Chapter 4: Environmental Enrichment

Environmental enrichment involves the enhancement of an animal's physical or social environment. Environmental enrichment is increasingly viewed as a significant component of refinement efforts for animals used in research and teaching, and should be considered where opportunities for social interactions are not available or where the animals' physical environment is restricted or lacking in complexity.

Environmental enrichment has been shown to have wide-ranging physiological and behavioral effects on a variety of species of animals (Young, 2003) and can be particularly effective in the research setting to reduce the incidence or severity of undesirable or abnormal behaviors. Abnormal behaviors observed in farm animals include locomotor stereotypies such as weaving, pacing, and route-tracing and mouth-based behaviors such as wool-eating by sheep, feather pecking and cannibalism by poultry, bar biting by pigs, tongue rolling by cattle, and wind-sucking by horses (Price, 2008). These behaviors can cause injury to the animal performing them or to other animals in the social group and are most commonly observed in situations in which the quality or quantity of space provided to the animal is inadequate. Environmental enrichment may reduce the frequency or severity of these behaviors, or even prevent them from developing in the first place (Mason et al., 2007).

Unfortunately, the term "environmental enrichment" does not have a precise definition and is used inconsistently (Newberry, 1995; Young, 2003), often referring simply to changes that involve adding one or more objects to an animal's enclosure rather than specifying the desired endpoints of these changes. Newberry (1995) suggested a useful concept: the endpoint of enrichment should be to improve the biological functioning of the animal. Therefore, goals of enrichment programs include 1) increasing the number and range of normal behaviors shown by the animal; 2) preventing the development of abnormal behaviors or reducing their frequency or severity; 3) increasing positive utilization of the environment (e.g., the use of space); and 4) increasing the animal's ability to cope with behavioral and physiological challenges such as exposure to humans, experimental manipulation, or environmental variation. To accomplish these goals, enrichment strategies should be based on an understanding of species-specific behavior and physiology, and the enrichments provided should not only be attractive to the animals but also result in interest that is sufficiently sustained to achieve the desired performance outcomes. Bloomsmith et al. (1991) provided a useful categorization of enrichment types:

1. Social enrichment, which can involve either direct or indirect (visual, olfactory, auditory) contact with conspecifics (other individuals of the same species) or humans.
2. Occupational enrichment, which encompasses both psychological enrichment (e.g., devices that provide animals with control or challenges) and enrichment that encourages exercise.
3. Physical enrichment, which can involve altering the size or complexity of the animal's enclosure or adding accessories to the enclosure such as objects, substrate, or permanent structures (e.g., nestboxes).
4. Sensory enrichment, or stimuli that are visual (e.g., television), auditory (music, vocalizations), or in other modalities (e.g., olfactory, tactile, taste).
5. Nutritional enrichment, which can involve either presenting varied or novel food types or changing the method of food delivery.

All of these types of enrichment have been assessed for use with agricultural animals. In the following sections, validated or potential enrichments for each species are discussed as appropriate. All agricultural animals are social (with the exception of the adult boar), and social behavior and management of social groups are covered in the respective species chapters; in this chapter, the focus is on indirect contact or contact with humans as substitutes for conspecific contact in situations in which animals must be individually housed. Genetic differences between breeds, lines, or strains of agricultural animals may be present that affect their use of, or responses to, enrichment (e.g., Hill et al., 1998).

Cattle

Social Enrichment. If the experimental protocol dictates individual housing for cattle, visual and auditory contact with conspecifics is desirable. Research on cattle–human interactions indicates that humans may serve as a substitute for conspecific contact if social contact is not possible. Gentle and confident handlers benefit animals and may result in improved milk production. For example, when humans stroke body parts commonly groomed by other cattle such as the neck, cattle are more likely to approach humans, indicating that appropriate and gentle contact with humans can improve human–animal interactions (Schmied et al., 2008). Conversely, rough handing is stressful for cattle. Cattle recognize individual people and become frightened of those who handle them aggressively (Rushen et al., 1999). Shouting, hitting, and use of the cattle prod are frightening and cattle should not be handled in this way (Pajor et al., 2000, 2003). Indeed, cattle will show more vigilance behavior when exposed to a human who has handled them roughly compared with a gentle or unfamiliar handler (Welp et al., 2004).

Occupational Enrichment. Tied dairy cattle should have daily exercise in a yard. Exercise provides numerous health benefits; for example, cattle given daily exercise had fewer illnesses requiring veterinary attention and fewer hock injuries (Gustafson, 1993). Cattle provided with such exercise use this time to groom parts of the body that they cannot reach while tied (Loberg et al., 2004). Indeed, loose-housed cattle increase grooming when provided a mechanical brush and will use these brushes to groom hard-to-reach areas, such as the hindquarters (Wilson et al., 2002; DeVries et al., 2007). Scratching/ribbing devices were used more frequently and for longer by cattle compared with other types of enrichment devices tested (Wilson et al., 2002).

Nutritional Enrichment. Weather permitting, access to well-managed pasture is beneficial and recommended for all cattle. Dairy cows with access to pasture have fewer health problems such as mastitis (e.g., Washburn et al., 2002). Cattle also do not exhibit stereotypic tongue rolling while at pasture (Redbo, 1990). Indeed, provision of exercise (Redbo, 1992), adequate roughage (Redbo and Nordblad, 1997), and group housing calves (Seo et al., 1998) have all been found to reduce stereotypic tongue rolling in cattle.

