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(Ag Guide)

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Poultry Science Association

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Preface

This is the third edition of the *Guide for the Care and Use of Agricultural Animals in Research and Teaching*, commonly referred to as the Ag Guide. The first edition was published in 1988 and the first revised edition was published in 1999. This third edition differs from the past editions in several meaningful ways. For the first time, the Ag Guide is available online at no cost to readers. This is possible thanks to countless hours of voluntary time by 62 authors.

Authors included experts in each species and in animal care and use including animal scientists, veterinarians, teachers, and engineers. Experts reviewed the scientific literature to update the Ag Guide. Authors were chosen for their prominence in the many fields of the animal sciences so that the best available science could be applied to this revision.

The full name of the Ag Guide has changed in this edition. Previous editions were titled the *Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching*. This edition drops the second use of the word agricultural in the title. By doing so, the title reflects a new philosophy. Farm animals have certain needs and requirements and these needs and requirements do not necessarily change because of the objectives of the research or teaching activity. Therefore, regardless of the teaching or research objective, the ADSA-ASAS-PSA Ag Guide (previously referred to as the FASS Ag Guide) should serve as a primary reference document for the needs and requirements of agricultural animals.

The writing team included two co-chairs and species and topic chapter sub-committee chairs. Each chapter sub-committee chair had a sub-committee of species and/or topic experts. Individual chapters were updated based on the scientific literature. Then, each chapter writing team reviewed all the other chapters. The co-chairs and sub-committee chairs met in person and online to discuss difficult matters and they solicited input from other outside experts, especially in the specialized area of genetically modified and cloned farm animals. After a first draft of the current edition was produced, it was sent to three fully constituted Institutional Animal Care and Use Committees (IACUC) for peer review. Each peer-review IACUC included experts on farm animal care and a range of other species normally found at major research institutions. In addition, these IACUCs included nonscientific and administrative representatives and farm animal users and experts. Their peer-review comments were incorporated and then a 60-day period of public comment was opened during July and August 2009. After public comments were considered, the final version was produced and made available online. This edition expands on information on some topics that were covered incompletely in past editions due in large part to a developing literature. With more information now available on (a) environment enrichment and (b) handling and transport, these topics now have dedicated chapters. In addition, new information is included on biosecurity and genetically engineered and cloned farm animals. Several species chapters were expanded to be more complete and the veal chapter was eliminated in favor of incorporating calf care into the beef and dairy cattle chapters. This guide has been deliberately written in general terms so that the recommendations can be applied in the diverse institutions that use agricultural animals in agricultural research and teaching in the United States. In the context of this guide, the verb *must* is used for considerations or practices that are viewed as imperatives. The verb *should* indicates a strong recommendation but one for which alternative strategies might be justified after careful consideration. A *recommendation* connotes a practice or policy that is generally preferred but for which there are acceptable alternatives. It should be emphasized, however, that professional judgment is essential in the application of these guidelines. Veterinarians, institutional animal care and use committees, and users of agricultural animals must play a critical role in making specific suggestions regarding animal care and use at their institution. The *US Government Principles for the Utilization and Care of Vertebrate Animals Used in Testing, Research, and Training* of the IRAC (1985; Appendix 1) are endorsed in this guide as a basis for professional judgments about the appropriate treatment and use of agricultural animals in research and teaching activities. These judgments can be validated by third-party peer review, such as that provided by accreditation through Association for Assessment and Accreditation of Laboratory Animal Care International (AAALAC).

ADSA, ASAS and PSA solicit comments and suggestions related to this current edition of the Ag Guide during the period from now until the next revision is undertaken. Comments will be kept on file until the next revision. Comments about this version should be addressed in writing or by e-mail to any or all of the following:

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Chapter 1: Institutional Policies

Scientific and professional judgment and concern for the humane treatment of animals are required for the proper care of animals used in agricultural research and teaching (referred to in this guide as agricultural animal care and use). Because a variety of management systems and physical accommodations may be used for agricultural animals, an understanding of the husbandry needs of each species and of the particular requirements of agricultural research and teaching is essential for an effective institutional program of agricultural animal care and use (Stricklin and Mench, 1994; Granstrom, 2003). Critical components of such a program should include 1) clearly established lines of authority and responsibility; 2) an active Institutional Animal Care and Use Committee (**IACUC**); 3) procedures for self monitoring of the IACUC through semi-annual review of programs and facility oversight by the institutional officer; 4) appropriately maintained facilities for proper management, housing, and support of animals; 5) an adequate program of veterinary care; and 6) training and occupational health programs for individuals who work with the animals (ARENA/OLAW, 2002). This chapter is intended to aid in the development of institutional policies and programs for agricultural animal care and use.

MONITORING THE CARE AND USE OF AGRICULTURAL ANIMALS

Each institution should establish an agricultural animal care and use program with clearly designated lines of authority in accordance with this guide and in compliance with applicable federal, state, and local laws, regulations, and policies.

The chief executive officer or responsible administrative official of the institution should appoint a committee, the IACUC, to monitor the care and use of agricultural animals in agricultural research and teaching activities. The IACUC should be composed of individuals who are qualified by experience or training to evaluate the programs and proposals under review and should include at least one individual from each of the following categories (no individual category should be over-represented):

- A scientist who has experience in agricultural research or teaching involving agricultural animals;
- An animal, dairy, or poultry scientist who has training and experience in the management of agricultural animals;
- A veterinarian who has training and experience in agricultural animal medicine and who is licensed or eligible to be licensed to practice veterinary medicine;
- A person whose primary concerns are in an area outside of science (e.g., a faculty member from a nonscience department, a staff member, a student, a member of the clergy, or an institutional administrator);
- A person who is not affiliated with the institution and who is not a family member of an individual affiliated with the institution. This public member is intended to provide representation for general community interests in the proper care and treatment of animals and should not be a person who uses animals in agricultural or biomedical research or teaching activities at the college or university level; and
- Other members as required by institutional needs and applicable laws, regulations, and policies.

Because of experience and training, however, one individual may adequately fulfill more than a single role on the IACUC, but the committee should not have fewer than 5 members. It is strongly recommended that this committee be one that also monitors the care and use of laboratory animals at the institution, providing that the special membership requirements outlined above are met. This recommendation can be fulfilled by several different types of committee structures, including a single institutional committee, unit committees (e.g., departmental, college, or program) that review agricultural as well as biomedical uses of animals. The overriding goal should be to facilitate centralized, uniform, and high-quality oversight of the institution's animal care program.

The IACUC should meet at regular intervals, as appropriate, to ensure that the use of agricultural animals in research and teaching programs is humane, appropriate, and in accordance with this guide. Meetings of the IACUC need not always be conducted in person. Electronic technology, including web-based or telecommunications, can allow the committee to function appropriately. Such communications must be held with a quorum of members in real time and provide the same interactive opportunities as a face-to-face meeting. It is preferred that the IACUC work with investigators to resolve issues while ensuring animal health. The IACUC is authorized to

- review and approve or disapprove protocols and other proposed activities, or proposed significant changes in activities, related to agricultural animal care and use in research and teaching;
- conduct, at least twice a year, an inspection of agricultural animal facilities and study areas and review of the overall agricultural animal care and use program, and to provide a written report to the responsible institutional official regarding the institution's compliance with this guide;
- investigate concerns, complaints, or reports of noncompliance involving agricultural animals at the facility;
- suspend an activity involving agricultural animals when it is not in compliance with approved protocols or written operating procedures (see section on Written Operating Procedures);
- make recommendations regarding the development and implementation of institutional policies and procedures to facilitate, support, and monitor the humane and appropriate use of animals in agricultural research and teaching as well as any other aspect of the agricultural animal care program; and
- perform other functions as may be required by institutional need and by applicable laws, regulations, and policies.

Other useful information about IACUC functions can be found in the *Institutional Animal Care and Use Committee Guidebook* (ARENA/OLAW, 2002), the *Public Health Service Policy on Humane Care and Use of Laboratory Animals* (PHS, 2002), and Silverman et al. (2006).

