge," human capital in the skills of effective animal husbandry, was built up by a combination of information from the older generation and new experience (Ekesbo 1988).

In extensive production systems similar to the Thorstensson system, this broad biological knowledge is still necessary to enable animal handlers to see all the symptoms of health and disease that are revealed in the animals' behaviors in different situations. However, as Ekesbo (1988) has noted, the changeover from traditional husbandry with several species to animal production systems with only one species, and even one age group, per farm means the individual farmer's own "fund of broad biological 'silent' knowledge" (his or her human capital) is disappearing. It may be difficult for modern producers to come by it, because of restrictive technologies, they can only observe their livestock in restrictive environments (e.g., crate housing for pregnant sows, gilts, and for boars, weaner cages for piglets, and battery cages for laying hens). In these cases, most normal behavioral expressions are prevented and, therefore, are unobservable. Rebuilding the lost human capital of "broad biological 'silent' knowledge" must take place before many producers will be able to adapt to production systems that give animals more control over their environments.

The Thorstensson system is one example of ethological research applied to the specific problem of designing a welfare-compatible feeder pig production system that maintains animals' productivity while also meeting other sustainability objectives (some of which, in this case, are embodied in strict Swedish laws protecting human, environmental, and animal health). The productive performance of the animals in this system also is high, implying that making our production systems more compatible with animal welfare can bring individual rewards as well as accomplish societal goals relating to designing sustainable agricultural systems.

## REFERENCES

- Algers, Bo. "Group Housing of Farrowing Sows: Health Aspects on a New System." Forthcoming presentation to Alternative Husbandry Systems Conference, Leipzig, Germany, August 1991.
- Algers, Bo. "Group Housing of Nursing Sows." Video. Skara: Swedish University of Agricultural Sciences, Faculty of Veterinary Medicine, Department of Animal Hygiene, Summer 1990.
- Algers, Bo, and Per Jensen. "Communication during Suckling in the Domestic Pig: Effects of Continuous Noise," in Applied Animal Behaviour Science. Vol. 14(1985):49-61.
- Baker, F.H., F.E. Busby, N.S. Raun, and J.A. Yazman. "The Relationships and Roles of Animals in Sustainable Agriculture and on Sustainable Farms." The Professional Animal Scientist. Vol. 6, No. 3. December, 1990:36-49.
- Baxter, M.R. "Animal Welfare from First Principles," in Farm Animal Housing and Welfare. S.H. Baxter, M.R. Baxter, and J.A.D. MacCormack, Eds. Boston: Martinus Nijhoff Publishers, 1983:1-7.
- Baxter, S.H. Discussion. Farm Animal Housing and Welfare. S.H. Baxter, M.R. Baxter, and J.A.D. MacCormack, Eds. Boston: Martinus Nijhoff Publishers, 1983:51.
- Beauchamp, E.G. "Animals and Soil Sustainability." Journal of Agricultural Ethics. December 1990.
- Brambell, F. Rogers, Chmn. Report of the Technical Committee to Enquire into the Welfare of Animals kept under Intensive Livestock Husbandry Systems. (1965) London: Her Majesty's Stationery Office, Reprinted 1974.
- Broom, Donald. "The Scientific Assessment of Animal Welfare," in Applied Animal Behaviour Science, Vol. 20, 1988:5-19.
- Brouwer, Rudi, Klaas Biersteker, Paulien Bongers, Bregt Remijn, and Danny Houthuijs. "Respiratory Symptoms, Lung Function, and IgG4 Levels Against Pig Antigens in a Sample of Dutch Pig Farms." American Journal of Industrial Medicine. Vol. 10, No. 3 (1986): 283-285.
- Business Farmer-Stockman. "Colorado Studies Environmental Effects of National Hog Farms." Scotts Bluff, NE, April 26, 1991.
- Callan, Hilary. Ethology and Society: Towards an Anthropological View. Oxford: Clarendon Press, 1970.
- Carson, T.L., K.J. Donham, M.A. Dominick, and T.A. Bertram. "Carbon Monoxide Induced Abortion in Swine: An Update," in Twenty-Third Annual Proceedings: American Association of Veterinary Laboratory Diagnosticians, 1980.

