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Assessing Animal Well-Being: Common Sense, Uncommon Science

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Summary

The scientific assessment of the well-being of an animal involves finding indicators of three broad criteria: 1) a high level of biological functioning; 2) freedom from suffering in the sense of prolonged fear, pain, and other negative experiences; and 3) positive experiences such as comfort and contentment. The tools available to assess animal well-being include a mixture of common sense and cutting-edge science. Measures of animal productivity can help to assess an animal's level of biological functioning, but they need to be used with care. Among veterinary approaches, pathology detects breakdown in biological functioning, while epidemiology identifies the circumstances under which such breakdown is likely to occur. Useful physiological approaches include 1) "pre-pathological" states such as reduced immune competence, which are predictive of breakdown of biological functioning, and 2) corroborative measures of short-term negative experiences such as fear and pain. Behavioral approaches include the study of abnormal behavior, expression of emotions, environmental preference tests, and various approaches to studying motivation strength, which provide insights into the animals' positive and negative reactions to its environment. As well as contributing to the assessment of well-being, research is needed on how well-being is related to values, economics, and regulation. Research must also support the development of alternative housing and management systems which will be positive for both animals and animal producers.

Introduction: Values and Goals in Research on Animal Well-Being

To paraphrase Broom (1988, 1991), the "welfare" of an animal can be defined as:

> its state as regards its attempts to cope with its environment, and refers to how much has to be done to cope, and how well or how badly coping attempts succeed.

Broom (1988) also states that the welfare of an individual can be assessed precisely in a scientific way, without the involvement of moral considerations.

It is instructive to compare this definition with definitions of other scientific terms, such as "viscosity,"

> a property of liquids that causes them to resist flowing as a result of internal friction from the fluid's molecules, usually measured by letting the fluid flow through a narrow capillary tube,

or "basal metabolic rate,"

> the rate of energy expenditure of an animal at rest, often expressed as the output of Calories per unit of body surface per hour.

On the surface, the definition of "animal welfare" (or "animal well-being," to follow the convention I am adopting[1]) sounds much like the definitions of viscosity or basal metabolic rate, but a little reflection reveals that it really tells us very little about what animal well-being involves or how it can be assessed or expressed.

The inadequacy of such definitions is perhaps best explained by Tannenbaum (1991), who argues that we cannot treat animal well-being simply as a scientific variable because it is a concept where values are inextricably involved. Tannenbaum points out, first, that in any normal sense of the word, well-being is inherently value-laden because, unlike viscosity or metabolic rate, it implies something conducive to a *better* or *preferable* life. Second, the different definitions of animal well-being proposed by scientists involve differences in values. Whether well-being requires merely "absence of suffering" (i.e., absence of certain negative conditions) or "complete mental and physical health" (a much more demanding criterion) involves a value judgement on what is important for a better or preferable life. Third, human values and biases are inextricably entwined with the scientific assessment of well-being because the measures we choose, and how we interpret them, depend on what we feel is important for animal well-being. This does *not* mean that we cannot do objective scientific studies in assessing well-being. For example, housing sows in raised farrowing crates has many different effects (on piglet survival, plasma cortisol levels in the sow, farrowing behavior, disease transmission, and so on) which we can study as objectively as other scientific variables; but how we use them to interpret well-being, and even which ones we choose to study, reflect a value judgement on what we feel is important for the well-being of animals.

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[1] Confusion over when to use "animal welfare" versus "animal well-being" continues to dog discussions such as this. I perceive four approaches. The *lexical* approach considers "welfare" and "well-being" interchangeable, as supported by dictionary definitions. The *timorous* approach uses "well-being" because "welfare" sounds like a political hot potato. The *subtle* approach (suggested to me by Jerrold Tannenbaum) recognizes different shades of meaning, with "welfare" referring more to the long-term good of the animal and "well-being" referring more to the animal's short-term state, especially how the animal feels; thus, a painful vaccination may enhance an animal's welfare but reduce its feelings of well-being. The *pragmatic* approach tries to reduce confusion by using "well-being" to refer to the state of the animal and "animal welfare" to refer to the broader constellation of social and ethical issues. I will follow the pragmatic approach, except when quoting or discussing the work of others who use a different convention.

It follows that in order to decide how to assess the well-being of animals, we first need to decide what we hold as the important components of well-being. As space precludes a detailed discussion of this fundamental issue, I will simply outline three broad criteria intended to incorporate the thinking of many other workers.