PROTOCOL REVIEW

The review of research and teaching activities using animals is one of the most important functions of the IACUC. Protocols describing these activities must be reviewed before the initiation of the research or teaching activity to determine whether the proposed care and use of animals is appropriate and humane. Approval of the protocol may be granted, withheld pending modifications, or denied. The IACUC should perform a complete review at least once every three years, with additional continuing reviews if and when deemed necessary by the IACUC. The following topics should be considered in the preparation and review of animal care protocols:

- Objectives and significance of the research or teaching activity;
- Unnecessary duplication of previous studies;
- Availability or appropriateness of alternative procedures or models (e.g., less invasive procedures, cell or tissue culture, or computer simulations) for the proposed research or teaching activity. It should be noted, however, that hands-on training involving animals is a particularly important component of agricultural research and teaching;
- Aspects of the proposed experiment or demonstration having to do directly with animal care and use, including justification for the species and (or) strain of animal used; justification for the number of animals used; and a description of procedures that may cause discomfort, distress, or pain and of methods of alleviation including anesthesia, analgesia, tranquilizers, and nonpharmacologic means, as well as justification for any procedures that involve unalleviated pain, discomfort, or distress;
- Appropriateness of procedures and post-procedural care;
- Criteria and process for timely intervention, removal of animals from a study, or euthanasia if painful and stressful outcomes are anticipated;
- Unusual husbandry requirements (Note: describing a procedure as a "standard farm practice" may be acceptable if the institution's written operating procedure is being used or if the practice is needed to serve as an appropriate control);
- Aspects of animal husbandry not covered under written operating procedures (see section on Written Operating Procedures);
- Method of euthanasia or disposition of the animal; and
- Responsibilities, training, and qualifications of the researchers, teachers, students, and animal care personnel involved in the proposed activities.

The *US Government Principles for the Utilization and Care of Vertebrate Animals Used in Testing, Research, and Training* (Appendix 1 of this guide) state that "Procedures involving animals should be designed and performed with due consideration of their relevance to human or animal health, the advancement of knowledge, or the good of society." Because IACUCs are not ordinarily constituted to function as scientific peer-review committees, the IACUC should be judicious in reviewing the merit of proposed research and teaching activities (Mann and Prentice, 2004). Institutions should consider developing other mechanisms for peer merit review of research projects that have not already been reviewed by outside agencies. Although qualified peer review of research and teaching is important to consider, such peer review does not eliminate the need for the IACUC to thoughtfully review animal use.

Institutions must develop policies for animal care and use related to research conducted off site as well as research using privately owned animals on and off site. The fact that research is conducted off site does not lessen the responsibility of the institution to assure appropriate and humane animal care and use.

IACUCs are encouraged to work with investigators to help them refine their protocols and proposed animal care and use practices.

The common acceptance and use in animal agriculture of a production system, management practice, or routine procedure does not reduce the responsibility of every animal user to follow applicable laws, regulations, and policies, including the standards outlined in this guide. Exceptions to some provisions, however, may be justifiable to obtain new knowledge or to demonstrate methods commonly used in commercial agricultural animal production. For example, applied research and teaching may require the use of production practices that are consistent with those currently in use in the appropriate industry even though those practices differ from those outlined in this guide; also, research and teaching dealing with infectious diseases, toxins, or products of biotechnology may require special facilities. Exceptions to this guide should be stated explicitly in research and teaching protocols and be reviewed and approved by the IACUC.

WRITTEN OPERATING PROCEDURES

It is important to develop written policies or procedures for animal care and husbandry in the form of written operating procedures for each operating unit in the program. The IACUC must review and approve all written operating procedures involving the potential to cause pain or distress and should review all written operating procedures pertaining to animal care and husbandry. The written procedures must be filed in the appropriate administrative office and in locations accessible to those individuals involved in carrying out the designated procedures and must be monitored regularly by personnel designated by the institution.

There are certain commercial husbandry practices routinely carried out on agricultural animals that may cause temporary discomfort or pain. These standard agricultural practices (see Chapter 3 and Chapters 6 to 11) need not necessarily be described separately for each study, experiment, or demonstration, but are acceptable as written operating procedures provided that the practices 1) are warranted to sustain the long-term welfare of the animal and(or) the animal's caretakers or handlers; 2) are performed by or under the direct supervision of capable, trained, and experienced personnel; and 3) are performed with precautions taken to reduce pain, stress, and infection. The written operating procedures for alleviating pain and distress should be reviewed and approved by the IACUC.

Husbandry procedures and production methods at agricultural research facilities should be revised as research demonstrates improvements. Research on improved methods and procedures is encouraged.

ANIMAL HEALTH CARE

Adequate health care and records thereof must be provided for all agricultural animals used in research and teaching (see Chapter 2: Agricultural Animal Health Care). Institutional requirements will determine whether full-time, part-time, or consulting veterinary services are appropriate.

BIOSECURITY

It is essential that the agricultural animal care staff maintain a high standard of biosecurity to protect the animals from pathogenic organisms that can be transferred by humans. For additional details on biosecurity issues, see Chapter 3: Husbandry, Housing, and Biosecurity.

PERSONNEL QUALIFICATIONS

It is the responsibility of the institution to ensure that scientists, agricultural animal care staff, students, and other individuals who care for or use agricultural animals are qualified to do so through training or experience. Appropriate supervision should be provided to personnel until their competency is assured. Training programs should be tailored to institutional animal user needs but provide information about the humane care and use of agricultural animals, including, if applicable, 1) husbandry needs, proper handling, surgical procedures, and pre- and post-procedural care; 2) methods for minimizing the number of animals used and techniques for minimizing pain and distress, including the proper use of anesthetics, analgesics, tranquilizers, and nonpharmocologic methods; 3) methods for reporting deficiencies in the animal care program; 4) use of information services such as the Animal Welfare Information Center at the National Agricultural Library (NRC, 1991; CFR, 1992); and 5) methods of euthanasia. Records of participation in training programs should be maintained and available for review as needed.

Employees who provide routine animal care should participate regularly in in-service education and training relevant to their responsibilities. Formal or on-the-job training opportunities should be made available to all technical and husbandry support staff, including those who are temporary or part-time employees. It is recommended that the training program include information provided by experts from a broad range of disciplines such as animal husbandry, behavior, nutrition, environmental physiology, experimental surgery, veterinary clinical and diagnostic medicine, agricultural engineering, and instrumentation, and others as deemed appropriate. A variety of reference materials is available for use in training programs (Kreger, 1995; Underwood, 2005).

In addition to having in-house training, it is desirable for agricultural animal care staff to be professionally trained or certified. Many states have colleges with accredited programs in veterinary technology (AVMA, 2007). Technician and technologist certification is available through the American Association for Laboratory Animal Science (**AALAS**), although that program primarily emphasizes the care and use of laboratory animals rather than agricultural animals. Animal scientists with educational credentials ranging from the baccalaureate to the doctorate who seek recognition of their expertise in the biology and production of agricultural animals can be certified by examination by the American Registry of Professional Animal Scientists (**ARPAS**).

OCCUPATIONAL HEALTH

An occupational health and safety program must be established for individuals who work with agricultural animals. The program should be consistent with federal, state, and local regulations and will depend on the facilities, research activities, and hazards involved. The degree of participation of individuals in the program should be based on an assessment of risk by health and safety specialists involving consideration of the hazards posed by the animals and materials used; the duration, frequency, and intensity of exposure; the susceptibility of the personnel; and the history of occupational injury and illness in the particular workplace (Clark, 1993).

General guidelines for such programs have been published by the NRC (1997). The program for individuals working with agricultural animals may include a physical examination before placement, periodic medical evaluations for people in some job categories, surveillance to ensure protection from health hazards, and provisions for treating illness or injury. The program should also include an educational component to teach personnel about agricultural animal diseases and zoonoses, physical hazards, personal hygiene, precautions to be taken by individuals who are at unusual risk (e.g., pregnant women), and other considerations as appropriate (e.g., safety precautions with chemicals, radiation, and other hazardous agents that are part of a particular experimental protocol).

An appropriate immunization schedule should be adopted. It is important that all agricultural animal caretakers be immunized against tetanus every 10 years based on the institution's risk assessment. Immunizations should be offered to people (before exposure) who handle animals and risk infection from certain infectious agents. Prophylactic vaccinations should also be considered when research is being conducted on infectious diseases for which effective vaccines are available.