Castren, H., B. Algers, and P. Jensen. "Occurrence of Unsuccessful Sucklings in Newborn Piglets in a Semi-Natural Environment." Applied Animal Behaviour Science 23(1989:61-73.

Center for Rural Social Development. Draft Report, in Process. University of Minnesota, 1991.

Cohen, Mitchell L. and Robert V. Tauxe. "Drug-Resistant Salmonella in the U.S.: An Epidemiological Perspective." Science. Vol. 234. November 1986:964-969.

Council for Agricultural Science and Technology. Alternative Agriculture: Scientists' Review. Special Publication No. 16, July 1990. Ames: Council for Agricultural Science and Technology, 1990.

Crabo, Bo. Department of Animal Science, University of Minnesota, personal communication, January 1991.

Curtis, Stanley. "The Air They Breathe May Cause Disease." Hog Farm Management. April, 1985:34-5.

Curtis, Stanley. "Gestation System May Revolutionize Sow Housing." National Hog Farmer. April 15, 1990:54-56.

Curtis, Stanley. "Management and Environment Considerations for Successful Use of Repartitioning Agents." The Repartitioning Revolution: Impact of Somatotrophin and Beta Andrenergic Agonists on Future Pork Production. University of Illinois, Pork Industry Conference. December 10-11, 1987. Urbana-Champaign: University of Illinois College of Agriculture, 1987.

Curtis, Stanley. "Stress Related to Animal Handling." Systems Approach to Animal Health and Production: A Symposium. Fred W. Knapp, ed. Lexington, KY: College of Agriculture, University of Kentucky, 1981:196-202.

Curtis, Stanley, Robert J. Hurst, Harold W. Gonyou, Aldon H. Jensen, and Arthur Meuhling. "The Physical Space Requirement of the Sow." Journal of Animal Science. May 1989. Vol. 67, No. 5:1242-1248.

Dantzer, R., P. Mormede, and J.P. Henry. "Physiological Assessment of Adaptation in Farm Animals." Farm Animal Housing and Welfare. S.H. Baxter, M.R. Baxter, and J.A.D. MacCormack, Eds. Boston: Martinus Nijhoff Publishers, 1983a:1-7.

Dantzer, R., P. Mormede, and J.P. Henry. "Significance of Physiological Criteria in Assessing Animal Welfare," in Indicators Relevant to Farm Animal Welfare: Seminar in the CEC Programme of Coordination of Research on Animal Welfare. November 9-10, 1982. D. Smidt, Ed. Boston: Martinus Nijhoff Publishers 1983b.

Donham, Kelley J. "Hog Dust Clouds Producers' Lungs." Pork Producers Reference. March 1982:8-9.

Donham, Kelley J. "Prologue: Agricultural Occupational and Environmental Health: Policy Strategies for the Future." American Journal of Industrial Medicine. Vol. 18, No. 2. (1990):107-119.

Donham, Kelley J. and Kim E. Gustafson. "Human Occupational Hazards from Swine Confinement." Annual American Conference of Governmental Industrial Hygienists. Vol. 2, 1982:137-142.

Donham, Kelley J., James A. Merchant, Deborah Lassise, William J. Pependorf, and Leon F. Burmeister. "Preventing Respiratory Disease in Swine Confinement Workers: Intervention Through Applied Epidemiology, Education, and Consultation." American Journal of Industrial Medicine. Vol. 18, No. 3 (1990):241-261.

Donham, Kelley J., Donald C. Zavala, and James Merchant. "Acute Effects of the Work Environment on Pulmonary Functions of Swine Confinement Workers," in American Journal of Industrial Medicine. Vol. 5, 1984:367-375.

Easterling, Edward H., Curtis H. Braschler, and John A. Kuehn. Structural Characteristics and Market Power in the Broiler Industry. WP 1985-14. Columbia: University of Missouri, Department of Agricultural Economics, 1985.

Ekesbo, Ingvar. "Animal Health Implications as a Result of Future Livestock and Husbandry Developments." Applied Animal Behaviour Science. Vol. 20, 1988:95-104.