Sensory Enrichment. Noise is a possible stressor within cattle housing environments and during routine management practices such as handling, milking, and transport. Beef cattle exposed to either human shouting or noise of metal clanging move more while restrained in the chute; thus, quiet environments facilitate animal handling and well being (Waynert et al., 1999). Quiet environments may be even more important for dairy cattle, as they are more reactive to sound than beef cattle (Lanier et al., 2000). Although music and noise can serve as a cue that will synchronize attendance at an automatic milking machine (Uetake et al., 1997), cows will avoid noise, such as a radio or sounds of a milking machine, associated with milking when given the choice (Arnold et al., 2008).

Olfactory enrichment may also be important for cattle; feedlot cattle are reported to be more attracted to scented (milk or lavender) enrichment devices than to unscented devices (Wilson et al., 2002). As mentioned above feedlot cattle will spend time scratching their skin against brushes (Wilson et al., 2002), which may act as a form of tactile enrichment.

Horses

Social Enrichment. As prey species, horses are highly motivated to interact with individuals of their own species for comfort, play, access to food and shelter resources, and as an antipredator strategy. During fearful situations and when separated from closely bonded companions, restlessness, pacing, and vocalizations occur and suggest experiences of acute anxiety and distress. Horses housed singly display greater activity and reduced foraging compared with horses kept in pairs or groups (Houpt and Houpt, 1989). Horses housed singly also display more aggression toward human handlers and learn new tasks more slowly than horses housed in groups (Sondergaard and Ladewig, 2004). Confining horses for long periods may produce behavioral problems (depression or aggression) that sometimes progress to the exhibition of stereotypies, commonly referred to as vices. Examples include stall weaving, cribbing, or wind sucking. Management efforts to minimize stereotypies include companionship (another horse or pony, or even a goat, cat, dog, or chickens), exercise (hand walking, lunging, or turning out into a paddock), environmental enrichment objects (large ball, foraging device, plastic bottle hung from the ceiling, or mirrors), or increasing dietary fiber by pasture grazing, availability of hay, or providing multiple forage types (Winskill et al., 1996; McAfee et al., 2002; Thorne et al., 2005).

In feral and wild situations, horses maintain long-term relationships. Stallions and mares stay together year-round over multiple breeding seasons, whereas colts and fillies emigrate from the natal herd when they are juveniles (Feh, 2005). Mare–mare bonds are very stable and persist for years, although social interactions decrease markedly during the postparturient period when mares direct social behavior toward their foals (van Dierendonck et al., 2004). For mares and fillies, social bonds are likely to develop between individuals that are familiar, closely related, and similar in social rank (Heitor et al., 2006). Social relationships between females are characterized by mutual grooming and maintaining close proximity (Kimura, 1998; van Dierendonck et al., 2004). In the absence of these factors, social bonds are directed toward unfamiliar individuals that have the same coat color as the filly's dam (Sawford et al., 2005).

Mutual grooming is directed toward the withers and neck region and is associated with reduced heart rate

(Feh and de Mazieres, 1993), suggesting a role in reducing anxiety. Mutual grooming is rarely performed by stallions (Crowell-Davis et al., 1986), except following periods of social deprivation (Christensen et al., 2002). In contrast, colts and gelding are highly motivated to play with each other. When housed in extensive conditions, colts perform hourly play bouts, such as mock fighting, whereas mares do not typically engage in this behavior (Sigurjonsdottir et al., 2003).

Because aggression and play can result in injuries, stallions are typically housed singly. Aggression is influenced by reproductive status, with greater aggression in established groups occurring in the breeding and foaling season (Grogan and McDonnell, 2005). In mixed groups, mares display more aggression in the postparturient period, primarily in the form of interventions to protect foals from barren mares and geldings (Rutberg and Greenberg, 1990; van Dierendonck et al., 2004). Similarly during feeding trials, yearling females perform significantly more agonistic interactions (e.g., head threats, biting, kicking) than geldings of the same age, likely because of circulating steroid levels at estrus (Motch et al., 2007).

When horses are housed singly or in isolation facilities, distress associated with social deprivation can be alleviated by providing visual contact with other equids. Weaving and head-nodding stereotypies, which are associated with frustration (Mills and Riezebos, 2005), are significantly reduced when horses can see other equids through grilled side windows (Cooper et al., 2000), or when mirrors (McAfee et al., 2002) or life-sized poster images of a horse's face (Mills and Riezebos, 2005) are placed in the stalls. Lateral visual contact appears to be important, because weaving is significantly more likely to occur when stalls are arranged face-to-face than side-by-side (Ninomiya et al., 2007).

In the absence of equids, horses readily form social relationships with other species, such as goats, dogs, and humans. Intensively managed horses detect and respond to subtle indicators of emotional state and confidence in their human handlers, eliciting both fearfulness and calmness (Chamove et al., 2002; von Borstel, 2007; von Borstel et al., 2007). Horses accept being groomed by humans; reductions in heart rate that occur when horses perform mutual grooming (Feh and de Mazieres, 1993) are also observed when humans brush or scratch the withers and neck regions (Lynch et al., 1974; Hamas et al., 1996). However, this positive association with tactile stimulation by humans appears to be learned rather than innate (Henry et al., 2006), and in the absence of positive interactions, foals begin to avoid humans at 3 wk of age (Lansade et al., 2007).

Physical Enrichment. Horses provided access to paddocks or pasture can alleviate foraging motivation through grazing, but horses also benefit from opportunities to exercise, with activity positively associated with paddock size (Jorgensen and Boe, 2007). Horses appear to be motivated to perform exercise in its own right, with motivation building up and compensatory activity performed after periods of deprivation (Houpt et al., 2001; Christensen et al., 2002; Chaya et al., 2006). Furthermore, horses provided with turn-out display more varied rolling behavior, which is believed to be associated with comfort (Hansen et al., 2007). In a study of racing horses, benefits of regular turn-out also included less aggression directed toward handlers (Drissler et al., 2006) and superior race and career performance (Drissler, 2006).

