Nonhuman animal welfare is of significant public interest, globally and within the United States. Value-based judgments are intrinsic to animal welfare assessment, according to the relative weighting of factors associated with animal performance, health, affective states, and natural living. The concept of animal welfare is consistent with the scientific method because questions are open to deductive reasoning, formation of hypotheses and predictions, and collection and analysis of empirical data. Multidisciplinary techniques used in the laboratory are helpful to understanding a whole animal response to particular situations and are especially important in interpretation of data about affective states. Epidemiological techniques can be used to identify prevalence and risk factors associated with particular animal welfare challenges in field conditions and are particularly useful for motivating change and evaluating the effectiveness of interventions intended to improve animal welfare on farms. Compromised animals who are affected by injury or illness represent a vulnerable population with unique animal welfare challenges for which laboratory and field-based studies are needed.
Attitudes about the roles of nonhuman animals in society are changing, and at the same time greater proportions of the human population live in urban areas and have less direct experience with agriculture. Approximately 58% of U.S. households include companion animals, and human-animal bond has become an increasing component of companion animal veterinary practice (Brown & Silverman, 1999). Pets are often considered family members; during the emergency response efforts following Hurricane Katrina, evacuation efforts were hampered by the reluctance of residents to leave their animals behind. This prompted the U.S. federal “Pet Evacuation and Transportation Standards Act of 2006” (H.R. 3858, Pub. L. No. 109-308, §120 Stat. 1726 [2006]), enacted in 2006, which requires state and local emergency planning agencies to develop infrastructure to ensure that pets are evacuated with their owners.

The prevalence of vegetarianism is increasing but remains less than 5% of the populations: 2.8% in the United States, (Vegetarian Times, 2008); 1.5% in Australia, (Lea & Worsley, 2003); and 5–8% in European countries (Mayfield, Bennett, Tranter, & Woolridge, 2007). However, in public opinion surveys, the majority of respondents express concerns that livestock should have good standards of care. For example, in a U.S. survey commissioned by Animal Rights International, 93% of respondents agreed that “animal suffering should be reduced as much as possible, even though the animals are going to be slaughtered” (Caravan Opinion Research Center, 1995). Similarly, European surveys indicate concern about animal welfare is high, with regional differences in degree and in concern about particular practices (European Commission, 2007; Mayfield et al., 2007). In a survey funded by the American Farm Bureau, 95% of respondents agreed with the statement, “It is important to me that animals on farms are well cared for” (Norwood, Lusk, & Prickett, 2007), suggesting that compassion is a basic human value and consistent over time. Furthermore, 81% of those who responded agreed that “farm animals have roughly the same ability to feel pain and discomfort as humans.”

It is interesting that, despite these statements, well being of animals ranked poorly relative to other public concerns: Well being of animals scored 4.15 in importance versus 23.95 human poverty, 23.03 the U.S. health care system, and 21.75 food safety. This discrepancy may reflect the manner in which consumers view food-animal production, such that animal welfare concerns are integrated with public health, food safety, and environmental impacts rather than as an isolated issue (Pew Commission on Industrial Farm Animal Production, 2008).

Willingness of respondents to act on animal welfare issues appears to be high. In the American Farm Bureau survey (Norwood et al., 2007), respondents reported that the government should take an active role in promoting animal welfare (68%) and were willing to vote for a law requiring farmers to treat their animals better (75%). These results are consistent with recent voter referendum
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initiatives (Mench, 2008), whereby particular husbandry practices have been banned in some states, including the following:

1. Sow gestation stalls (Florida, 2002; Arizona, 2006; Oregon, 2007; and Colorado, 2008);
2. Veal crates (Arizona, 2006; Colorado, 2008); and
3. Foie gras production (California, 2004).

Particularly noteworthy is the response of California citizens during the November 2008 election to a proposed “Prevention of Farm Animal Cruelty Act.” Of all voters, 63% chose in favor of the ballot initiative, which will require all animals on the farm to be housed with sufficient space to lie down, turn around, and stretch their limbs freely.

Globally, there is also increasing regulation of production practices by retailers and by producers themselves, with quality assurance labels and branding of products that have specific animal husbandry criteria (Fraser, 2006; Mench, 2008). At present, farmers face a mixture of requirements, mandatory and voluntary, that vary according to the program and supply chain they are servicing (Fraser, 2006).