First, well-being[2] implies a high level of biological functioning. The animals should be free from disease, injury, and malnutrition. They should be thriving, without significant checks on normal growth, and without reliance on pharmaceutical intervention to compensate for unsuitable environments. An unresolved issue is whether the animals should also be free from genetic traits, produced by selective breeding, which interfere with normal health and functioning.

Second, well-being implies freedom from suffering in the sense of prolonged pain, fear, distress, discomfort, hunger, thirst, and other negative experiences. Short-term negative states, such as short-term pain, hunger, and anxiety, are virtually inevitable in animal life, and the border-line between acceptable and unacceptable will remain a source of debate.

Third, well-being implies that the animals should have positive experiences, such as comfort and contentment, and freedom to engage in presumably pleasurable activities, such as play and exploration. This aspect is likely to cause the most controversy. Animal welfare scientists recognize the difficulty of studying positive states such as contentment (Fraser and Broom, 1990). Scientists in the behaviorist tradition may dismiss such states as outside the realm of science or deny that animals experience such states at all (Rollin, 1990). On the other hand, many people who have worked closely with animals consider it ludicrous to deny, for example, that dogs *enjoy* playing or that cats *derive pleasure* from being stroked. For such people, depriving animals of pleasure is one of the fundamental issues in animal well-being (see Harrison, 1964). Hence, despite the difficulty of studying states such as contentment, we cannot realistically exclude them from our criteria for well-being.

Thus, we can conceptualize the assessment of animal well-being as three goals, summarized in the three columns of Figure 1: recognizing a high level of biological functioning, detecting suffering or other negative experiences, and detecting contentment and other positive experiences. The following sections review the scientific tools commonly used to achieve these three goals.

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[2] Another linguistic clarification: Here I am using "well-being" in the dictionary sense of a good or satisfactory condition of existence. Elsewhere I refer to a certain "level of" well-being and thus use the word for a kind of continuum, running from high to low, pertaining to *how* good or satisfactory an animal's condition is. This may occasionally cause confusion, but, as Broom (1988) clearly recognized, we do not have any suitable term for the continuum, and using "well-being" in this dual sense fills the need. A comforting precedent is the word "health," which means both 1) freedom from illness and injury and 2) the general condition of an organism with reference to freedom from illness and injury.

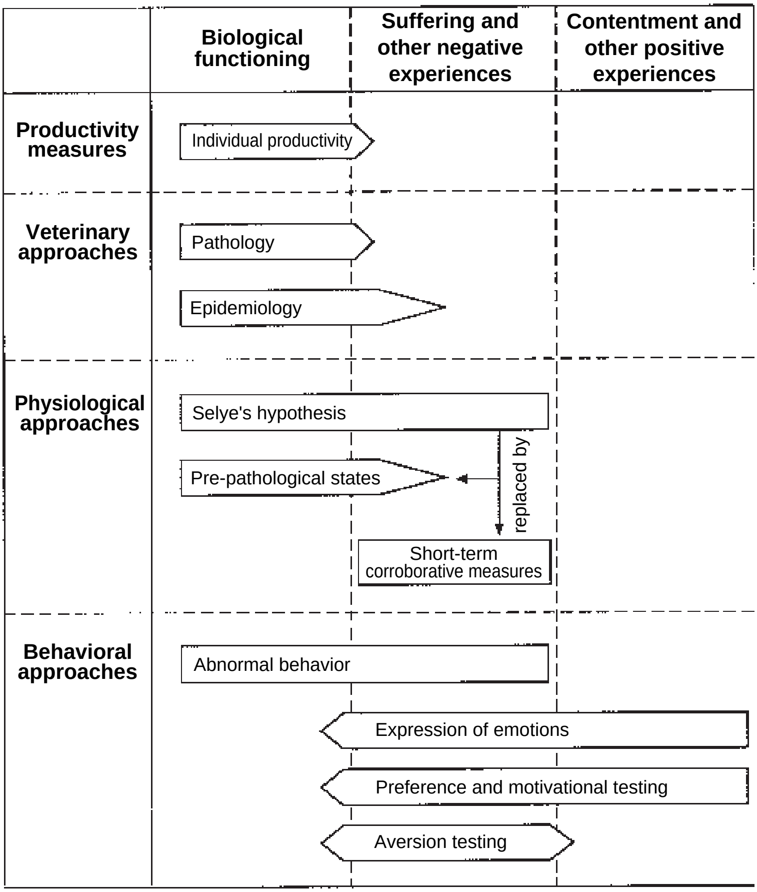

Figure 1.