Occupational Enrichment. In the absence of turning out in paddocks or pastures, horses can direct play behavior toward "toys" placed in the stall. Several commercially available products such as the large durable balls designed to be used with stabled horses can be provided, as well as home-made devices such as plastic jugs hanging on ropes. Scientific evidence regarding the efficacy of these products is lacking.

Sensory Enrichment. In many stables, it is common for background noise to be provided by a radio, with the assumption that this provides a calming effect on the horses and alleviates boredom. However, the presence or type of music was not found to significantly affect the behavior of ponies subjected to short-term isolation distress (Houpt et al., 2000). These authors speculate that background music may indirectly affect equine behavior through the attitudes of their human caretakers. Conversely, a synthetic Equine Appeasement Pheromone product is commercially available, and there is minimal evidence that this product effectively reduces behavioral and physiologic fear responses of horses subjected to a stressful situation (Falewee et al., 2006).

Nutritional Enrichment. Opportunities to forage provide significant enrichment for stabled horses. Horses typically spend 10 to 12 h grazing per day (Ralston, 1984), and lactating mares spend 70% of their time grazing on pasture (Crowell-Davis et al., 1985). In the absence of foraging material, horses frequently may direct foraging toward the stall bedding or stall surfaces (Drissler et al., 2006), or may display oral stereotypies such as crib-biting, wind-sucking, sham chewing, hair eating, and wood chewing/licking. Undesirable oral behavior can be addressed by providing at least 6.8 kg of hay per day (McGreevy et al., 1995), providing multiple forages (Goodwin et al., 2002; Thorne et al., 2005), and dividing concentrate feed into smaller and more frequent meals throughout the day (Cooper et al., 2005). Horses provided with straw bedding perform less stereotypic behavior than those bedded on paper or shavings (Cooper et al., 2005). Several food toys are commercially available, which horses manipulate to obtain high-fiber food pellets. These food-balls result in increased foraging time (Winskill et al., 1996) and reduced stereotypic behavior (Henderson and Waran, 2001). Toys with round or polyhedral designs are most effective (Goodwin et al., 2007). These toys can be provided in the manger to prevent horses from ingesting

pathogens and nonnutritive materials from the stall bedding.

Poultry

Social Enrichment. Socialization of poultry with humans can be carried out with relative ease by frequent exposure to kind, gentle care (Jones, 1996). Even brief periods of handling, beginning at the youngest possible age, confer advantages for ease of later handling of birds and increase feed efficiency, body weights, and antibody responses (Gross and Siegel, 1983). In addition, Gross and Siegel (1982) found that positively socialized chickens had reduced responses to stressors and that resistance to most diseases tested was better than that of birds that had not been socialized.

Occupational Enrichment. A primary method for promoting exercise in poultry is the provision of perches or other elevated areas that encourage the use of vertical space in the enclosure. Egg-laying strains of chickens are highly motivated to use perches at night (Olsson and Keeling, 2002), and the entire flock (100% of hens) will utilize perches at night if sufficient perch space is provided (Appleby et al., 1993; Olsson and Keeling, 2002). When hens are housed in floor pens, perches allow them to roost comfortably with a minimum of disturbance and provide them with an opportunity to seek refuge from other birds to avoid cannibalistic pecking (Wechsler and Huber-Eicher, 1998). Perches can also minimize bird flightiness and fearfulness (Brake, 1987), and the exercise facilitated by vertical movement can improve bone strength (Whitehead, 2004). Early exposure to perches during rearing facilitates perching behavior in adult birds (Faure and Jones, 1982; Heikkliä et al., 2006).

Poults and young broiler chickens also use perches but use tends to decrease when the birds are older. At later stages of the production cycle, perches are used much less frequently by broilers and turkeys than by laying hens (LeVan et al., 2000; Martrenchar et al., 2001). Because of their body size and conformation, older turkeys and broiler chickens need to be provided with lower perches of a shape and size that allow them to easily access the perches and to balance properly when perching. For older turkeys it advisable to locate the perches high enough that turkeys on the ground cannot peck and pull the feathers of perching birds; ramps can be installed in front of these higher perches to facilitate access (Council of Europe, 2006). Straw bales can also be added to pens to provide an elevated surface for broilers and turkeys (Council of Europe, 2006), but again ramps may need to be installed so that older birds can easily access these. Because straw is also used as a foraging substrate, however, the bales may be rapidly pecked apart and scattered (Martrenchar et al., 2001).

In general, perches should be free of sharp edges, of a size that can be readily gripped by the claws but large enough in diameter that the bird's toenails do not damage its footpad, and made of a material that is nonslip but that can be cleaned. Perches soiled with feces are a major contributing factor to the development of a painful foot condition, bumblefoot, in floor-housed poultry, so it is important that perches be properly designed to minimize this problem. In addition, hens may develop deviated keel bones from resting on perches, although it is unknown if this condition is painful (Tauson and Abrahamsson, 1996). Laying hens prefer high perches. However, hens tend to develop osteoporosis and this makes perch placement (e.g., spacing between perches when multiple perches are provided) critical to ensure that the hens can navigate the perches without breaking bones during landings (see Keeling, 2004).