Persons working with farm animals may develop allergies. The occupational safety and health program should identify high-risk areas with potential for allergy development. Persons with known allergies should be provided personal protective equipment or avoid exposure to animals.

Physical injuries constitute health hazards for individuals working with agricultural animals. Institutions should identify high-risk areas and tasks and should educate animal care personnel about methods for reducing risk. Injuries can be minimized by providing training in proper animal handling, lifting, and equipment use. Access to first aid and medical treatment should be readily available, and personnel should be trained and familiar with access procedures. Such access may include readily available and properly stocked first-aid kits. Cases of animal bites and scratches should be documented, and tetanus prophylaxis should be considered.

Caretakers working with agricultural animals in closed buildings may develop respiratory problems, including chronic and irreversible lung damage (Kirkhorn and Garry, 2000). Appropriate respiratory protection should be provided for these individuals.

Zoonoses can also be a serious risk. Personnel (including animal care staff, technicians, investigators, clinicians, students, maintenance workers, and security staff) who have contact with or an opportunity for contact with animals or their excreta, products, or tissues should be made aware of hazards that have been identified and that are determined to be a risk (Acha and Szyfres, 2001, 2003). Zoonotic disease in animal populations should be screened for or monitored regularly as appropriate. Table A-1 in Appendix 2 of this guide lists the most common zoonotic diseases found in agricultural animals and the means by which they are spread; refer to Chapter 2: Agricultural Animal Health Care for more information.

The noise level in some animal facilities may sometimes be high. When personnel are exposed to noise exceeding federal standards, appropriate protection programs should be implemented (CFR, 1995).

Work assignments and health records should be a part of an occupational health program. Records should be kept of individual work assignments and should include the date and time of injuries or unusual illnesses. Supervisors should be instructed to fully inform personnel of potential health hazards, and personnel should be instructed to notify their supervisor if a zoonosis occurs.

SPECIAL CONSIDERATIONS

Hazardous Materials

The use of certain hazardous biological, chemical, or physical materials necessitates compliance with applicable laws and regulations as well as compliance with guidelines issued by granting agencies and organizations. Institutions should have written policies governing experimentation with hazardous materials and should ensure that staff members conducting and supporting research projects involving hazardous materials are qualified to assess the dangers to animals and humans and are capable of selecting appropriate safeguards. Special facilities and equipment may be required for certain hazardous materials, and additional requirements exist for those biological materials or toxins deemed as select agents by federal law. Further information about recommended practices and procedures can be found in publications by CDC and NIH (2000, 2007), CFR (2005), and NRC (1997).

Genetically Engineered and Cloned Animals

As advancements in research drive the discovery and development of new technologies, specific considerations may need to be made for the care and use of agricultural animals in research and teaching. Institutions, researchers, and IACUCs should assure that assessment of animal care and use protocols reflects differences in various animal technologies. Guidelines for research involving genetically engineered (GE) animals or livestock clones do not differ materially from those that apply to conventional animals used in research except under special conditions. The published scientific literature has not established the need for unique guidelines. The general standards of care associated with GE or cloned agricultural animals should be the same as those applied to all agricultural animals in research unless the specific genetic modification requires an alteration in management within the research environment to specifically facilitate animal welfare.

In the future, institutions may wish to establish guidelines used in keeping with federal, state, and local government regulatory requirements. The animal biotechnology industry recently released guidelines for research and development with GE animals as a stewardship program for GE animals (Biotechnology Industry Organization, 2009). The BIO Guidance provides information for the development and implementation of stewardship programs for all institutions and researchers that plan to engage in research and development, and possible commercialization, of GE animals.

Research Involving Genetic Engineering of Agricultural Animals

Genetic engineering of agricultural animals is the direct manipulation of an organism's genes, including heritable and nonheritable recombinant DNA constructs. Genetic engineering is different from traditional breeding, in which the organism's genes are manipulated indirectly. The genetic engineering of agricultural animals has been extensively reviewed (National Research Council, 2002; Council on Agricultural Science and Technology, 2003, 2007, 2009; Wheeler, 2007). All GE animals in the United States are in research and development, with currently only one approved product from a GE agricultural animal in the United States. Animal welfare for GE animals used in research is regulated by law, regulations, and guidelines of the US Department of Agriculture (USDA) and the National Institutes of Health (NIH). For animals used in biomedical research, their needs for thermal comfort, humidity control, floor space, and husbandry practices should be based on the performance standards outlined in this Ag Guide. Animals in certain biomedical settings and with certain genetic backgrounds may have special requirements that should be understood so that animals are comfortable. The same performance standards that indicate adequate animal welfare in an agricultural setting will apply for animals in a biomedical setting. Welfare of animals used in biomedical research is currently regulated by law, regulations, and guidelines of the USDA and the NIH. Specific information can be obtained by reviewing the NIH guidelines for research involving recombinant DNA molecules (NIH, 2002) and the Animal Welfare Act regulations overseen by USDA. Furthermore, the US Food and Drug Administration (FDA) recently released guidance for industry that may be helpful in the conduct of research with GE animals (FDA, 2009).

Research Involving Cloning of Agricultural Animals

Animal cloning is an assisted reproductive technology (FDA, 2008) similar to artificial insemination, embryo transfer, and in vitro fertilization. The current technique used for animal cloning is somatic cell nuclear transfer (SCNT). In research, GE animals may be produced using SCNT. There are no published US guidelines for unique requirements regarding the care and use of animal clones in research. The care and use of animal clones in research does not differ from care provided for conventional animals to assure good animal welfare and animal well-being. In addition, because the progeny of animal clones are not clones, clearly progeny do not require special consideration.

Disposition of Animal Clones

The disposition of animal clones may be of interest to animal agriculture, stakeholders in the food chain, and the US government because of issues involving the emergence of new policies by international country governments. Thus, it is recommended that institutions and researchers participate in the Livestock Industry Clone Registry whereby animal clones are registered in the database or registry. This Registry is part of the Supply Chain Management program developed by the livestock cloning companies in the United States to identify cattle and porcine clones in the United States. For more information about the registry, please see www.livestockcloneregistry.com.

Commercial Animal Cloning

In contrast to research with agricultural animal clones, commercial livestock cloning has been conducted in the United States for food purposes since the US Food and Drug Administration's 2008 conclusion that cloning and products of animal clones and progeny are safe. Information within their comprehensive scientific risk assessment might be useful in the future as agricultural animal clones are used in research (FDA, 2008). Furthermore, all commercially produced animal clones in the United States are registered in the aforementioned Livestock Industry Clone Registry.

Regardless of the animal technology, the IACUC should monitor the care and use of the agricultural animals in research and teaching activities and conduct careful review of protocols as noted earlier in Chapter 1 with respect to scientific protocols, public safety and animal welfare. Aspects of the review should include adequacy of methods to individually identify research animals and assure that the disposition of the research animals meets any federal, state and local government laws and regulations. Furthermore, institutions are required to meet federal, state and local laws and regulations regarding biosafety, biosecurity, and environmental issues in the conduct of research with animals derived from new technologies (see Chapter 3: Husbandry, Housing, and Biosecurity). International guidelines for GE animals either have not been initiated or are in various stages of development. Recently, the Codex Alimentarius (2008) adopted a new guideline for the conduct of food safety risk assessment for GE animals which might be helpful for institutions and researchers. As research with GE animals, animal clones, or animals derived using other technologies advances, institutions and researchers should keep abreast of new guidelines or policies being developed both domestically and internationally.

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Chapter 2: Agricultural Animal Health Care

Agricultural animal health care involves proper management and husbandry as well as veterinary care. Proper management is essential for the well-being of animals, the validity and effectiveness of research and teaching activities, and the health and safety of animal care personnel. Sound animal husbandry programs provide systems of care that permit the animals to grow, mature, reproduce, express some species-specific behavior, and be healthy. Specific operating procedures depend on factors that are unique to individual institutions. Well-trained and motivated personnel can often achieve high-quality animal care with less than ideal physical plants and equipment.