ANIMAL WELFARE SCIENCE—CONSIDERING THE ANIMAL’S PERSPECTIVE

Defendable animal welfare standards require scientific knowledge about animal biology to determine their physiologic, health, environmental, and behavioral requirements. However, it is important to note that ethical or value-based judgments provide the underpinning for the scientific questions posed (Croney & Millman, 2007). Historically, scientists have disagreed about how animal welfare should be assessed and the relative weight placed on different categories of parameters, in terms of biological function (Broom, 1996; Curtis, 2007), affective states or feelings (Dawkins, 1980; Duncan, 1996), and the animal’s essential nature (Barnard & Hurst, 1996; Rollin, 1995, pp. 17, 18). Conceptual frameworks have been proposed to reconcile polarized differences (Dawkins, 2004; Fraser, Weary, Pajor, & Milligan, 1997). In some cases, disagreements are rooted in the fundamental concept of Positivism, whereby science can only legitimately be applied to a tangible phenomenon for which observations can be made directly. Positivism precludes scientific scrutiny of affective states, such as pain and fear, but these are among the issues that society is struggling with when asking questions about animal welfare (Rollin, 1990). Academic debates about scientific definitions of animal welfare are fundamental for evolution of the discipline. At the same time, there are proximate needs for factual
information to enable thoughtful decision making about where certain practices are morally acceptable and whether our production systems stress animals in excess of their biological capacities and evolved behavioral strategies. The World Animal Health Organization defines animal welfare as the state of being of an individual, involving health and conditions of life, and uses terms such as “animal protection,” “animal care,” and “humane treatment” for human actions to provide for animals.

The scientific method can provide information to society upon which ethical decisions may be made. The scientific method follows logic, deductive reasoning, and transparency so that experiments can be replicated and results compared. Hence, we can attempt to understand animal experiences by examining physiologic and behavior changes during short-term responses and performance and cognitive effects during longer term responses in chronic situations. A key component is development of a testable hypothesis upon which a priori predictions can be made rather than collecting a laundry list of measurements that remain to be interpreted afterward. A criticism of animal welfare research is based on differences in outcomes by researchers from differing disciplines. For example, conclusions about the degree of suffering associated with sow gestation stalls may vary according to the parameters measured. Animal scientists may report benefits to the sow in terms of feed efficiency, body condition score, and reproductive performance. Swine veterinarians may emphasize health effects in terms of individual sows and sow population levels. Conversely, applied ethologists may report costs in terms of behavioral restriction and prevalence of stereotypies. Hence, scientists may differ in interpretation of results because of the importance placed on the parameters quantified, the relative importance placed on individuals or populations, and concerns about scientific uncertainty.

Affective states, such as fear, pain, and contentment, can only be measured indirectly and hence present challenges for both human and veterinary medicine. Multidisciplinary studies can strengthen interpretation of results, especially when data from a variety of parameters consistently point in the same direction. For example, an interdisciplinary project was developed to explore postsurgical pain associated with disbudding of dairy calves (Heinrich, 2007), including researchers with expertise in dairy health management, epidemiology, endocrinology, and applied ethology. Disbudding involves removal of the horn bud and is performed to prevent horn-related injuries to handlers and to other cattle. In North America, most dairy cattle are disbudded using heat cautery (Misch, Duffield, Millman, & Lissemore, 2007), and the Canadian Veterinary Medical Association and American Veterinary Medical Association have issued animal welfare position statements that recommend pain management for this procedure. Sixty 6–12-week-old Holstein heifer calves were blocked by age and randomly assigned to two treatment groups, one that received a nonsteroidal anti-inflammatory drug, meloxicam, and one control group. All calves were
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disbudded using heat cautery, receiving a lidocaine corneal nerve block and an intramuscular injection of either meloxicam or a placebo solution for the control group calves. Three categories of pain assessment were used as follows:

1. Physiological (serum cortisol, heart rate, respiratory rate);
2. Mechanical (pain sensitivity based on withdrawal response from pressure algometry); and

All measurements were collected after a sham disbudding procedure to determine baseline values, so that each calf acted as its own control. This experimental design provided increased statistical power; hence, fewer calves were required in the study. For all calves, disbudding resulted in increased pain responses in all three categories of measurement. Changes in cortisol levels were significantly lower in meloxicam-treated calves until 6 hr after dehorning ($p = .006$). Heart rates ($p = .04$) and respiratory rates ($p = .048$) were also lower in the meloxicam group. Meloxicam-treated calves displayed significantly less ear flicking ($p = .003$), a behavior associated with disbudding pain (Weary, Neil, Flower, & Fraser, 2006). Similarly, significant differences were observed for head shaking ($p = .03, +6h$), head rubbing ($p = .045, +30h$), and tail flicking ($p = .02, +20h$). Accelerometers were used to measure activity continuously during the experiment, and meloxicam-treated calves displayed more resting during the first 5 hr after disbudding ($p = .02$). Meloxicam-treated calves displayed less pain sensitivity by tolerating more pressure around the horn bud region after dehorning ($p = .004$). This integrated approach allowed for simultaneous pain assessment using multiple modalities and within calf comparisons. This detailed approach is practical in research laboratories; however, it is not amenable to large-scale field studies that are required in some countries for approval of analgesic drugs by regulatory government bodies or for acceptance by the commercial sectors.