Fox, Michael W. Farm Animals: Husbandry, Behavior, and Veterinary Practice: Viewpoints of a Critic. Baltimore, MD: University Park Press, 1984.

Fox, Michael W. Toward a Humane Sustainable Agriculture. Washington, DC: Humane Society of the U.S., 1988.

Fraser, David. "The Role of Behavior in Swine Production: A Review of Research." Applied Animal Ethology. 11(1983/4):317-339.

Gallo, Anthony E., et al. Food Marketing Review 1987. Agricultural Economic Report 590. Washington, DC: Commodity Economics Division, Economic Research Service, U.S. Department of Agriculture, August 1988.

Hahn, G. LeRoy. "Compensatory Performance in Livestock: Influences on Environmental Criteria," in Livestock Environment II: Proceedings of the Second International Livestock Environment Symposium. April 20-23, 1982, Iowa State University. St. Joseph, MI: American Society of Agricultural Engineers, 1982:285-294.

Halverson, Marlene. Farm Animal Welfare: Crisis or Opportunity for Agriculture? Staff Paper P91-1; Fourth Printing. St. Paul, MN: Department of Agriculture and Applied Economics, University of Minnesota, May 1991.

Harrison, Ruth. Animal Machines: The New Factory Farming Industry. London: Vincent Stuart Ltd. 1964.

Hassebrook, Chuck. Center for Rural Affairs, Walthill, Nebraska. Personal Communication, January 1991.

Hayenga, Marvin, and John McDaniel. "Restructuring in the Packing Industry." Hog Farm Management. December 1987.

Hemsworth, P.H. and J.L. Barnett. "The Human-Animal Relationship and its Importance in Pig Production," in Pig News and Information. Vol. 8, No. 2, June 1987.

Henderson, Ruth, and A. Stolba. "Incidence of Oestrus and Oestrous Trends in Lactating Sows Housed in Different Social and Physical Environments." Applied Animal Behaviour Science. 22(1989):235-244.

Honeyman, Mark. "Sustainable Swine Production," in Extending Sustainable Systems: A Training Conference on Sustainable Agriculture. St. Paul, MN: University of Minnesota Extension Service, May 9-10, 1990.

Institute for Southern Studies. "Inside the Slaughterhouse." Southern Exposure. Vol 17, No. 2. Summer 1989:27-30.

Jackson, Bill. "Weld Warns Hog Farm: National Farms Ordered to Cut Down Nitrate Levels." Greeley Tribune. June 11, 1991:1A.

Jensen, Per. "Maternal Behaviour of Free-Ranging Domestic Pigs: Results of a Three-Year Study." Report 22. Skara: Swedish University of Agricultural Sciences, Faculty of Veterinary Medicine, Department of Animal Hygiene, 1988.

Jensen, Per. "Observations on the Maternal Behaviour of Free-Ranging Domestic Pigs." Applied Animal Behaviour Science. Vol. 16 (1986):131-142.

Jensen, Per, K. Floren, and B. Hobroh. "Peri-parturient Changes in Behaviour in Free-Ranging Domestic Pigs." Applied Animal Behaviour Science. Vol 17, 1987.

Johnson, Hugh. Farm Animals. American Farm Bureau Federation, November 1989.

Juffer, Virginia. Department of Rural Sociology, Center for Rural Social Development, University of Minnesota. Personal communication, June 1991.

Kilgour, Ron. "Stress and Behaviour: An Operational Approach to Animal Welfare," in Farm Animal Housing and Welfare. Baxter, et al. Eds. Boston: Martinus Nijhoff Publishers, 1983:45-50.

Lorenz, Konrad. The Waning of Humaneness. Boston: Little, Brown, & Co., 1987.

Marshall, Randy. "Hog Farm Wells Show Rising Nitrates." Greeley Tribune, December 20, 1990.

Marx, James J., Judith Guernsey, Dean A. Emanuel, James A. Merchant, Donald P. Morgan, Michael Kryda. "Cohort Studies of Immunologic Lung Disease Among Wisconsin Dairy Farmers." Amer. Journal of Industrial Medicine. 18(1990) No. 3, 263-268.