ANIMAL PROCUREMENT

When an institution acquires new animals, attention must be paid to applicable international, federal, and state regulations and institutional procedures, particularly those dealing with transportation and animal health. All animals must be obtained and transported legally. The attending veterinarian, in conjunction with the principal scientist, should formulate written procedures to assess the health status of a herd or flock obtained from a vendor before acquiring animals. The institution should develop a mechanism and process of control for animal acquisition that ensures coordination of resources that will preclude the arrival of animals in advance of preparation of adequate housing and appropriate veterinary quarantine procedures. Quality control for vendors and knowledge of the history of purchased animals is part of an adequate institutional veterinary care program. Animals of unknown origin or from stockyards should only be used if necessary; such animals may pose significant unknown health risks compared with animals of known origin and therefore should be handled appropriately. Newly acquired animals should undergo a quarantine and acclimation period, including preventive and clinical treatments as appropriate for their health status.

Acclimation and Stabilization

Newly arrived animals require a period of acclimation. Acclimation refers to a stabilization period, before animal use, which permits physiological and behavioral adaptation to the new environment. The attending veterinarian should establish general acclimation guidelines for each species. Any modifications to the general program should be discussed with the attending veterinarian before animals are shipped. In some cases, animals may require an extended acclimation period because of their history or health status. On the other hand, some studies, such as comparisons of metaphylactic treatments for shipping fever, need to begin as soon as animals arrive. Such exemptions from the acclimation period must be scientifically justified and approved by the Institutional Animal Care and Use Committee (**IACUC**).

Quarantine

Quarantine is the separation of newly received animals from those already in the facility or on the premises until the health of the new animals has been evaluated and found to be acceptable. The attending veterinarian should ensure that quarantine facilities or locations are appropriate and that quarantine procedures are consistent with current veterinary practices and applicable regulations. The quarantine period should be long enough to observe signs of infectious disease or obtain diagnostic evidence of infection status. Quarantine and testing of animals before introduction is especially important for herds or flocks that have attained specific-pathogen-free status, but these additions should be discouraged. If the health history of newly received animals is unknown, the quarantine program should be more comprehensive and sufficiently long to allow expression or detection of diseases present in the early incubation stage. Exceptions to quarantine practices should be approved by the attending veterinarian in advance of shipment of the animals.

The attending veterinarian, or skilled personnel under the direction of the attending veterinarian, should perform an initial examination and subsequent daily observations for newly arrived animals. Animals should be observed in quarantine until they are cleared for introduction into a herd or facility. During the quarantine period, animals should be vaccinated and treated for diseases and parasites as appropriate to protect their health and maintain the health of animals in the home facility. In addition to having adequate quarantine procedures, research facilities and animal use protocols should be designed to minimize the risk of introducing or transmitting disease agents.

VETERINARY CARE

Attending Veterinarian

The agricultural animal health care program is the responsibility of the attending veterinarian. The Institute for Laboratory Animal Research (**ILAR**), National Research Council *Guide for the Care and Use of Laboratory Animals* (The ILAR Guide; Clark, 1996) defines the attending veterinarian as "a veterinarian who has direct or delegated authority" and who "should give research personnel advice that ensures that humane needs are met and are compatible with scientific requirements." Animal Welfare Act regulations and the Public Health Service policy require that the attending veterinarian have the authority to oversee the adequacy of other aspects of animal care and use, including animal husbandry and nutrition, sanitation practices, zoonoses control, and hazard containment.

Research and teaching institutions must provide investigators and instructors with access to a veterinarian who has experience in the care of agricultural animals. The veterinarian can be full-time or part-time and must have authority to ensure that the provisions of the program are met. The attending veterinarian must be provided access to all research and teaching animals and to any related documents including health care records. The attending veterinarian also must be involved in the development and oversight of the veterinary care program, as well as in other aspects of animal care and use such as protocol review, establishment of anesthetic and analgesic guidelines, study removal criteria, training of animal users, and responsible conduct of research activities. Veterinary involvement in these activities helps to ensure animal health and well-being. The attending veterinarian is not required to be the sole provider of veterinary care and can delegate authority to another qualified veterinarian. However, the attending veterinarian must communicate with, and oversee veterinary care provided by, other veterinarians. When necessary, the attending veterinarian should utilize the expertise of other professionals when making determinations about agricultural animal care. Trained nonveterinary staff may administer treatments according to standard operating procedures approved by the attending veterinarian.

Preventive Medicine

Adequate agricultural animal health care in research and teaching involves a written and implemented program for disease prevention, surveillance, diagnosis, treatment, and endpoint resolution. The objectives of such a program are to ensure animal health and well-being, minimize pain and distress, maintain animal production, prevent zoonoses, provide assistance to investigators on study-related animal health issues, and avoid contaminants or residues in animal products. The program should include training for animal users regarding animal behavior, humane restraint, anesthesia, analgesia, surgical and postsurgical care, and euthanasia.

A mechanism for direct, frequent, and regular communication must be established among personnel who are responsible for daily animal care and observation, animal users, and the attending veterinarian. This will help ensure that timely and accurate animal health information is effectively communicated.

Sick, Injured, and Dead Animals

Animal care personnel must be trained to recognize signs of illness and injury. In general, sick and injured animals should be segregated from the main group to protect them and the other animals, observed at least once daily, and provided with veterinary care as appropriate. When animals are separated, a mechanism should be in place to communicate to staff the status of the animals and to ensure proper daily, weekend, holiday, and emergency care. In some circumstances, segregation is not feasible or may disrupt the social hierarchy, cause additional stress to the animal, or adversely affect research. The advantages of segregation should be weighed against its disadvantages, especially for mild illnesses or injuries that can be easily managed. Care should be taken to minimize spread of pathogens from ill animals to healthy animals by observing appropriate biocontainment measures. Incurably ill animals or ill or injured animals with unrelievable pain or distress should be humanely killed as soon as possible. Unexpected deaths should be reported to the attending veterinarian. Dead animals are potential sources of infection and should be disposed of promptly by a commercial rendering service or other appropriate means (e.g., burial, composting, or incineration), following applicable state and local ordinances and regulations. Postmortem examination of fresh or well-preserved animals may provide important animal health information and aid in preventing further losses. When warranted, waste and bedding that have been removed from a site occupied by an animal that has died should be moved to an area that is inaccessible to other animals and the site appropriately disinfected.

Medical Records

An important component of an agricultural animal health program is maintaining records that can be used to monitor animal health events, both physical and behavioral health events, as well as outcomes and levels of production. Medical records should comply with the American College of Laboratory Animal Medicine (**ACLAM**) (www.aclam.org/print/position_medrecords.pdf) statement on medical records (Field et al., 2007).

Group health records may be appropriate for animals that are kept as cohorts (e.g., in a colony, school, flock, herd, or room), particularly when animals undergo periodic evaluation by means of examining several representative individuals of the group. The institution, under the guidance of the attending veterinarian, should determine the method(s) by which medical records are maintained. Oversight of medical records is the responsibility of the attending veterinarian and the IACUC. When institutional representatives determine that a medical record should be created, the record typically contains the following information:

1. Identification of the animal(s) or group(s);
2. Clinical information, such as the animal's behavior, results of physical examinations, and observed abnormalities, illnesses, and/or injuries;
3. Immunizations and other prophylactic treatments and procedures;
4. Documentation and interpretation of diagnostic tests;
5. Documentation of research interventions;
6. Treatments prescribed and administered;
7. Clinical response and follow up information;
8. Descriptions of surgical procedures, anesthesia, analgesia, and perioperative care;
9. Methods used to control pain and distress;
10. Documentation of resolution;
11. Documentation of euthanasia or other disposition; and
12. Necropsy findings if necropsy is indicated.

The record system must be structured so that information is easily collected, gathered, analyzed, summarized, and available to the veterinarian, the principal scientist, and the IACUC. The ACLAM statement on *Medical Records for Animals used in Research Teaching and Testing* suggests that:

> Notations in the medical record should be made by individuals who have administered treatments, or made direct observations or evaluations of the animal(s) or their diagnostic results, or their designee. Individuals typically responsible for making notations in the record include veterinary staff (veterinarians and/or veterinary technicians), animal husbandry staff (animal care staff, managers, supervisors), and research staff (e.g., principal investigators, study directors and/or research technicians). All entries in the record should be dated, indicate the originator of the entry (e.g., initials, signature, and electronic signature) and be legible to someone other than the writer.