A conceptual framework in which the assessment of animal well-being is seen as three goals: recognizing a high level of biological functioning, detecting suffering and other negative experiences, and detecting contentment and other positive experiences. Scientific approaches are placed according to their primary contribution, with arrows indicating additional implications.

Brief summary: Individual productivity can reflect biological functioning, with reductions in productivity having possible implications for suffering and other negative experiences. Pathology indicates breakdown in biological functioning, with likely implications for suffering. Epidemiology, by identifying conditions conducive to disease, not only detects biological breakdown, but also situations likely to involve suffering or discomfort which have not yet led to clear pathology. Selye's (1950) hypothesis saw the General Adaptation Syndrome as a non-specific response to "stress," including both biological challenge and negative psychological states. Moberg (1987) advocates identifying "pre-pathological states," predictive of some breakdown in biological functioning. Physiological measures of short-term arousal (e.g., increased heart rate) can also be used to corroborate and quantify negative experiences (e.g., fear). Abnormal behavior is a form of biological breakdown generally thought to be caused by negative psychological states. Expressions of emotions and testing of animal preferences and motivation reflect both positive and negative experiences of animals. Aversion testing detects negative experiences. Assuming that emotions, preferences, and aversions help animals to avoid unfavorable situations, these measures also have likely implications for avoiding breakdown of biological functioning.

Productivity and Well-Being

In agricultural contexts, productivity measures such as rate of growth or reproduction are traditional indicators of biological functioning, and those who identify well-being closely with biological functioning may argue that high productivity is by itself adequate assurance of a high state of well-being. The link between well-being and productivity is probably very real at low levels of productivity, where depressed health, growth, reproduction, and survival indicate significant problems with normal functioning, and Hurnik (1993) argues that longevity effectively integrates many different aspects of biological functioning. Up to a point, then, agriculturalists are right to hold that improved survival and growth, achieved through changes such as improved nutrition and protection from harsh weather, indicate positive contributions to well-being.

However, productivity measures must be used with great caution. Consider, for example, a standard cage for laying hens measuring 30.5 by 50.8 cm. As the number of birds per cage is increased from three to five, productivity per bird is depressed and the mortality rate increases (Adams and Craig, 1985), clearly indicating reduced well-being. Nonetheless, calculations show that the most profitable stocking rate is often four birds and occasionally even five birds per cage, depending on the relative costs of eggs, feed, and birds (Adams and Craig, 1985; Roush, 1986). The relationship between productivity and well-being is also obscured by many confounding factors (Sambraus, 1981b), including use of antibiotics to avoid disease in sub-optimal environments and strong genetic selection for certain productivity traits which may have weakened the link between these traits and other aspects of biological functioning. Luescher et al. (1989) distinguish between “economic performance” (i.e., performance with respect to specific economically important production traits) and broader “biological performance,” and note that the two are not always compatible.

Perhaps because productivity arguments are often misused to support the status quo, they have been ignored too often in assessing alternative management systems. Most piglet deaths occur either from starvation or accidental injury, both of which are obvious animal welfare problems. Alternative management systems are sometimes proposed as high-welfare systems, even though they involve a much higher level of piglet mortality than would be seen on a well-run confinement unit (e.g., Kerr et al., 1988). In such cases, productivity measures have arguably received too little attention as welfare indicators. With suitable research and development, such alternatives may well become high-welfare systems, but such a claim seems premature when glaring problems remain in productivity-related indicators of well-being.

Veterinary Approaches

Traditional veterinary studies of the incidence of disease and injury are obvious indicators of biological functioning.

Pathology is the study of failure of biological functioning. Examples relevant to the assessment of well-being include studies linking injury to housing conditions (e.g., Edwards and Lightfoot, 1986; Furniss et al., 1986), respiratory tract lesions to air quality (e.g., Anderson et al., 1968), and gastro-intestinal lesions to management and nutritional factors (e.g., Muggenburg et al., 1967). Studies of foot abnormalities, plumage condition, and accidental death have led to significant changes in poultry cage design which have improved both well-being and productivity (e.g., Tauson, 1984, 1985).