- McMahon, Karen Brown. "Enter: The Sustainable Sow." Hogs Today. October 1990:16-17.
- McFarlane, J.M., K.E. Boe, and S.E. Curtis. "Turning and Walking by Gilts in Modified Gestation Crates." Journal of Animal Science 66(1988):326-333.
- Minnesota Center for Survey Research. Minnesota Farmers Survey: Results and Technical Report No. 90-8. Minneapolis: University of Minnesota, Minnesota Center for Survey Research, May 9, 1990.
- Morris, Peter D., Steven W. Lenhart, and William S. Service. "Respiratory Symptoms and Pulmonary Function in Chicken Catchers in Poultry Confinement Units." American Journal of Industrial Medicine. Vol. 19, No 1. (1991):195-204.
- National Research Council. Alternative Agriculture. Washington, DC: National Academy of Sciences, 1989.
- Oppedal, Al. "Issues of the Nineties." Hog Farm Management. December 1988:30-36.
- Pearce, Neil, and John S. Reif. "Epidemiologic Studies of Cancer in Agricultural Workers." American Journal of Industrial Medicine. Vol. 18, No 2. (1990):133-148.
- Petersen, Volker, Boel Recen and Klaus Vestergaard. "Behavior of Sows and Piglets During Farrowing under Free Range Conditions." Applied Animal Behaviour Science. 26(1990):169-179.
- Preuschen, G. "Air Pollution and Human Work Capacity." Livestock Environment: Proceedings of the International Livestock Environment Symposium. April 17-19, 1974. Lincoln, NE. St. Joseph, MI: American Society of Agricultural Engineers, 1974:195ff.
- Pursel, Vernon. "Potential for Inserting the Somatotropin Gene into the Swine DNA: Long Term Goals and Implications." The Repartitioning Revolution: Impact of Somatotrophin and Beta Andrenergic Agonists on Future Pork Production. University of Illinois, Pork Industry Conference. December 10-11, 1987. Urbana-Champaign: University of Illinois College of Agriculture, 1987.
- Pursel, Vernon, Carl A. Pinkert, Kurt F. Miller, Douglas J. Bolt, Roger G. Campbell, Richard D. Palmiter, Ralph L. Brinster, and Robert E. Hammer. "Genetic Engineering of Livestock." Science. June 16, 1989.
- Rachels, James. Created from Animals: The Moral Implications of Darwinism. New York: Oxford University Press, 1990.
- Regan, Tom. Ed. Animal Sacrifices. Philadelphia: Temple University Press, 1986.
- Rylander, Ragnar. "Lung Diseases Caused by Organic Dusts in the Farm Environment." American Journal of Industrial Medicine. Vol. 10, No. 3 (1986):221-228.
- St. Paul Pioneer Press. "Methane from Manure Pit Kills Five." July 28, 1989.

Samraus, H.H. and Schunke, B. "Behavioral Disturbances in Breeding Sows Kept in Stalls," in Wein. Tierarztl. Mschr., 69 (1982):200-208.

Scottish Farm Buildings Investigation Unit. Does Close Confinement Cause Distress in Sows? A Review of the Scientific Evidence Commissioned by the Athene Trust. Aberdeen, United Kingdom: Scottish Farm Buildings Investigation Unit, 1986.

Seabrook, Martin F. "The Psychological Relationship Between Dairy Cows and Dairy Cowmen and its Implications for Animal Welfare." International Journal for the Study of Animal Problems. 1(5):1980:295-298.

Steele, N.G., R.G. Campbell, T.J. Caperna, J.P. McMurtry and M.B. Solomon. "PST Efficacy in North America: Management Variables and Advantages." Mimeo, U.S. Department of Agriculture, 1987.

Stolba, Alex. "A Family System in Enriched Pens as a Novel Method of Pig Housing." Alternatives to Intensive Husbandry Systems. R. Ewbank, ed. UFAW Conference, Potters Bar. Potters Bar, UK: Universities Federation for Animal Welfare, 1981:52-67.

Stolba, Alex. "Designing Pig Housing Conditions According to Patterns of Social Structure." Presentation to a Conference on Pigs, Perth, organized by the Scottish Agricultural Colleges and the Meat and Livestock Commission, 1982.