Vermin Control

Refer to Chapter 3: Husbandry, Housing, and Biosecurity for information on vermin control.

SURGERY

Multiple Major Surgical Procedures

The ILAR Guide differentiates major from minor surgery as follows: "Major survival surgery penetrates and exposes a body cavity or produces substantial impairment of physical or physiologic functions (i.e., laparotomy, thoracotomy, craniotomy, joint replacement, and limb amputation). Minor survival surgery does not expose a body cavity and causes little or no physical impairment (i.e., wound suturing; peripheral-vessel cannulation; such routine farm-animal procedures as castration, dehorning, and repair of prolapses; and most procedures routinely done on an "outpatient" basis in veterinary clinical practice)." Minimally invasive surgery such as laparoscopy may benefit the animal relative to traditional surgical techniques.

Performance of more than one major survival surgical procedure on a single animal is discouraged but may be necessary to ensure or maintain the health of the animal. Long-lived animals may undergo multiple major surgeries, such as a cow that requires surgery for correction of displaced abomasum and cesarean section for therapeutic purposes. Multiple major survival surgeries performed for nontherapeutic reasons should be performed only when justified and must be reviewed and approved by the IACUC. Multiple major surgeries that produce minor physiologic or physical impairment and reduce overall animal use, such as multiple endoscopic laparotomies in sheep for reproductive purposes, might be appropriate. Likewise, multiple surgical procedures might be justified when they are related components of the same project (e.g., cannulation of the digestive tract at several locations).

Anesthesia and Analgesia

Certain animal husbandry-related procedures (standard agricultural practices) may be conducted without anesthesia after consideration and approval by the IACUC. These procedures should be performed early in the life of the animal in accordance with accepted veterinary practices. When surgery is performed on older animals, appropriate anesthesia and sterile instruments should be used, trauma minimized, and hemorrhage controlled. It is important that husbandry practices be established to minimize stress, prevent infection, and ensure the comfort of the animals during the recovery period. Specific recommendations for each species are provided in subsequent chapters.

The attending veterinarian should advise investigators about the choice and use of analgesics and/or anesthetics or any other pain- or distress-relieving measure, including recommended times for withholding of food and water. After being trained and subsequently supervised by a qualified scientist or veterinarian, technical personnel may administer anesthetics and analgesics as part of a research or teaching protocol. If a painful or distressful experimental procedure must be conducted without the use of an anesthetic or analgesic because such use would prevent collection of useful data, this must be scientifically documented in the animal care and use protocol and approved by the IACUC.

Paralytic drugs (e.g., succinylcholine, other curariform drugs) are not anesthetics. They must not be used unless animals are in a surgical plane of anesthesia and thus unconscious. Use of paralytic agents must be justified in the animal use protocol and appropriate monitoring for depth of anesthesia described.

Tranquilizers are psychotropic substances that alter mental processes or behavior but do not produce anesthesia (Upson, 1985). These medications can reduce the dose of anesthetic required. When used alone, tranquilizers should only be used to allay fear and anxiety. Their use may render restraint less stressful and enable animals to adapt more easily to novel situations.

Surgery Personnel

Inappropriately performed surgical techniques or inadequate postoperative care will result in unnecessary pain and distress. Experimental surgery on agricultural animals should be performed or supervised by an experienced veterinarian or his/her designee in accordance with established protocols approved by an IACUC. Institutions must provide basic surgical training and opportunities to upgrade surgical skills for persons who will conduct or assist with experimental surgery. The training program must be reviewed by the IACUC and under the direction of the attending veterinarian or his/her designee. Training provided must be documented and the competency of personnel assured.

Surgical Facilities and Aseptic Technique

Major survival surgeries should be performed in facilities designed and prepared to accommodate surgery whenever possible, and appropriate aseptic surgical procedures should be employed. Good surgical practice includes the use of surgical caps, masks, gowns, and gloves, as well as aseptic surgical site preparation and draping. Sterile instruments must be used. Manufacturers' recommendations must be followed for chemical sterilants. For nonsurvival surgeries, during which the animal is euthanized before recovery from anesthesia, it may not be necessary to follow all aseptic techniques, but the instruments and surrounding area should be clean.

Minor surgical procedures that do not penetrate a body cavity or produce substantial impairment (e.g., wound suturing, peripheral-vessel cannulation, certain standard agricultural practices) may be performed under less stringent conditions if performed in accord with standard veterinary practices (Brown et al., 1993).

Therapeutic and emergency surgeries (e.g., caesarean section, treatment of bloat, repair of displaced abomasum) may sometimes need to be performed in agricultural settings that are not conducive to rigid asepsis. However, every effort should be made to conduct such surgeries in a sanitary or aseptic manner and to use anesthetics and (or) analgesics commensurate with the risks to the animal's well-being. Research protocols that carry a high likelihood of the need for emergency surgery should contain provisions for handling anticipated cases. Surgical packs and equipment for such events should be prepared and be readily available for emergency use.

Postsurgical Care

Appropriate facilities should be available for animals that are recovering from general anesthesia and major surgery. The following are required:

- Segregation from other animals until recovery from anesthesia;
- Clean and sanitary recovery area;
- Adequate space, with consideration for physical comfort and well-being of the animal, in a place suitable for recovery from anesthesia without injury (e.g., a room or stall with protective covering on floors and walls);
- Environmental controls sufficient to ensure maintenance of environmental temperature within the thermoneutral zone and animal temperature within the normal range during postsurgical recovery; and
- Trained personnel for postsurgical observation to help to ensure a safe recovery.
- Postsurgical observation should be provided until the animal is fully recovered from anesthesia, ambulatory, and able to safely return to its original housing location.

Signs of Pain and Distress

Pain is a sensation of discomfort that may lead to distress and feelings of urgency. Although pain and distress in animals can often be detected by an experienced observer, these conditions can sometimes be unapparent, especially in stoic animals. When unanticipated pain and (or) distress are detected, animal-care attendants or research staff should take immediate ameliorative action as necessary and contact the attending veterinarian.

Pain can be one of the earliest signs of disease or injury. Animals in pain may become less active, restless, may continually get up and down, and refuse to stay in one place, reduce feed consumption, grind their teeth, or vocalize. Some animals become less active, whereas others appear frightened or agitated. Animals in pain may resist handling or favor the painful area by adopting an abnormal stance or abnormal behavior.

In some cases, pain may not be noticed until a physiological act is induced such as swallowing, coughing, chewing, or defecating. The observer should try to determine whether pain appears to be constant or associated with a provoking act. Sudden, severe pain is often associated with fractures, rupture or torsion of visceral organs, or acute inflammatory processes and should be considered an emergency.

Relief of pain and/or distress in agricultural animals involves removing or correcting the inciting cause when possible, administering appropriate analgesics, and taking steps to reduce stimulation of pain receptors (e.g., immobilizing a fracture, elevating an injured claw by securing a wood block under the opposite claw). Relief of pain should be one of the first tasks of the attending veterinarian, adhering to the following principles (Radostits et al., 1994):

- Relief of pain is a humane act;
- Relief of pain must be initiated promptly once it is deemed necessary;
- It may be necessary to protect animals in pain from self-injury.

The attending veterinarian must be familiar with analgesics labeled for use in agricultural animals and must be able to prescribe and establish withdrawal times for extra-label use of analgesics when indicated. Animals with severe or chronic pain that cannot be alleviated must be euthanized.

ZOONOSES

For the purposes of this guide, zoonotic diseases are defined as infectious diseases in agricultural animals used in research and teaching that can be transmitted to humans and a natural reservoir for the infectious agent is an agricultural animal. Table A1 in Appendix 2 contains a list of many, but not all, zoonotic pathogens, mode of transmission, disease signs in ruminants, and disease signs and symptoms in humans. A current list and incidence of notifiable diseases such as Q-fever (*Coxiella burnetii*) may be obtained from the US Centers for Disease Control and Prevention (http://www.cdc.gov/).

The attending veterinarian, working with the animal scientists, should establish appropriate preventive medicine programs and husbandry practices to decrease the likelihood of transmission of zoonotic agents. Each institution must have an appropriate occupational health and safety program for evaluating the human health risks associated with animal contact and must take steps to ensure that health risks for each individual are assessed and managed to an acceptable level.