Epidemiology goes further by identifying circumstances in which certain failures in biological functioning are likely to occur. In a pioneering study, Bäckström (1973) surveyed Swedish swine herds and found that mortality and disease rates were related to such management variables as the type of flooring, manure handling system, and degree of confinement of the sow. Numerous studies have shown that the incidence of bovine mastitis is influenced by the physical environment, including stall length and width, drafts, use and type of bedding, use of cow trainers, and restriction of movement by tying or manger design (International Dairy Federation, 1987). The best such studies use the statistical sophistication of modern epidemiology to identify and explore interactions among relevant factors. For example, Martin (1983) showed that the likelihood of calves developing bovine respiratory disease is increased by mixing calves from different farms, by large group size, by certain changes of diet, and by early exposure to the stress of castration and dehorning.

Physiological Approaches

It has been recognized at least since the work of Cannon (1929) that physiological events reflect an animal’s emotional state. The “physiology of stress” received a major impetus from a bold hypothesis by Selye (1950), who found that a variety of what he called “stressors,” including physical restraint, exposure to cold, and injection of harmful substances, produced several characteristic bodily changes. These were hypertrophy of the adrenal glands, involution of the thymus and lymph nodes, and gastric ulcers, which Selye grouped under the name “General Adaptation Syndrome.” Selye theorized that the activation of the anterior pituitary and adrenal cortex, with increased secretion of the hormone ACTH and glucocorticoids, had (in the words of Mason, 1968) “a unique, pre-eminent, and non-specific” relation to stress. Thus it appeared that the General Adaptation Syndrome would reflect both challenges to biological functioning and unpleasant psychological states. Applied workers seized on this hypothesis, with the result that increased secretion of glucocorticoids and changed responsiveness of the adrenal cortex to ACTH have been widely used as alleged measures of stress in a wide range of studies of animal housing and management methods (e.g., reviews by Dantzer and Mormède, 1983; Moberg, 1987; Barnett and Hemsworth, 1990; Rushen and de Passillé, 1992).

Selye’s “General Adaptation Syndrome” was not a beautiful theory murdered by ugly facts, but rather a starry-eyed simplification jilted by the complexities of real life. The uncooperative complexities number at least five.

First is the sheer complexity of physiological responses to distressing events. Classical stressors affect not only the adrenal cortex but practically all major endocrine systems of the body (Mason, 1968) together with other widespread effects on reproduction, immunity, and metabolism (Moberg, 1985).

For example, Farmer et al. (1991) showed that acute restraint of pigs leads to changes in all of the seven hormones they studied, each following its own temporal pattern.

Second, increased glucocorticoid output is not specific to unpleasant situations (Moberg, 1985). It can also occur after exposure to a novel environment (Dantzer and Mormède, 1983), after exercise (Arave et al., 1978), and after such presumably pleasant activities as mating and nursing (see Rushen and de Passillé, 1992).

Third, the non-specific nature of the glucocorticoid response to bodily challenge seems to have been misconstrued. Work by Mason and others (see Dantzer and Mormède, 1983; Moberg, 1985) has shown that glucocorticoid secretion is increased by a wide range of stressors (e.g., cold, heat, fasting) mainly because the experimental situation generally evokes an emotional reaction in the animal. If the emotional reaction is eliminated, then the increased glucocorticoid secretion may not occur. For example, chronic exposure of dairy cattle to high temperatures actually reduces corticosteroid output if the exposure is done gradually and without emotional upset (Dantzer and Mormède, 1983).

Fourth is a technical difficulty identified by Ladewig and Smidt (1989), who pointed out that cortisol secretion is strongly pulsatile. In their study, bulls tethered in a housing system which interfered with normal resting behavior had higher peaks of cortisol secretion compared to controls, but the pulses of cortisol release were fewer in number. Ladewig and Smidt noted that it is not clear whether bodily responses to cortisol depend on the height of the peaks, the frequency of the pulses, or the average circulating levels. Hence, simple measures of cortisol output, which generally involve “average” levels over time periods which may involve peaks, troughs, or both, are difficult to interpret.

Finally, glucocorticoid secretion has given disappointing results when used to reflect long-term effects of housing. For hens in battery cages, compared with hens in pens, corticosteroid levels are reported to be higher, lower, or the same, depending on the study (Rushen, 1991). Ladewig and Smidt (1989) found that the altered secretory patterns of cortisol in bulls had returned to normal levels after four weeks of tethering in uncomfortable stalls despite other evidence of continued discomfort.