Ducks will swim if water of sufficient depth is provided. If swimming water is made available to ducklings, the water should be very shallow so that the ducklings do not drown, and care must be taken until their waterproof feathers emerge to ensure that they do not become soaked and chilled (BVAAWF/FRAME/RSPCA/UFAW Joint Working Group on Refinement, 2001; Council of Europe, 2006).

Physical Enrichment

Nestboxes: The most important physical enrichment for laying hens is a nestbox. Egg laying involves a complex sequence of behaviors, including searching for a suitable site in which to lay an egg and then preparing that site by pecking, treading, and molding the substrate to create a nest. Laying hens that are not provided with a nest site (e.g., those housed in conventional cages) may show agitated pacing behavior during the nest-seeking phase, which has been interpreted as evidence of frustration (Appleby et al., 2004).

Hens place a high value on accessing nests, and their motivation for nest use increases greatly as the time of oviposition approaches (Cooper and Albentosa, 2003). Even hens without prior exposure to nests show a strong motivation to use nests for egg laying (Cooper and Appleby, 1995; 1997). Laying hens also generally prefer enclosed nesting sites to ones that are more open (Appleby and McRae, 1986; Cooper and Appleby, 1997). Providing an appropriate substrate in the nestbox is also important to allow for nest-building behavior (Appleby et al., 2004).

There have been few experimental studies of prelaying behavior or nest-site selection in either ducks or turkeys. However, it is likely that they have a similarly strong motivation to lay their eggs in a nest box. There are many different types of nestboxes available commercially and most have been used successfully in both industry and research settings for ducks and turkeys, suggesting that the important features of a nest to these species, as for laying hens, are fairly simple (Appleby et al., 2004).

Substrate: The provision of suitable substrate, such as friable litter material for turkeys and fowl and both water and friable material for ducks, facilitates both foraging and grooming behavior. Poultry would normally spend a large part of their day foraging, and increasing foraging opportunities can help to reduce the incidence of two abnormal behaviors, feather pecking and cannibalism (Newberry, 2004; Rodenburg and Koene, 2004). These behaviors are not related to aggression but, like aggression, are directed toward other birds in the flock. Feather pecking can consist of gentle pecking that does not result in the removal of feathers from the pecked bird or more severe pecking that results in feather loss (Savory, 1995). Having a feather removed is painful (Gentle and Hunter, 1991), and severe feather pecking can lead to birds having denuded areas that expose the skin to injury and impair thermoregulation. These denuded areas may also attract tissue pecking and cannibalism by other birds. Cannibalism involves the pecking and tearing of skin, underlying tissues, and organs. Cannibalistic pecking is most often directed toward the toes, tail, vent area, or emerging primary feathers on the wings and can cause high flock injury and mortality if birds are not beak- or bill-trimmed (Newberry, 2004; Riber and Mench, 2008). Outbreaks of feather pecking and cannibalism are difficult to control once started because these behaviors are socially transmitted among birds in the flock, so it is best to prevent their occurrence through early intervention.

Other factors such as nutritional deficiencies or environmental or management variables (such as high light levels or large group size) can contribute to outbreaks of feather pecking and cannibalism. There are also strong genetic effects (Kjaer and Hocking, 2004), and these behaviors are more difficult to control in some species or strains than in others. For example, Muscovy ducks are much more likely to engage in cannibalistic behavior than Pekin ducks (Gustafson et al., 2007a, b), and providing Muscovy ducks with a variety of water- and food-based foraging enrichments was found to be ineffective in preventing cannibalism (Riber and Mench, 2008).

Aggressive behaviors in turkeys can be reduced by the provision of foraging materials. Martrenchar et al. (2001) provided growing turkeys with straw and hanging chains and found reduced pecking injuries in both toms and hens. Sherwin et al. (1999) reared turkeys with a variety of pecking substrates (e.g., vegetable matter, rope, flexible plastic conduit, chains) and found that this reduced injuries due to wing and tail-pecking. These types of items can be effective in reducing behavior problems, even in cage environments. For example, chickens are attracted to and manipulate hanging strings (Jones, 2004), and providing these in cages was found to reduce feather damage, presumably because of reduced feather pecking, in caged laying hens (Jones et al., 2004).

If an appropriate substrate is provided, chickens and turkeys will dustbathe in long bouts on most days, particularly in sunny or bright locations in their enclosure. During dustbathing, loose particles are worked through the feathers and then shaken out. This improves feather condition by dispersing lipids (van Liere, 1992) and possibly serves to remove ectoparasites. Chickens will dustbathe in different types of loose material, but prefer litter with smaller diameter particles (e.g., peat or sand) to litter with larger diameter particles (e.g., wood shavings or paper bedding material; Shields et al., 2004); smaller particles are also more effective in penetrating the feathers.

Ducks maintain good plumage condition by water bathing. If swimming water is not provided for practical or hygienic reasons, providing a source of water that is at least deep enough for the ducks to immerse their heads and shake water over their body can help them to maintain good plumage, nostril, and eye condition, as can providing them with an overhead shower (Jones et al., 2009)

Bedding material can become contaminated with feces and produce unacceptable levels of atmospheric ammonia if not well maintained. Wet or contaminated bedding can also cause foot and leg problems such as footpad dermatitis (Berg, 2004). Certain types of litter can also become aerosolized, creating excessive dust. When water is provided as a swimming, foraging, or grooming substrate for ducks, it must be changed frequently to prevent it from becoming contaminated. The resulting moisture in the environment can also lead to unacceptable levels of ammonia, and contact with feed and bedding that has become moldy because of excess moisture in the atmosphere predisposes ducks to infection with Aspergillosis (Brown and Forbes, 1996).