RESIDUE AVOIDANCE

Residues of 3 groups of chemicals must be prevented from occurring in research animals if those animals, or their products, are going into the human food chain. These are 1) approved drugs used according to directions on the label, 2) drugs used in an extra-label fashion, and 3) other chemicals such as herbicides, pesticides, and wood preservatives. The Food Animal Residue Avoidance Database (**FARAD**; http://www.farad.org/) is a project sponsored by the USDA Cooperative State Research, Education and Extension Service. The FARAD *Compendium of FDA Approved Drugs* provides information about drugs that are available for treating animal diseases, the withholding times for milk and eggs, and preslaughter withdrawal times for meat. Information about the drugs approved for use in food animals in the United States is included in this online database (http://www.farad.org/). The FARAD compendium allows selection of over-the-counter products that satisfy particular needs as well as alerts to the need for veterinary assistance with prescription drugs; FARAD also supplies estimated meat and milk withdrawal times for extra-label use of drugs.

Drug administration to animals destined to enter the food chain requires special consideration. Before animals may be slaughtered for human or animal food purposes, time must be allowed for medications, drugs approved by the Food and Drug Administration (**FDA**), or substances allowed by the FDA for experimental testing under the Investigational New Animal Drug (**INAD**) exemption to be depleted from the tissues. Such use is only permitted when it adheres to the regulations in the Animal Medicinal Drug Use Clarification Act of 1994, Public Law 103-396 (http://www.fda.gov/cvm/amducatoc.htm). A record of the product used, dose, route of administration, duration of treatment, and period of withdrawal must be maintained. Adherence to proper withdrawal times must be ensured before animals are transported to the auction, market, or abattoir.

Drug Storage and Control

Pharmaceuticals intended for use in food-producing animals must be managed responsibly. Storage should be in an area that is clean and dry and that offers protection from changes in temperature, sunlight, dust, moisture, and vermin. The manufacturer's labeling should be consulted for specific information regarding appropriate storage conditions and product shelf-life. In addition, the integrity of product containers should be periodically evaluated to assess for potential leakage or contamination of the stored product. Products in damaged containers or with missing or illegible labels should be disposed of properly.

To minimize the potential for treatment errors, products should be physically segregated according to indicated use, with special attention to separate drugs that are intended only for animals of a certain age or production state (e.g., lactating, nonlactating, pregnant, neonate). For large inventories, separate storage cabinets for each group of products will further reduce the opportunity for errors in selection and use. When necessary, lockable storage units should be used to prevent access by unauthorized persons.

Record Keeping

Records of all potentially harmful products used in the facility, their storage, their use, and their disposal should be maintained. Such record keeping should be similar to the quality assurance programs used by responsible farmers in the food animal industry. If used in accord with the label and with allowance for the correct withdrawal time, approved drugs should not result in violative residues. Record-keeping and management should be audited and should confirm that drugs are not outdated and that the directions on the label have been followed. Records should be maintained for at least 3 months or in timelines consistent with state and federal requirements as they apply.

Quality Assurance Programs

The food animal industries have developed several quality assurance programs such as the Milk and Dairy Beef Quality Assurance Program (AgriEducation Inc., Stratford, IA), the Beef Quality Assurance Program (National Cattlemen's Beef Association, Englewood, CO), the United Egg Producers Five Star Quality Assurance Program (UEP, Atlanta, GA), the Pork Quality Assurance Program (National Pork Producers Council, Des Moines, IA), and the Veal Producer Quality Assurance Program (American Veal Association, Harrisburg, PA). Agricultural research or teaching programs using animals that may be slaughtered for human consumption must institute quality assurance programs that are equivalent or superior to those used in the food animal industries. Many food animal industries, private corporations, and humane organizations have also developed animal welfare assurance programs that should be referenced.

Regulatory Oversight

In the event that animals are given a new animal drug for investigational purposes, no meat, eggs, or milk from those animals may be processed for human food, unless authorization has been granted by the FDA or the USDA, and an appropriate INAD exemption from the FDA has been obtained for use of the investigational drug. In such cases, the investigator must follow specifications outlined in the INAD. The authorization to process meat, eggs, or milk from such animals for human food will depend on the development of data to show that the consumption of food from animals so treated is consistent with public health considerations and that the food does not contain the residues of harmful drugs or their metabolites. In the event that animals are given a new animal drug, no meat, eggs, or milk from those animals may be processed for human food consumption under any circumstances. Proper methods of disposal of such meat, eggs, and milk may include incineration, burial, or other procedures ensuring safety, sanitation, and avoidance of the human food supply.

Extra-Label Use

The use of different dosages, formulations, or routes of administration, or the treatment of animals for conditions not specifically mentioned on the product label, constitutes extra-label use. Such use may be considered by licensed veterinarians when the health of the animal is immediately threatened and when suffering or death would result from failure to treat the affected animal. Such use is only permitted when it adheres to the regulations promulgated by the FDA under the Animal Medicinal Drug Use Clarification Act (AMDUCA) of 1994, Public Law 103-396. The major principles guiding such use are that 1) there must be a valid relationship between veterinarian, client, and patient, and 2) there must be an adequate safety margin in the withdrawal time that is based on the most complete pharmacokinetic data available. The FDA should be contacted whenever guidance is needed.

Organic Farming

Some institutions have organic farming components. The US National Organic Standards state that "producers must not withhold medical treatment from a sick animal to maintain its organic status. All appropriate medications and treatments must be used to restore an animal to health when methods acceptable to organic production standards fail." It is important that research animals managed under organic standards be provided prompt and adequate health care as necessary even if the animal will, as a result, be removed from organic production.

Hazardous Chemicals

There are many chemicals used on farms and in agricultural research establishments that could potentially result in residues in the meat, milk, or eggs of animals exposed to these chemicals. Examples are pesticides for insect control, herbicides, poisons for rodent control, wood preservatives, and disinfectants. Harmful products should be properly labeled and stored, a record of their purchase and expiration dates should be kept, and personnel must be informed of potential hazards and wear appropriate protective equipment. Chemicals must be stored, used, and disposed of in a manner that prevents contamination of animals and residues in milk, meat, or eggs.

RESTRAINT

Brief physical restraint of agricultural animals for examination, collection of samples, and a variety of other experimental and clinical manipulations can be accomplished manually or with devices such as stocks, head gates, stanchions, or squeeze chutes. It is important that such devices be suitable in size and design for the animal being held and be operated properly to minimize stress and avoid pain and injury (Grandin, 1983a,b). Refer to Chapter 5: Animal Handling and Transport for additional information. Personnel should be trained on the use of hydraulically operated restraint devices to prevent potential injury. Extended physical restraint should be reviewed and approved by the IACUC.

TRANSGENIC AND GENETICALLY ENGINEERED AND CLONED ANIMALS

Recent years have seen a growing interest in the development and use of transgenic and genetically modified agricultural animals for agricultural and human therapeutic purposes. A transgenic animal is one that carries a foreign gene that has been deliberately inserted into its genome. Genetically engineered animal models require deliberate modification of the animal genome by moving a desired trait into the genome. These modifications are accomplished by microinjection, retroviral transfection, and a variety of other techniques.

It is important not to confuse genetically engineered animals with cloned animals. Genetically engineered animals may be produced by cloning as well as other techniques noted above. The progeny of cloned animals are not properly termed "cloned animals." It is also important to distinguish between research and commercial application of cloning techniques. Cloning technology has been reviewed by the FDA and is one of several commercially available assisted reproductive technologies including in vitro fertilization and embryo transfer (FDA, 2008, 2009). As advancements in research continue and new technologies are developed, specific considerations may need to be made for the care and use of agricultural animals.

Both transgenic and genetically engineered animal models may have physiologic or phenotypic problems including abortions, large offspring, enlarged umbilicus, retained placenta, hydrops, multiple births, and placenta deformities. The scientist is responsible for identifying physiologic and phenotypic changes and must have a plan to address changes that affect animal health to facilitate and ensure animal welfare.

The US FDA is responsible for approving the use of genetically modified foods in the United States under the Food, Drug, and Cosmetic Act of 1992 (FDCA; 21 U.S.C. §301 et seq).