From Selye’s bold position, Moberg (1985, 1987) and other physiologists have sounded a prudent retreat. Because of the difficulties in interpreting changes in physiological variables such as glucocorticoid secretion, Moberg (1985, 1987) has suggested the use of “pre-pathological states” as a more useful index of well-being. Moberg notes that the biological changes induced by stressors sometimes lead to a clear pathology, such as clinical disease, failure of reproduction, or outbreaks of harmful behavior. However, such extreme breakdown of normal functioning is preceded by some “pre-pathological” condition, such as reduction of immune competence, suppression of an endocrine response fundamental to reproduction, or display of increased social aggression. Moberg (1987) considers that the full-blown pathological state is not a humane or a practical measure of impaired well-being, and he recommends the occurrence of pre-pathological states as an indicator of likely or incipient breakdown in biological functioning.

Suppression of immune competence is one of the best studied forms of pre-pathological state, and many different physiological responses to stressors impact in different ways on the immune system (Kelley, 1985; Griffin, 1989). Kelley (1985) suggests that events in the immune system effectively integrate the various hormonal and neurotransmitter responses to environmental change, and recommends such events as more realistic indices than traditional measures of blood hormone levels.

A second important application of physiological measures, stemming more directly from the work of Cannon, involves short-term indices of emotional upset. For example, the traditional method of catching broiler chickens for shipping to market has been for a handler to walk into the broiler pens, catch a number of birds, and carry them by the legs to the shipping cages. A relatively new alternative is the mechanical broiler harvester, a large machine that moves through the pens, catches birds in rotating arms, and transfers them to the cages by conveyor belt. When the broiler harvester first appeared in Britain, there was concern that the machine was inhumane. However, a radio telemetry study showed that the heart rate of birds loaded by the harvester returned to normal more rapidly than that of birds caught by human handlers. This, combined with behavioral measures of fear, suggested that the birds experienced *less* upset when moved by the machine (Duncan et al., 1986). On this basis, animal welfare advocates in Britain have begun supporting the use of broiler harvesters as a humane alternative to manual catching.

In cases such as this, the physiological measures (increased heart rate, increased catecholamine secretion, etc.) do not by themselves indicate that the animal is undergoing an unpleasant experience. However, where there is reason to believe that a short-term event does produce fear, pain, or other unpleasant states, physiological measures are useful to corroborate and quantify the animal's reactions. In fact, the increased corticosteroid output of Selye's syndrome might best be seen in the same way.

Thus we see a significant shift in the perceived relationship between physiological measures and well-being. Selye's early theorizing led people to think that we can detect all manner of unpleasant psychological states and challenges to biological functioning on the basis of increased activation of the hypothalamic-pituitary-adrenocortical system. Instead, contemporary physiologists such as Moberg suggest that physiological indices should be used more conservatively, as indicators of likely or incipient breakdown in biological functioning, together with corroborative use of physiological measures to quantify reactions to short-term events believed to be detrimental to well-being.

Behavioral Approaches

Moberg's proposal, that we should consider well-being impaired only when a change is a likely precursor to pathology, is a sensible one for dealing with physiological changes that cannot be interpreted by themselves in terms of well-being. With behavior the situation is quite different. Consider an animal confined in a small cage, where it makes loud, plaintive calls; develops repetitive, stereotyped movement patterns; and escapes whenever the door is open. Here we recognize, or can determine from simple experiments, that the animal finds the confinement aversive. In such cases, behavior provides a more direct window on the animal's own perceptions of events. For this and other reasons, the study of behavior has become central to understanding animal well-being, and a number of research approaches have emerged.

Abnormal Behavior

For animals kept on farms or in zoos, abnormal activities, such as self-mutilation, extreme aggression, or behavior that appears to denote depression, are among the most persuasive indicators of impaired well-being (Sambraus, 1981a). Tail-biting by pigs is one of many forms of abnormal behavior thought to result from a mismatch between the animal's natural behavior and restrictive environments (Sambraus, 1985; Wiepkema, 1990). An explanatory hypothesis for tail-biting (Figure 2) illustrates the complex links between this behavior and