Cover: Providing floor-housed chickens with cover in the form of overhead vertical panels has been shown to improve pen usage, increase resting and preening behaviors, and decrease the number of times that birds disturb one another (Newberry and Shackleton, 1992; Cornetto et al., 2002). Striped panels providing 67% cover are effective, and are preferred by the chickens to solid, transparent, or less fully striped panels (Newberry and Shackleton, 1992).

Objects: Several studies have investigated whether providing novel objects can decrease fear in poultry. Chicks provided with such objects were less fearful during several standardized tests (Jones, 1982), although the birds were not tested as adults to determine whether this effect persisted. Reed et al. (1993) reported that exposing laying hen chicks to novel objects, a radio playing a human voice, and human handling resulted in less fearfulness to novel stimuli and decreased injury from handling when the hens were adults. In contrast, Nicol and Scott (1990) found no reduction in fear in broiler chickens exposed to human handling and auditory and novel object enrichment, and Nicol (1992) actually found that novel object enrichment could increase fearfulness in broilers. Although chickens do show interest in exploring semi-unfamiliar environments (Newberry, 1999), novel objects and food can themselves cause fear

reactions (Murphy, 1977) and so should be introduced cautiously to older birds.

Sensory Enrichment. The effects of 3 forms of sensory enrichment (videos, odors, and music) on chickens have been reviewed by Jones (2004). Both chicks and hens are attracted to video images shown outside of their enclosures. Bright, colored, complex, and moving video images are more attractive to the birds than dull, still, greytone, and simple images. Regular exposure of chicks to video stimulation reduced their fear of a novel place. Fear responses in a novel environment were also found to be reduced in chicks if the environment contained an odor with which the chicks had been reared (vanillin), and the chicks also showed less fear of novel food (food neophobia) and consumed that food sooner if it was associated with the familiar odor. Playing music has also been advocated to reduce fear responses in chickens, but claims about its efficacy are not based on empirical studies (Jones and Rayner, 1999).

Nutritional Enrichment. As discussed above, the provision of appropriate substrate, such as wood-shavings litter for fowl or water for ducks, also facilitates foraging behavior. Other methods of increasing foraging time include scattering feed in the litter when birds are housed on substrate, and placing rocks, edible items, or other objects in water containers for ducks (BVAAWF/FRAME/RSPCA/UFAW Joint Working Group on Refinement, 2001) or in the feed troughs of chickens (Sherwin, 1995). If scatter feeding or water feeding are used, body weight should be monitored to ensure that birds are maintaining adequate feed intake.

There has been only limited research on the effects of providing varied food items to poultry, but chickens are able to self-select among various ingredients to create a nutritionally balanced diet (Appleby et al., 2004). Several guidelines (BVAAWF/FRAME/RSPCA/UFAW Joint Working Group on Refinement, 2001; Council of Europe, 2006) recommend providing poultry with brassicas or similar foods to stimulate foraging and to vary the feeding regimen.

Sheep and Goats

Social Enrichment. Validation of enrichment devices and procedures for sheep is extremely limited. However, sheep are highly social animals, and if social contact must be limited it may be beneficial to provide the sheep with visual contact with other sheep through fencing or other transparent materials. It has also been suggested that a mirror or an inanimate object covered with animal skin could serve as a social surrogate. Mirrors can reduce but do not abolish the physiological stress response to social isolation in sheep (Parrott et al., 1988). However, because sheep appear to treat their own reflection as a strange individual it is also possible that a mirror image could cause social stress (Reinhardt and Reinhardt, 2002).

Nutritional Enrichment. Devices that provide feed supplements when manipulated by licking or pushing with the head may occupy the animals' attention. However, care must be taken to keep these objects clean, as they quickly become contaminated with manure.

Occupational and Physical Enrichment. An undesirable behavior called wool biting may develop in confined sheep. Wool-biting sheep take bites of and eat wool from other sheep (Vasseur et al., 2006). This may compromise the health and well-being of the sheep that are "victimized," and may alter the nutritional status of the sheep performing the wool biting. Wool biting seems to be a redirected behavior of confined sheep, and lack of environmental stimulation and diet may contribute to the onset of wool biting (Sambraus, 1985; Lynch et al., 1992). Strategies that have been used to prevent or stop wool biting include hanging chains above the surface of the pen, adding objects to the pen (e.g., basketballs, plastic bottles, or chewing bars), playing music, and altering the diet. Increasing the roughage content of the diet may reduce the incidence of wool biting, although definitive methods for preventing or reducing this behavior have not been reported (Vasseur et al., 2006).

Goats will climb a variety of objects such as tables, empty cable spools, or even elaborate jungle gyms. These structures will be used throughout the day. An enriched environment has been shown to increase feed consumption and reduce aggression in goats in feedlots (Flint and Murray, 2001). Care must be taken to provide appropriate climbing space that is ample for the number of animals in the group, as dominant animals will displace subordinates. Also, climbing devices should be placed in such a manner as to prevent the goats from vaulting out of the enclosure.

Swine

An enriched environment contributes to pig well-being in numerous ways, as indicated by increased behavioral diversity, adaptability to novelty, and learning ability, coupled with reduced aggression, fearfulness, stereotyped behavior, belly nosing, and tail and ear biting (Wood-Gush et al., 1990; O'Connell and Beattie, 1999; Beattie et al., 2000; Sneddon et al., 2000; Wemelsfelder et al., 2000; Day et al., 2002; Puppe et al., 2007). An extensive enrichment program would provide sufficient environmental complexity to enable pigs to express a wide range of normal behavior and to exercise a degree of control and choice in their environment, but also needs to promote pig health and be practical to employ (Van de Weerd and Day, 2009).