EUTHANASIA

Protocols for euthanasia should follow current guidelines established by the American Veterinary Medical Association (**AVMA**; www.avma.org) and copies of the protocols should be made available to all personnel who euthanize animals. The agents and methods of euthanasia appropriate for agricultural animals are available in the AVMA (2007) Guidelines for Euthanasia (http:www.avma.org/issues/animal_welfare/euthanasia.pdf) or subsequent revisions of that document. Refer to Chapters 6 through 11 for species-specific information on euthanasia and slaughter.

Euthanasia is the procedure of killing an animal rapidly, painlessly, and without distress. Euthanasia must be carried out by trained personnel using acceptable techniques in accordance with applicable regulations and policies. The method used should not interfere with postmortem evaluations. Proper euthanasia involves skilled personnel to help ensure that the technique is performed humanely and effectively and to minimize risk of injury to people. Personnel who perform euthanasia must have training and experience with the techniques to be used. This training and experience must include familiarity with the normal behavior of agricultural animals and how handling and restraint affect their behavior. The equipment and materials required to perform euthanasia should be readily available, and the attending veterinarian or a qualified animal scientist should ensure that all personnel performing euthanasia have demonstrated proficiency in the use of the techniques selected.

Acceptable methods of euthanasia are those that initially depress the central nervous system to ensure insensitivity to pain (Canadian Council on Animal Care, 1980). Euthanasia techniques should result in rapid unconsciousness followed by cardiac or respiratory arrest and the ultimate loss of brain function. In addition, the technique used should minimize any stress and anxiety experienced by the animal before unconsciousness (AVMA, 2007). For this reason, anesthetic agents are generally acceptable, and animals of most species can be quickly and humanely euthanized with the appropriate injection of an overdose of a barbiturate. Certain other methods may be used for euthanasia of anesthetized animals because the major criterion (insensibility) has been fulfilled (Lucke, 1979).

Physical methods of euthanasia (e.g., penetrating captive-bolt devices for large animals) may be used. Every attempt should be made to minimize stress to the animal before euthanasia. Personnel must be trained on the proper use of the captive bolt per species, and the captive bolt device must be appropriately maintained.

Electrocution is an acceptable means of euthanasia if the electrodes are placed so that the current travels through the brain and through the heart. Methods in which the current is directed through the heart only are not acceptable (www.grandin.com). It is imperative to ensure that the animal is indeed dead (i.e., no heartbeat and no possibility of recovery). Techniques that apply electric current from head to tail, head to foot, or head to moistened metal plates on which the animal is standing are unacceptable (AVMA, 2007).

Agents that result in tissue residues cannot be used for euthanasia of animals intended for human or animal food unless those agents are approved by the FDA. Carbon dioxide is the only chemical currently used for euthanasia of food animals (primarily swine and poultry) that does not lead to tissue residues. The carcasses of animals euthanized by barbiturates may contain potentially harmful residues and should be disposed of in a manner that prevents them from being consumed by human beings or animals.

No matter what method of euthanasia is performed, personnel must ensure that death has occurred. Assurance of death may include ascertaining the absence of heartbeat and respiration, lack of corneal or other reflexes, and lack of physical movement. Personnel should be trained on how to assure death in animals.

Humane Slaughter

Slaughter of animals entering the human food chain must be accomplished in compliance with regulations promulgated under the federal Humane Methods of Slaughter Act (9 CFR. 313.1–90; CFR, 1987). These regulations outline the requirements for the humane treatment of livestock before and during slaughter (http://www.animallaw.info/administrative/adus9cfr313.htm). The Food Safety and Inspection Service is the agency within the USDA responsible for ensuring compliance with this Act.

When stunning is used during slaughter, stunning must be done appropriately and effectively. All equipment for stunning must be properly maintained, and personnel performing stunning must be properly trained, including instruction in assessing insensibility. The use of carbon dioxide alone or in combination with other gaseous inhalants remains controversial.

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Chapter 3: Husbandry, Housing, and Biosecurity

Proper management is essential for the well-being of the animals, the validity and effectiveness of research and teaching activities, and the health and safety of animal care personnel. Sound animal husbandry programs provide systems of care that permit the animals to grow, mature, reproduce, and be healthy. Specific operating procedures depend on many factors that are unique to individual institutions. Well-trained and properly motivated personnel can often achieve high quality animal care with less than ideal physical plants and equipment.

FACILITIES AND ENVIRONMENT

Environmental Requirements and Stress

Domestic animals are relatively adaptable to a wide range of environments (Hale, 1969; Craig, 1981; Sossinka, 1982; Curtis, 1983; Price, 1984, 1987; Fraser, 1985; Yousef, 1985a,b,c). Domestication is a continuing process. Genetic strains of animals selected for growth or reproduction in different environments under varying degrees of control are used currently for much of the production of livestock and poultry (Siegel, 1995). These strains of animals are sometimes very different from the breeds or strains from which they were originally derived (Ollivier, 1988; Craig, 1994; Havenstein et al., 1994a,b). Agricultural animals may be kept in extensive environments (e.g., pasture or range) where they reside in large areas (e.g., acres or square miles) outdoors. They may also be kept in intensive environments (e.g., in houses, pens, or cages) where they are confined to an area that would not sustain them were the environment not controlled and where food, water, and other needs must be provided to them. Individual animals may be moved during their lives from extensive to intensive systems or vice versa. Species requirements for domesticated animals are thus variable and depend both on the genetic background of the animals and their prior experience.

Criteria of Well-Being

Various criteria have been proposed to identify inappropriate management and housing conditions for agricultural animals. For example, in poultry, significant feather loss that is not associated with natural mating or natural molting is widely accepted as an indication that birds are experiencing stressful conditions. More sophisticated measures of stress are not necessarily superior and may even yield confusing results and lead to inaccurate conclusions (Moberg, 1985; Rushen, 1991; Rodenburg and Koene, 2004). For instance, plasma corticosteroid concentrations of hens residing in spacious floor pens may be similar to those in high-density cages, even though other criteria may indicate that the caged hens are adversely affected by their environment (Craig and Craig, 1985; Craig et al., 1986). During stressful social situations, resistance to virus-induced diseases may be depressed, but resistance to bacterial infections and parasites may be increased (Siegel, 1980; Gross and Siegel, 1983, 1985).

Some researchers have placed emphasis on behavioral criteria of well-being (Wood-Gush et al., 1975), although others have pointed out the difficulties of interpretation involved (Duncan, 1981; Craig and Adams, 1984; Dawkins, 1990). In the same way, some researchers (Craig and Adams, 1984) have suggested that depressed performance of individuals, independent of economic considerations, is a relatively sensitive reflector of chronic stressors, but Hill (1983) was less convinced using the same parameters.

Animal well-being has both physical and psychological components (Fraser and Broom, 1990; Duncan, 1993; Fraser, 1993). No single objective measurement exists that can be used to evaluate the level of well-being associated with a particular system of agricultural animal production. There is consensus, however, that multiple integrated indicators provide the best means of assessing well-being (Curtis, 1982; Mench and van Tienhoven, 1986; Rushen and de Passillé, 1992; Mason and Mendl, 1993; Mitlöhner et al., 2001). Indicators in 4 categories are generally advocated: 1) behavior patterns; 2) pathological and immunological traits; 3) physiological and biochemical characteristics; and 4) reproductive and productive performance of the individual animal. A judgment as to the balance of evidence provided by these indicators has been used, when available, as the basis for the recommendations in this guide.

D. C. Hardwick postulated (cited in Duncan, 1978) and Duncan (1978) developed the idea that an acceptable level of animal welfare exists over a range of conditions provided by a variety of agricultural production systems, not under just one ideal set of circumstances. Improvements in certain environments may increase animal well-being somewhat, but any point in the range would still be considered acceptable with respect to animal welfare. Good management and a high standard of stockmanship are important in determining the acceptability of a particular production system (Hurnik, 1988) and should be emphasized in agricultural animal research and teaching facilities.