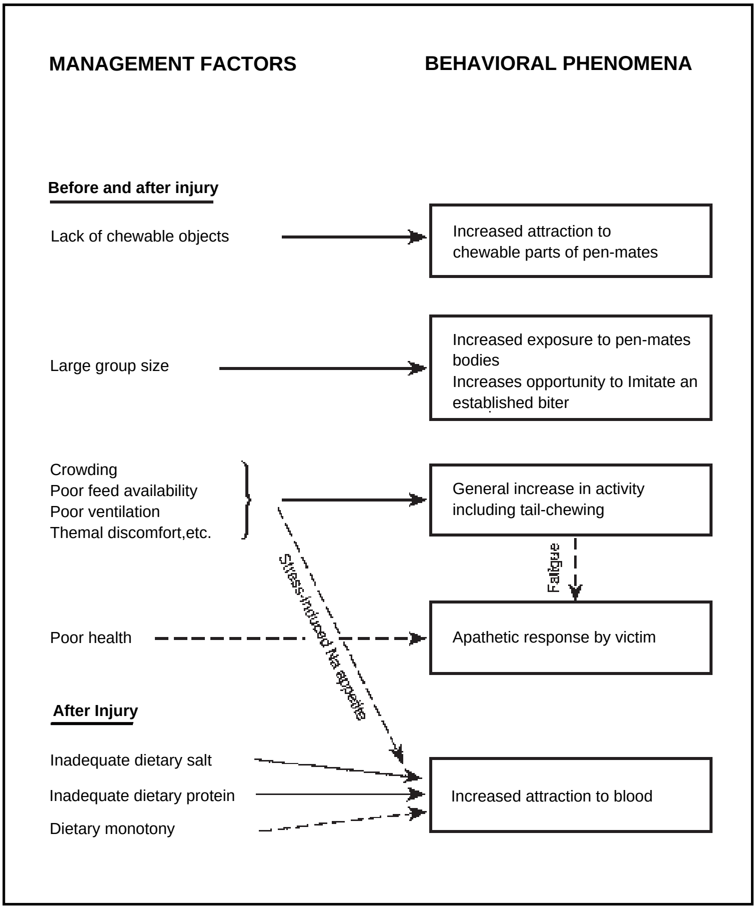

Figure 2.

Proposed explanatory model of tail-biting outbreaks by pigs, accounting for the wide range of environmental, management, and dietary factors that are believed to contribute to tail-biting (based on Fraser, 1987). (The more speculative relationships are shown as broken arrows.)

well-being. According to the hypothesis, the natural foraging and exploratory activities of pigs include rooting and chewing objects in the environment, and the animals direct this behavior to their pen-mates if more suitable substrates are not available. Most of this behavior is harmless, but the amount or intensity of the behavior can be increased by many factors, such as crowding, hunger, or discomfort, which increase restless activity. Once the behavior has led to a bleeding injury, any extreme attraction to the taste of blood, which can result from diets deficient in salt or protein, may cause the tail-biting to escalate. Thus, a high incidence of tail-biting can reflect many different problems in the animal's environment, diet, and management (Fraser, 1987). Like many other types of abnormal behavior, tail-biting is also a cause of reduced well-being among recipient animals and a source of important losses in productivity; hence, the behavior is linked to animal well-being in numerous ways (Luescher et al., 1989).

Expressions of Emotions

Another approach involves identifying behavioral signs of pain, fear, frustration, and other negative emotions (Sambraus, 1981b). For example, Duncan (1970) conducted experiments in which chickens were systematically frustrated in various ways under controlled conditions. This allowed him to identify certain signs of frustration in this species (especially displacement preening, increased aggression, and stereotyped pacing) and then search for these signs of frustration under normal husbandry conditions. More recently it has been shown that laying hens have a call that is given in response to frustrating situations, the intensity of which appears to correspond to the strength of the frustrated motivation (Wiepkema, 1990).

Environmental Preference Testing

One of the most powerful arguments in debates over animal well-being is that the animal itself prefers one environment over another (Duncan, 1978). For example, soon after a British government committee had recommended that hens in battery cages should not be housed on fine-gauge hexagonal "chicken wire" floors, Hughes and Black (1973) allowed hens to choose among different floor types and showed that the hens actually tended to prefer the fine wire flooring over other alternatives.

Since that early experiment, preference testing has been widely used in research on animal well-being, but there have been important shifts in the paradigm, including a move away from overly simplistic questions. In the 1970's it might have seemed reasonable to ask whether pigs prefer straw-bedded pens ahead of pens with bare concrete floors. Research in the intervening years has shown that pigs do prefer strawed areas for rooting and exploration, are indifferent to bedding when engaged in activities such as eating and drinking, and either prefer or avoid straw-covered floors for resting, depending on the ambient temperature (see Fraser et al., 1993). Also, because of diurnal patterns in these activities, preference for straw varies with the time of day. Thus, instead of asking simple, global questions (e.g., Do pigs prefer straw-bedded pens?), we need to ask more complex and specific questions that intercept the animals' natural behavior in more subtle ways. As questions have become more complex, response measures have become more comprehensive, and experiments have come to require more complex designs and controls (Fraser et al., 1993). Furthermore, there has been some trend away from making superficial, empirical comparisons and toward using preference testing to get at the principles underlying the animals' preferences. Thus, instead of asking whether pigs prefer one floor type or another, some work tries to identify the features used by the animals in making their choices (Farmer and Christison, 1982).