Social Enrichment. Housing pigs in stable social groups with ample space and environmental complexity enables them to adjust their proximity to different individuals according to their social relationships and current state. Alternative housing systems that mini-

mize regrouping and social stress are available and may be of use for certain research and teaching protocols or in certain herds (Stolba and Wood-Gush, 1984; Newberry and Wood-Gush, 1986; Wechsler, 1996; Weary et al., 1999b; Parratt et al., 2006).

When pigs must be isolated from conspecifics for experimental purposes, friendly social contact with familiar caretakers could be especially important. Pigs recognize familiar caretakers using visual (body size and facial features) as well as vocal and olfactory cues (Koba and Tanida, 2001). Caretakers can develop positive social contact with pigs by moving slowly and calmly, crouching to reduce apparent body size, avoiding aversive or inconsistent (sometimes pleasant and sometimes aversive) handling, and stroking or scratching pigs that approach (Hemsworth et al., 1996). When pigs have a positive attitude toward caretakers, they will approach confidently and seek interaction, which may have positive implications for handling strategies.

Providing companionship from familiar pen-mates and a warm, artificial udder with flexible nipples can decrease distress in piglets that must be weaned at an early age for experimental reasons (Jeppesen, 1982; Weary et al., 1999a; Toscano and Lay, 2005; Widowski et al., 2005; Colson et al., 2006; Bench and Gonyou, 2007).

Occupational Enrichment. Occupational enrichment is achieved by allowing and promoting physical exercise, foraging, exploration, nest-building, playing, and manipulative and cognitive activities. Access to pasture, soil, straw, peat, mushroom compost, hay, bark, branches, logs, and other malleable materials helps to satisfy these urges. These materials provide an outlet for exploration, sniffing, biting, rooting, and chewing activities, reducing the likelihood that these behaviors will be redirected toward the bodies of pen-mates or pen fixtures. Such enrichment materials can lower the risk of injuries and harassment from tail biting, ear chewing, and belly nosing, as well as reducing aggressive behavior and wear and tear on housing fixtures (Fraser et al., 1991; Beattie et al., 1995; Lay et al., 2000; Hötzel et al., 2004).

Pigs are initially attracted to materials that are odorous, deformable, and chewable, but for sustained occupational enrichment, the best materials are complex, changeable, manipulatable, destructible, and are ingestible or contain sparsely distributed edible parts (Van de Weerd et al., 2003; Bracke, 2007; Studnitz et al., 2007). Thus, pigs prefer to root in and manipulate materials such as corn silage mixed with straw, compost, turf, peat, forest soil, beets, spruce chips, and fir branches. Although somewhat less preferred than these materials, long straw is a useful enrichment material, being more effective than chopped straw, sand, or ropes, and much more effective than indestructible objects such as hoses, chains, and tires (Tuyttens, 2005; Van de Weerd et al., 2005; Scott et al., 2006; Jensen and Pedersen, 2007; Studnitz et al., 2007; Day et al., 2008; Zonderland et al., 2008). Unattached objects presented at floor level may be more attractive to pigs than hanging objects but lose their attractiveness when soiled with excreta (Van de Weerd et al., 2003).

Most research on enrichment materials has focused on straw. The amount of behavior directed toward long straw rather than toward pen-mates is proportional to the amount of straw provided (Kelly et al., 2000; Day et al., 2002). Although providing straw only after tail biting has started can reduce the behavior, it does not act as a complete curative. Providing straw from an early age helps to prevent tail biting, lowers aggression, and maintains normal activity (Day et al., 2002; Bolhuis et al., 2006; Chaloupková et al., 2007). However, the risk of tail biting is elevated, and activity is depressed, if pigs initially reared with straw are subsequently housed without straw (Day et al., 2002; Bolhuis et al., 2006). These findings highlight the importance of continuing an enrichment program once it has started.

Slatted floors and liquid-manure systems usually preclude the provision of ample amounts of long straw and other particulate foraging materials. In this situation, offering small amounts of such materials in racks or troughs, and replenishing the supply frequently, stimulates sniffing, rooting, and chewing while maintaining a degree of novelty that is important for sustaining the interest of curious pigs. When particulate materials cannot be used, hanging ropes with unraveled ends that can be pulled, shaken, chewed, and torn apart are the next best option (Jensen and Pedersen, 2007; Trickett et al., 2009). Less-destructible novel hanging objects can offer short-term enrichment by attracting exploration and stimulating play but they need to be changed frequently because pigs rapidly lose interest in such objects when they are no longer novel (Van de Weerd et al., 2003; Gifford et al., 2007). Enrichment materials and objects should be monitored to ensure that they do not cause health problems (e.g., strangulation, choking, poisoning, obstruction of the digestive tract, transmission of pathogens) or compromise food safety. Supplying ample free access to preferred enrichment materials and objects will minimize aggressive competition for these resources.

Offering opportunities for pigs to respond to environmental cues to find occasional food rewards and to work for access to foraging materials and hidden food treats can be rewarding (Puppe et al., 2007; de Jonge et al., 2008). This form of enrichment has been found to speed wound healing (Ernst et al., 2006).