ANIMAL WELFARE SCIENCE—MOVING FROM THE LABORATORY INTO THE FIELD

Whereas scientists continue to develop and refine techniques to assess animal welfare in laboratory settings, frustration has been expressed about the slow rate of progress of implementation (Dawkins, 1997; Millman, Duncan, Stauffacher, & Stookey, 2004). An exciting development is the emerging interest in epidemiology-based studies using field data for benchmarking, identification of risk factors, and assessment of interventions to address animal welfare in "real
One of the pioneers for bringing animal welfare from the laboratory into the field is Grandin (2005), who developed an objective numerical scoring system to assess cattle welfare in U.S. meat processing plants. Grandin (2005) quantified the proportion of cattle who were stunned correctly with a single shot, as per industry guidelines and other animal-based parameters such as the proportion of cattle who vocalized, slipped, and balked during handling.

In 1996, prior to the initiation of slaughter audits, only 3 of 10 companies met their industry animal welfare guidelines by correctly stunning 95% of the cattle correctly with a single shot (Grandin, 1998). In 1999, after the restaurant companies began auditing their suppliers, 9 of 10 companies achieved this score (Grandin, 2000). Hence, Grandin was able to provide the industry with empirical data relating to particular animal welfare criteria—and hence a tool the industry could use for quality control—and to evaluate effectiveness of interventions intended to improve animal welfare. Zurbrigg, Kelton, Anderson, and Millman (2005a, 2005b) used a similar approach to quantify animal-based parameters relating to the welfare of dairy cattle housed in tie-stall barns in Ontario, Canada. Prevalence of hock, neck, and knee lesions; broken tails; and lameness were determined and risk factors quantified. In addition to publishing in peer-reviewed scientific journals, Zurbrigg presented her data to producers at dairy seminars, together with instructions for how dairy producers and veterinarians could score their own farms. By comparing against the Ontario field data, producers were able to evaluate their farm scores against those of their peers (Table 1). It is noteworthy that, on some farms, not a single cow was afflicted by the conditions associated with poor cow comfort, whereas at the other end of the scale, all the cows on at least one farm had hock wounds and almost 50% of the cows on another farm had broken tails.

Last, culling and euthanasia are important components for addressing animal welfare, particularly where treatment options are not viable. Compromised animals are particularly vulnerable to the stressors of transportation, novelty, and social mixing during this phase of the production cycle. In an Alberta, Canada, report, producers estimated that their cull dairy cows would be slaughtered within 1.5–24 hr after shipping; however, in reality, cows may spend 3 weeks in transit between livestock markets before reaching a slaughter facility (Alberta Milk and Alberta Farm Animal Care Association, 2002). Dehydration, injury due to fighting, and exhaustion are risks to healthy beef cattle during transit from ranch to slaughter, particularly those who move through markets prior to reaching their destination (Jarvis, Harrington, & Cockram, 1996). Furthermore, few animals lie down and rest, even during 24 hr of lairage, affecting the ability of cattle to cope with multiple stressors (Cockram & Corley, 1991). Compromised animals require additional care during handling: taking more time to move, using nonslip floors to address their lack of balance and strength, and planning
TABLE 1
Herd Prevalence for Cow Comfort Parameters on Ontario Dairy Tie Stall Farms

<table>
<thead>
<tr>
<th>Condition</th>
<th>Best 20% of Farms</th>
<th>2nd Best 20% of Farms</th>
<th>Average 20% of Farms</th>
<th>2nd Worst 20% of Farms</th>
<th>Worst 20% of Farms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swollen hocks</td>
<td>0–3.8% cows</td>
<td>3.9–8.8% cows</td>
<td>8.9–15.4% cows</td>
<td>15.5–25.7% cows</td>
<td>25.8–60.8% cows</td>
</tr>
<tr>
<td>Hock wound</td>
<td>0–1.0% cows</td>
<td>1.1–3.4% cows</td>
<td>3.5–6.9% cows</td>
<td>7.0–12.2% cows</td>
<td>12.3–100% cows</td>
</tr>
<tr>
<td>Broken tails</td>
<td>0% cows</td>
<td>0% cows</td>
<td>0–1% cows</td>
<td>1.1–4.1% cows</td>
<td>4.2–47.8% cows</td>
</tr>
<tr>
<td>Dirty hind limb</td>
<td>0–2.9% cows</td>
<td>3.0–8.7% cows</td>
<td>8.8–18.2% cows</td>
<td>18.3–36.1% cows</td>
<td>36.2–94.4% cows</td>
</tr>
<tr>
<td>Rotated hind claw (lame)</td>
<td>0–6.7% cows</td>
<td>6.8–14.6% cows</td>
<td>14.7–22.0% cows</td>
<td>22.1–34.2% cows</td>
<td>34.3–73.7% cows</td>
</tr>
</tbody>
</table>

Note. To compare your farm with your peers, score each of the conditions listed by counting all the milking cows in your herd who have at least one limb affected by that condition. Divide this number by the total number of cows in your herd to obtain your herd prevalence for each condition (modified from Zurbrigg, 2005).

CONCLUSIONS

Animal welfare is based on both moral decisions and factual knowledge about how animals perceive, interpret, and respond to their environments. The scientific method can be applied to supply knowledge, using multidisciplinary techniques within the laboratory and in field conditions. International collaborations by applied ethology, animal science, and veterinary researchers are promising progressions for addressing farm animal welfare in a global market.
REFERENCES