Preference testing has a number of limitations which have been reviewed by Dawkins (1980), Duncan (1992), and Fraser et al. (1993). A major shortcoming is that preference testing does not indicate the degree of importance that the animal attaches to the preferred option. Depending on what alternatives are offered, both the preferred and unpreferred options may be perfectly acceptable, or both may be seriously deficient. To deal with this problem, we need to measure the strength of the animal's attraction to the preferred option or aversion to the unpreferred. For example, after earlier work had shown that hens generally prefer litter ahead of wire floors, Dawkins and Beardsley (1986) attempted to determine the strength of the preference by requiring hens to perform a task in order to gain access to litter.

Experiments can also titrate an unknown motivation against a known motivation that can be manipulated. For example, Dawkins (1983) trained hens to enter two cages from a common choice point. One cage contained litter (to permit dust-bathing) but no food, while the other contained food but no litter. The hens were then required to choose between the two cages after different periods of food deprivation. In principle, this procedure should allow us to say that a hen's motivation to dust-bathe is, under the given conditions, about as strong as its motivation to eat when it has been without food for a certain number of hours.

A further approach blends motivation testing with a concept borrowed from economics. As summarized by Dawkins (1990), economists observe that for certain goods, an increase in price has little effect on the amount purchased by consumers. Such goods are said to have "inelastic demand" and are sometimes called "necessities." For other commodities, consumption declines as price increases. These are said to have "elastic demand" and are sometimes called "luxuries." In studies with animals, a commodity such as food can be provided in response to some work that the animal has to perform, such as pecking on a key, and this "price" can then be varied experimentally. Dawkins argues that commodities that are very important to the animal will show relatively inelastic demand. By establishing demand curves, we should be able to make a better judgement of the importance that the animals themselves attach to food, companionship, bedding, exercise, and other features. The approach has been used relatively little, perhaps because of the considerable technical and interpretational difficulties that have been identified by Dawkins (1990) and others.

Thus we see, in a sense, four generations of a research paradigm, much of it driven by the conceptual innovations of M.S. Dawkins, proceeding from straightforward environmental preference testing, to tests of motivational strength, then titration of one motivation against another, and finally attempts to establish demand elasticity. At each stage, the logical link with animal well-being arguably becomes tighter, but the difficulties of technique and the unpredictable impacts of procedural variables become more daunting. Shettleworth and Mrosovsky (1990) suggest that comparison of motivation strength and demand elasticity are so complex that they are not likely to be used widely in the near future.

Finally, aversion testing provides a way of determining the strength of an animal's motivation to avoid a situation. Immobilization by passing a pulsed, low-voltage electric current through the body had been claimed to reduce the stress experienced by animals during physical restraint for such procedures as shearing of sheep. Rushen (1986) trained sheep to move down a run-way, at the end of which they were restrained in various ways with or without electro-immobilization. Sheep given the electrical treatment became more reluctant to move down the run than those that were restrained without electro-immobilization. This indicated that, far from reducing distress, electro-immobilization made restraint more aversive.

Basic Knowledge of Behavioral Systems

To assess and improve animal well-being, we need a better understanding of the animal's basic behavior and forms of communication. For example, basic research showed that the vocalizations of the sow coordinate the behavior of the piglets during suckling. When these vocalizations are masked by noise from ventilation fans, the synchrony in piglet suckling behavior is lost (Algers and Jensen, 1985). Pigs also communicate using certain postures and movements when fighting. If space is too limited, young pigs fail to develop normal responsiveness to these postures, and abnormal fighting may persist later in life (Schouten, 1986). In mammalian farm animals, olfactory communication appears involved in such processes as modulating aggression (McGlone, 1990), establishing parental care (Poindron and Lévy, 1990), and signalling alarm (Vieuille-Thomas and Signoret, 1992); by understanding this communication we might be much better positioned to evaluate and improve animal well-being as well as productivity.

Concluding Remarks

Important as it is, scientific knowledge about the assessment of well-being is only part of what we need to resolve animal welfare problems. Figure 3 shows a conceptual framework illustrating that farm animal welfare is affected by the five interrelated factors of knowledge, values, technology, economics, and regulation. Fraser and Leonard (1993) have discussed how these five factors impact on animal welfare, with specific reference to agriculture in Canada. Here I conclude by using this framework to argue that knowledge is needed on how all of the other factors influence animal well-being.