At least 24 h before farrowing, provision of an earth or sand substrate along with straw, branches, or other nesting materials enables sows to address their strong motivation to engage in nest-building behavior, which, under natural conditions, involves digging a shallow depression with the snout and then gathering nesting materials such as long grass, twigs, and branches, carrying them to the nest site in the mouth, and arranging them into a nest (Jensen, 1989, 1993). Providing nest materials can contribute to early piglet survival although results are variable (Herskin et al., 1998; Jarvis et al.,

1999; Damm et al., 2005). Long straw is preferred over cloth tassels as a nesting material although the latter may have some benefit in liquid-manure systems that preclude the use of straw (Widowski and Curtis, 1990).

Physical Enrichment. Pigs show spatial separation of different behaviors such as lying, feeding, and excretion. Providing ample space or appropriate subdivision of the enclosure area enables the establishment of separate functional areas. For example, Simonsen (1990) subdivided pens into areas with straw bedding, a pig-operated shower, straw racks, and logs hung on chains, and Stolba and Wood-Gush (1984) subdivided enclosures into areas for nesting, feeding, rooting, and excretion. Two-level pens also subdivide the pen space, thereby encouraging exercise, making handling and herding of pigs easier, and allowing pigs to exercise choice of thermal environment (Fraser et al., 1986; Pedersen et al., 1993). Habituation to ramps and alleys in the housing environment reduces novelty-induced fear when pigs are subsequently handled (Lewis et al., 2008). Allowing pigs daily access to enriched areas that are not accessible full time can stimulate anticipation and play (Dudink et al., 2006; Casey et al., 2007). To avoid overcrowding and competition in one area of a subdivided or multi-level pen, calculation of stocking density and feeder space should take into account variations in the distribution of pigs across different areas of the pen (Pedersen et al., 1993).

Providing visual barriers helps pigs to avoid aggressive pen-mates. This can be achieved by installing solid partitions between feeding spaces, boxes, or holes in the wall where pigs can hide their heads (the prime target of aggression), straw bales, dividers between different functional areas, or an upper pen level accessed by a ramp (Stolba and Wood-Gush, 1984; McGlone and Curtis, 1985; Fraser et al., 1986; Pedersen et al., 1993; Waran and Broom, 1993; Andersen et al., 1999). In outdoor pens, bushes, trees, and varied terrain can serve to create visually discrete areas.

Loose housing of sows allows freedom of movement leading to a shorter farrowing duration and lower stress at parturition relative to confinement in crates, and the risk of injuries can be reduced by secure footing and well-managed bedding (Lawrence et al., 1994; Marchant and Broom, 1996; Boyle et al., 2002; Karlen et al., 2007; Oliviero et al., 2008). Pens with stalls along with communal activity and resting areas allow gestating sows in groups to move freely and rest together while enabling temporary separation in stalls for feeding or experimental purposes. In addition to providing occupational enrichment, bedding gives thermal comfort in cool weather as well as cushioning the body against hard surfaces (Fraser et al., 1991; Tuyttens, 2005). Only good-quality bedding should be used to avoid introduction of mycotoxin molds, and bedding must be managed to avoid wet litter and high ammonia emissions. Certain types of artificial lying mats may also contribute to lying comfort (Phillips et al., 1995; Tuyttens et al., 2008). In outdoor pens, huts or kennels supplied with straw create suitable lying areas in cold weather. In hot weather, wallows, snout coolers, or snout-operated showers aid thermoregulation (Stansbury et al., 1987; McGlone et al., 1988). An earth substrate allows pigs to dig a simple depression in the ground for nesting. Shade may be needed to protect outdoor pigs from heat stress and sunburn (Miao et al., 2004).

Sensory Enrichment. Pigs can learn to associate olfactory, vocal, and color cues with a food reward (Croney et al., 2003; Puppe et al., 2007). For example, pigs use the odor of dimethyl sulfide to locate buried truffles, a highly desired food item that has a musky garlic/mushroom flavor and contains the boar sex pheromone 5-α-androstenol (Talou et al., 1990). Pigs also seek opportunities to interact with materials that provide tactile stimulation of different areas of their snout and mouth (Dailey and McGlone, 1997). Sensory cues paired with rewards, including access to enrichment materials, can be used to stimulate anticipatory excitement and play (Dudink et al., 2006; Puppe et al., 2007). Habituation to a wide array of nonharmful sensory stimuli when young may reduce fear in novel situations when older, and exposure to sensory stimuli that evoke comforting associations may be helpful at times of unavoidable stress.

Decisions about cleaning regimens should take into account that pigs communicate through odors. It is important to avoid disruptive cleaning routines during the first week after farrowing, which is an important time for social attachment between the sow and her piglets and the establishment of the teat order. Although moderate levels of ammonia do not appear to be highly aversive and do not disrupt social recognition (Jones et al., 1998; Kristensen et al., 2001), keeping ammonia to a minimum should facilitate exploration of diverse environmental odors. Enrichment materials with noticeable odors attract exploration, and pigs show preferences for foods with certain odors or flavors, whereas materials soiled by excreta are aversive (Van de Weerd et al., 2003; Bracke, 2007; Janz et al., 2007). Providing chewable tubes offering flavored water may not be sufficient to prevent tail biting (Van de Weerd et al., 2006).

To facilitate vocal communication between pigs, continuous loud noise (e.g., from fans, radios, and human activity) should be avoided. This is especially important in the farrowing area because vocalizations between sows and piglets are important for social bonding and effective nursing, and masking these vocalizations with high levels of ambient sound can disrupt suckling behavior (Algers and Jensen, 1985, 1991). Piglets should be handled in a manner that minimizes loud vocalizations that signal piglet distress and disturb the sows. Consideration should be given to handling piglets outside the hearing range of sows if loud calling by piglets is unavoidable. Silence is more effective in quieting piglets separated from the sow than playback of meditation music, white noise, or vocalizations of unfamiliar piglets (Cloutier et al., 2000). Furthermore, pigs are

not especially attracted to enrichment materials that produce sound when manipulated (Van de Weerd et al., 2003; Bracke, 2007). On the other hand, habituation to a variety of environmental sounds should help to reduce fear when pigs are moved to new environments, and playing a radio (following habituation) may be useful for masking sounds on occasions when sudden, unpredictable, loud noises are anticipated, such as those generated during construction.