Stolba, Alex. "The Pig Park Family System: Housing Designed According to the Consistent Patterns of Pig Behaviour and Social Structure." Conference on the Human-Animal Bond, Minneapolis, MN: June 1983.

Stolba, A., R. Henderson, and B. Wechsler. "The Influence of Different Social and Physical Environments on the Incidence of Lactational Oestrus in Sows." Applied Animal Behaviour Science. 27(1990):269-276.

Tauxe, Robert V. "Anti-Microbial Resistance in Human Salmonellosis in the U.S." Journal of Animal Science. 62(Suppl.3) 1986:65-73.

Tillon, J.P. and F. Madec. "Diseases Affecting Confined Sows. Data from Epidemiological Observations." Ann. Rech. Vet. 15(2) 1984:195-199.

Universities Federation for Animal Welfare (UFAW). The UFAW Handbook on the Care and Management of Farm Animals. Edinburgh: Churchill Livingstone, 1971.

U.S. Congress. "Here's the Beef: Underreporting of Injuries, OSHA's Policy of Exempting Companies from Programmed Inspections Based upon Injury Records, and Unsafe Conditions in the Meatpacking Industry." 42nd Report by the Committee on Government Operations, March 30, 1988. Washington, DC: 100th Congress, Second Session.

Van Arsdall, Roy N. and Kenneth E. Nelson. Economies of Size in Hog Production. Technical Bulletin 1712. Washington, DC: Economics, Statistics and Cooperatives Service, U.S. Department of Agriculture, 1985.

van Putten, G. "Farming Beyond the Ability of Pigs to Adapt." Applied Animal Behaviour Science. 20(1988).

van Putten, G. "The Pig: A Model for Discussing Animal Behaviour and Welfare." Applied Animal Behaviour Science. 22(1989):115-128.

Wiepkema, P.R. "Umwelt and Animal Welfare." Farm Animal Housing and Welfare. S.H. Baxter, M.R. Baxter, and J.A.D. MacCormack Eds. Boston: Martinus Nijhoff Publishers, 1983.

Wiepkema, P.R., G.M. Cronin, J.M. Van Ree. "Stereotypies and Endorphins: Functional Significance of Developing Stereotypies in Tethered Sows." Proceedings of the International Congress on Applied Ethology in Farm Animals. Federal Ministry of Food, Agriculture, and Forestry, Bonn, West Germany. Kiel: KTBL, 1984:93-96.

Wood-Gush, David G.M. Elements of Ethology. London: Chapman and Hall, 1983.

Zartman, D.L. "Intensive Rotational Grazing with Seasonal Dairying." Extending Sustainable Systems: A Training Conference on Sustainable Agriculture. St. Paul, MN: University of Minnesota Extension Service, May 9-10, 1990.

## APPENDIX

Public interest in alternatives to production in the intensive, indoor confinement systems of animal rearing that, since the 1950's, had become popular in Europe and North America grew as the public became aware of the sometimes poor conditions under which animals were kept in these systems. But the interest was given voice in a book by Ruth Harrison entitled Animal Machines: The New Factory Farming Industry, published in the United Kingdom in 1964.

The immediate impact of this book on the British consuming and producing public caused the British government to set up a committee of experts in government service and universities to investigate the conditions under which animals were kept in intensive husbandry systems and report its findings and recommendations. This committee, later known as the Brambell Committee, began its work in July, 1964. The committee members received evidence from a broad range of organizations and individuals and visited intensive animal-production units in the United Kingdom, Denmark, and the Netherlands. The committee's report, Report of the Technical Committee to Enquire into the Welfare of Animals kept under Intensive Livestock Husbandry Systems, was published in November, 1965.

The committee considered each farm animal species separately and made recommendations designed to safeguard its welfare. Having seen many systems in which these basic freedoms were not available, the committee specified that a production animal at minimum should have the five basic freedoms to 1) turn around; 2) groom itself; 3) get up with ease; 4) lie down with ease; and 5) stretch its limbs. In addition, the committee stated its disapproval of "a degree of confinement which necessarily frustrates most of the major activities which make up an animal's behavior" (Brambell 1974); it specifically

rejected the argument that productivity indicates contentment; it discussed the importance of good husbandry to animal welfare; and it recommended scientists study animal behavior as a way of learning about the effects of intensive systems on animals' welfare.