According to a widely held view, the well-being of farm animals was protected in the past by traditional animal husbandry values, whereby concern for animals and pride of stockmanship overrode purely economic considerations. Critics of agriculture often claim that these values are rapidly being displaced by entrepreneurial values and that animal well-being is being sacrificed in the name of efficiency, mechanization, cost-cutting, and profit. Is this true? We need research to identify what values are displayed in both family- and corporation-controlled farming, whether they differ from those of the general public, and what is needed to reconcile the values inherent in agricultural practices with the values of society. Furthermore, we need research to help harmonize values related to animal well-being and other important values: humane systems of raising animals should also provide safe, pleasant environments for farm workers; they should be ecologically sound; and they should produce healthy food products at prices that make them accessible to those who need them.

Economic factors place major constraints on animal well-being, but these remain virtually unstudied. Critics of agriculture sometimes claim that farmers allow low standards of well-being in the pursuit of large profits (e.g., Singer, 1990). My own experience is often quite different: that well-motivated producers cannot improve the well-being of their animals as they would like because the profits from raising animals are too slight and unpredictable. If this is true, then perhaps we could achieve significant improvements in animal well-being through economic instruments, as an alternative to legal regulation.

A society's will to regulate can get ahead of the necessary knowledge base. Some well-motivated attempts to regulate animal rearing methods have been

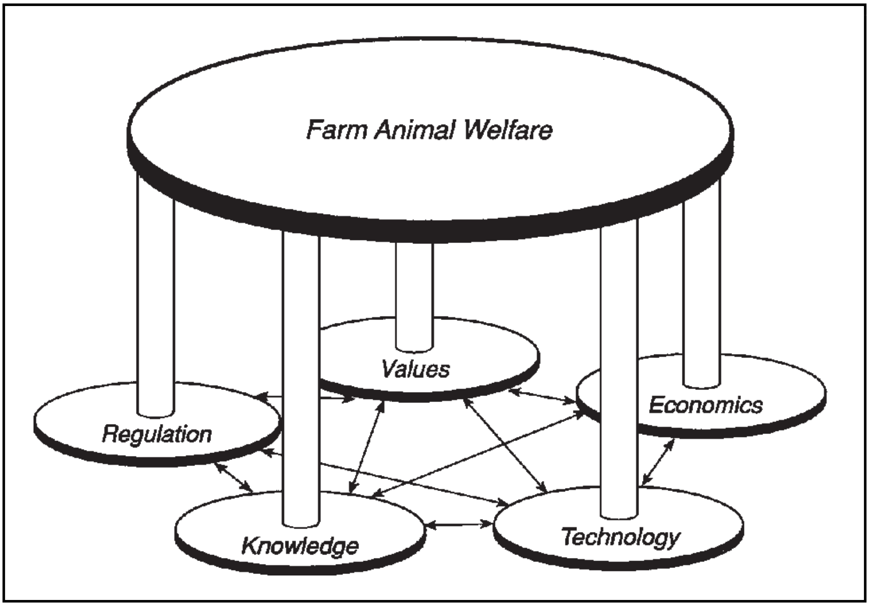

Figure 3.

Conceptual framework showing farm animal welfare as influenced by five constellations of factors (values, economics, knowledge, technology, and regulation) which are themselves interconnected in complex ways. Based on Fraser and Leonard (1993).

phrased in terms that have so little basis in science that they have proven uninterpretable (Sambraus, 1981a). For example, the European Convention for the Protection of Animals kept for Farming Purposes requires that the "ethological needs" of animals be met, even though "ethological need" is not well defined and arguably not a useful scientific concept at all (Dawkins, 1983; Hughes and Duncan, 1988). The result is that scientific research is being pursued to interpret a legal concept that may have little scientific basis. Researchers need to be proactive to generate the kind of knowledge that will allow regulations to be formulated so as to be interpretable and of genuine benefit.

Finally, research linking science and technology must not be confined to assessment of how well-being is affected by current animal rearing technologies. In all likelihood, North American society will demand significant changes in animal rearing methods before behavioral research has yielded all the answers that we would like to have and long before the complex physiological responses to bodily challenge have been well enough understood to allow confident conclusions. Hence, we need a mixed program of research whereby scientists, with the guidance of producers, consumers, and animal protectionists, proceed to develop and perfect animal rearing methods which will work well for both animals and producers and be perceived as ethically positive by society.

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