Nutritional Enrichment. When feeding concentrated diets, feed restriction is usually needed during pregnancy to prevent excessive weight gain, which may result in later difficulties during farrowing and lactation. Although the ration fulfills their nutrient requirements, the sows eat it quickly and are hungry for much of the day. The sows' normal response is to forage for additional food. When sows are housed in an environment with no outlet for diverse foraging behaviors, aggression may increase, foraging behavior may be channeled into a few elements performed repetitively in stereotyped sequences (e.g., bar biting, sham chewing), or abnormal amounts of water may be consumed (Terlouw et al., 1991, 1993). These behaviors are reduced by providing straw and other ingestible foraging substrates that occupy the sows in diverse foraging activities and by feeding a diet high in fermentable nonstarch polysaccharides (e.g., sugar beet pulp, soybean hulls) to increase satiety (Spoolder et al., 1995; Meunier-Salaün et al., 2001; Robert et al., 2002; van der Peet-Schwering et al., 2003; de Leeuw et al., 2005). Although increasing the fiber content of the diet does not always influence stereotyped oral-nasal-facial behaviors (McGlone and Fullwood, 2001), the incidence of gastric lesions may be reduced in pigs given straw compared with those lacking access to roughage (Bolhuis et al., 2007).

Chewable and destructible but inedible substrates and objects such as ropes and cloth tassels are less satisfying to sows than straw or other fibrous materials but are better than hard, indestructible objects such as chains and stones toward which sows direct stereotypic behavior (Spoolder et al., 1995; Robert et al., 2002; Tuyttens, 2005; Studnitz et al., 2007). Incorporating a nutritional reward in a rootable or chewable object increases its attractiveness over objects that do not provide food reinforcement (Day et al., 1996; Van de Weerd et al., 2006). Although stereotyped behavior peaks in the period immediately following a meal suggesting that limit-fed sows should be given concentrated feed in a single daily meal rather than multiple smaller meals, provision of small food rewards does not appear to cause stereotypic behavior when combined with loose housing in straw-bedded pens (Terlouw et al., 1993; Haskell et al., 1996). Under these conditions, limit-fed sows can be extensively occupied by provision of food in devices that require work to extract it (e.g., the Edinburgh foodball; Young et al., 1994). It is important to make sure that there are sufficient nutritional enrichment devices to avoid aggressive competition. In general, the benefits of environmental enrichment for pigs are likely to be greatest when multiple forms of enrichment are supplied (Olsen, 2001).

General Considerations

When providing animals with environmental enrichment, it is critical to assess outcomes to ensure that the enrichment program is effectively meeting the intended goals. Observations of animal behavior, health, performance characteristics, and use of the enrichments are important components of such an assessment. Behavioral observations might include assessments of the frequency of normal behaviors, the frequency and severity of stereotypies and injurious behaviors, and the frequency and severity of undesirable behaviors such as excessive fearfulness or aggression.

For outcomes to be assessed adequately, it is important that the individuals who are making the observations be appropriately trained in sampling methods and that these methods are standardized across raters. These types of observations are often made by the animal caretakers, because they are typically the individuals with the most day-to-day contact with the animals. As Nelson and Mandrell (2005) point out, caretakers should therefore be "encouraged to become knowledgeable about the behavior of individual animals, to be active participants in the implementation of the enrichment programs, and to be made aware of the special role they play in communicating the successes and failures of enrichment strategies" (p. 175). These individuals should also be encouraged to be creative in developing environmental enrichment programs for agricultural animals. Books and articles about farm animal behavior are useful resources. In addition, Young (2003) provides helpful information about designing and analyzing enrichment studies as well as a list of sources of general information about various environmental enrichment methods. There are important practical considerations involved in providing animals with enrichments, including those related to safety (Bayne, 2005). Although there are a limited number of published papers (and none involving farm animals), animals are periodically reported to sustain injuries from environmental enrichment; for example, intestinal obstruction due to the provision of foraging enrichments or items that can be chewed and ingested (Hahn et al., 2000; Seier et al., 2005). Young (2003) lists several considerations that should be taken into account when evaluating the safety characteristics of potential enrichment devices:

- Does the enrichment have sharp edges?
- Can the animal's limbs or other parts of the animal's body become trapped in any part of the enrichment?
- Can the enrichment be broken or dismantled by the animal, and if so, would the fragments or constituent parts pose a safety risk?
- Can the enrichment or any part of it be gnawed and swallowed?

- Is the enrichment made of nontoxic material?
- Can the enrichment be cleaned adequately or sterilized to prevent disease transmission?
- Could the animal use the enrichment to damage its cage or pen-mates or its enclosure?

In addition, close monitoring is required when objects are introduced into social housing environments because aggression may increase if the animals compete for access to the resource.

Other constraints on enrichment are related to facility design, cost, sanitation, ease of management (including the amount of time and effort that caretakers must put into maintaining the enrichment program), and potential effects on research outcomes. Input should, therefore, be sought from the IACUC, veterinarians, researchers, and the caretakers who will be responsible for the day-to-day implementation of the enrichment program (Weed and Raber, 2005).

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