As a result of the committee's report, a Farm Animal Welfare Advisory Committee was formed by the British Government in 1966. In 1968, The Agriculture (Miscellaneous Provisions) Act was passed by the British Parliament, also as a result of the Brambell Committee recommendations. The Act provided for the preparation of codes containing recommendations for the welfare of livestock. The Farm Animal Welfare Advisory Committee was charged with the production of these codes of practice covering the main species of farm livestock. The codes were presented to Parliament and approved in 1969.

Both the Brambell Committee Report and the Agriculture Act of 1968 were firsts in regard to their response to public concerns about the welfare of farm animals. The Brambell Committee Report was the "first careful examination and frank discussion of the welfare aspects of intensive animal-husbandry in any country" and the Act was acclaimed as "a landmark in farm animal welfare, not only in the British Isles, but for all developed countries" (UFAW 1971).

Another significant outcome of the Brambell Committee Report was the formation of the international Society of Veterinary Ethology in 1967. With the establishment of this society, for the first time, the science of ethology (animal behavior), previously focused on the study of undomesticated animals in the wild, was turned to the study of domesticated animals. Basic and applied research was designed for the purpose of identifying indicators of well-being and distress in various production environments and identifying key behavioral activities and requirements of farm animals. The society's formation met another expectation of the Brambell Committee, that "the evaluation of welfare must consider the

scientific evidence available concerning the feeling of animals that can be derived from their structure and functions and also from their behaviour."

The first such ethological experiment with pigs was begun in 1978 as a cooperative experiment by David Wood-Gush and Alex Stolba at the Edinburgh School of Agriculture (Stolba 1981; 1982; 1983). Known as the Pig Park Family System, the experiment consisted of observing the activities of domesticated Large White pigs released into a partially wooded, partially pasture and marsh enclosure. It was known that if the motivation of the animal (to build a nest, for example) and the availability of key stimuli in the environment (dry grass and twigs, proper position of bushes) did not correspond, the animal, perceiving that the environment was not quite right to satisfy its motivation (to build the nest), would engage in exploratory behavior to find the right environment and materials. In environments where the key stimuli are not present (e.g., barren pen without straw), the unsatisfied motivation will lead to heightened arousal, stereotypical and, if other animals are present, socially redirected behaviors which could have harmful consequences (e.g., fighting, tail biting, and other vices). The hypothesis of the Stolba-Wood-Gush experiment was that if these key stimuli could be identified, the production environment could be qualitatively enriched to include the various key stimuli for each species (in this case, for swine) and enable the performance of the important behavioral sequences, preventing the destructive redirection of frustrated behavior patterns.

The observations made in Pig Park laid to rest a good many misconceptions, including the notion that instinctive behaviors, and thus, behavioral needs, had been bred out of domestic livestock by modern genetics. Very quickly, the pigs introduced into Pig Park adapted to their "natural" environment.

Among the most important activities Wood-Gush and Stolba observed were nest site seeking and nest building by pregnant sows. Other "natural" behaviors included nest site seeking and building for night rest, social organization and interactions, territorial marking, rooting, and exploratory behaviors. From their work, Stolba and Wood-Gush drew conclusions about what elements might be changed in the production environment to improve pigs' welfare. It was also first learned from their work that, by duplicating certain natural conditions in the production environment, estrus could be induced while sows were still lactating. The sows could be bred then, litters per sow per year could be increased over those produced in conventional production systems, and weaning could be accomplished more gradually, giving the piglets a better start.

Stolba took his work to Zurich and simultaneously at Edinburgh and Zurich researchers continued with design and development of a Pig Family Pen that could be adapted to commercial systems and still retain some of the benefits of the more "natural" system. The work has been carried on by colleagues since Stolba's death in 1987 (Stolba, et al. 1990; Henderson and Stolba 1989). Development of a commercially-adaptable family pen style housing system designed to meet important ethological requirements of the pig is nearing completion.

Nearly three and a half decades of animal welfare research have been conducted since 1967 in Western Europe and Scandinavia and to a limited extent in Canada, Australia and the U.S.