Macroenvironment and Microenvironment

Animal well-being is a function of many environmental variables, including physical surroundings, nutritional intake, and social and biological interactions (Hafez, 1968; Curtis, 1983; Yousef, 1985a). Environmental conditions should be such that stress, illness, mortality, injury, and behavioral problems are minimized. Particular components of the environment that need to be taken into account include temperature, humidity, light, air quality, space (including complexity of space), social interactions, microbe concentrations, noise, vermin and predators, nutritional factors, and water. See Chapter 4: Environmental Enrichment for further information

Physical conditions in the room, house, barn, or outside environment constitute the macroenvironment; the microenvironment includes the immediate physical and biological surroundings. Different microenvironments may exist within the same macroenvironment. Both microenvironment and macroenvironment should be appropriate for the genetic background and age of the animals and the purpose for which they are being used. Domestic animals readily adapt to a wide range of environments, but some genetic strains have specific needs of which the scientist should be aware and for which accommodation should be made.

Even in relatively moderate climatic regions, weather events such as floods, winter storms, and summer heat waves may require that animals have access to shelter. If trees or geographic features do not provide enough protection, artificial shelters and (or) windbreaks or sunshades should be provided (Mitlöhner et al., 2001, 2002; Johnson et al., 2008; Marcillac-Embertson et al., 2009).

Genetic Differences

Some strains of agricultural animals may have requirements that differ substantially from those of other stocks of the same species (Gross et al., 1984). Some strains of pigs, for example, are particularly susceptible to stress because they carry a gene that causes malignant hyperthermia when they experience even mild stress (Bäckström and Kauffman, 1995). Transgenic animals may also have special needs for husbandry and care (Mench, 1998). Practices to ensure the well-being of special strains should be established independently of those made for the species in general. Refer to Chapter 4: Environmental Enrichment for more detailed information on enhancement of animals' physical or social environments.

Space Requirements

Floor area is only one of the components that determine the space requirements of an animal. Enclosure shape, floor type, ceiling height, location and dimensions of feeders and waterers, features inside the enclosure, and other physical and social elements affect the amount of space sensed, perceived, and used by the animals in intensive management systems (Strickland et al., 1979; Strickland and Gonyou, 1995). When possible, animals in stanchions, cages, crates, or stalls should be allowed to view one another, animal care personnel, and other activities where this would not interfere with research or teaching objectives.

Determination of area requirements for domestic animals should be based on body size, head height, stage of life cycle, behavior, health, and weather conditions. All area recommendations in this guide refer to the animal zone (i.e., the space that can be used by the animal). Unless experimental or welfare considerations dictate otherwise, space should be sufficient for normal postural adjustments, including standing, lying, resting, self-grooming, eating, drinking, and eliminating feces and urine. When animals are crowded, body weight gain and other performance traits may be depressed (Gehlbach et al., 1966; Adams and Craig, 1985), and the animals may show altered levels of aggressive behavior (Bryant and Ewbank, 1974; Al-Rawi and Craig, 1975).

Temperature, Water Vapor Pressure, and Ventilation

Air temperature, water vapor pressure, and air velocity are some of the most important factors in the physical environment of agricultural animals. In addition, factors related to animal health (i.e., infectious status) and genetics (i.e., trangenic modification) affect the thermal balance of animals and thus their behavior, metabolism, and performance.

Most agricultural animals are quite adaptable to the wide range of thermal environments that are typically found in the natural outdoor surroundings of various climatic regions of the continental United States. The range of environmental temperatures over which animals use the minimum amount of metabolizable dietary energy to control body temperature is termed the thermoneutral zone (NRC, 1981; Curtis, 1983; Yousef, 1985a). Homeothermic metabolic responses are not needed within this zone. Temperature and vapor pressure ranges vary widely among geographic locations. The long-term well-being of an animal is not necessarily compromised each time it experiences cold or heat stress. However, the overall efficiency of metabolizable energy use for productive purposes is generally lower outside the thermoneutral zone than it is within the zone.

The preferred thermal conditions for agricultural animals lie within the range of nominal performance losses (Hahn, 1985). Actual effective environmental temperature may be temporarily cooler or warmer than the preferred temperature without compromising either the overall well-being or the productive efficiency of the animals (NRC, 1981). Evaluation of thermoregulation or of heat production, dissipation, and storage can serve as an indicator of well-being in relation to thermal environments (Hahn et al., 1992; Eigenberg et al., 1995; Mitloehner and Laube, 2003).

The thermal environment that animals actually experience (i.e., effective environmental temperature) represents the combined effects of several variables, including air temperature, vapor pressure, air speed, surrounding surface temperatures, insulative effects of the surroundings, and the age, sex, weight, infectious status, transgenic modification status, adaptation status, activity level, posture, stage of production, body condition, and dietary regimen of the animal.

To overcome shortcomings of using ambient temperature as the only indicator of animal comfort, thermal indices have been developed to better characterize the influence of multiple environmental variables on the animal. The temperature-humidity index (**THI**), first proposed by Thom (1959), has been extensively applied for moderate to hot conditions, even with recognized limitations related to airspeed and radiation heat loads (NOAA, 1976). At the present time, the THI has become the de facto standard for classifying thermal environments in many animal studies and selection of management practices during seasons other than winter (Hahn et al., 2003).

The THI has further been used as the basis for the Livestock Weather Safety Index (**LWSI**; LCI, 1970) to describe categories of heat stress associated with hot-weather conditions for livestock exposed to extreme conditions. Categories in the LWSI are alert ($74 < \text{THI} < 79$), danger ($79 \leq \text{THI} < 84$), and emergency ($\text{THI} \geq 84$). Additionally, THI between 70 and 74 is an indication to producers that they need to be aware that the potential for heat stress in livestock exists.

The index {wind chill temperature index (°C) = 13.12 + (0.6215 × AT) − [11.37 × (WSPD)0.16] + [0.3965 × AT × (WSPD)0.16]}, where AT = air temperature, °C, and WSPD = wind speed, m/s, is a physiological based model and accounts for inherent errors in the earlier wind chill index (**WCI**), which was not based on heat transfer properties of body tissues. However, the old WCI closely mimicked heat loss and equivalent temperature equations reported by Ames and Insley (1975) for sheep and cattle. Equations developed by Ames and Insley (1975) accounted for heat transfer through pelts and hides sections of previously harvested animals; however, they did not account for fat cover and other regulatory processes utilized in mitigating cold stress. In addition, body heat loss due to wind will be proportional to the surface area exposed and not the entire surface area of the body. This error was also inherent in the old WCI.

A ventilation system removes heat, water vapor, and air pollutants from an enclosed animal facility (i.e., a facility in which air enters and leaves only through openings that are designed expressly for those purposes) at the same time that it introduces fresh air. Adequate ventilation is a major consideration in prevention of respiratory and other diseases. Where temperature control is critical, cooling or heating may be required to supplement the ventilation system. For certain research projects, filtration or air conditioning may be needed as well.

Typically, ventilation is the primary means of maintaining the desired air temperature and water vapor pressure conditions in the animal microenvironment. The amount of ventilation needed depends on the size, number, type, age, and dietary regimen of the animals, the waste management system, and atmospheric conditions. Equipment and husbandry practices that affect heat and water vapor loads inside the animal house also should be considered in the design and operation of the ventilation system.

Ventilation rates in enclosed facilities (MWPS, 1989, 1990a,b) should increase from a cold-season minimum (to remove water vapor, contaminants, and odors as well as modify inside temperature) to a hot-season maximum (usually around 10 times the minimum rate, to limit the increase in temperature inside the house that is due to the solar radiation load and sensible animal heat). It is important to recognize the approximately 10-fold increase in ventilation rate from winter to summer that is required in a typical livestock or poultry house. Because the animals themselves are the major source of water vapor, heat, and (indirectly) odorous matter, ventilation rate calculated on the basis of animal mass is more accurate than that based on air-exchange rate guidelines.

Relative humidity is ordinarily the parameter used to manage the air moisture content. Hot weather ventilation rates should be sufficiently high to maintain the relative humidity below 80% in an enclosed animal house (Curtis, 1983; Hinkle and Strombaugh, 1983) except for situations in which high relative humidity does not cause animal health concerns. Conversely, ventilation rate during cold weather should be sufficiently low to ensure that the relative humidity does not fall to a level that causes animal health concerns, unless needs for air quality or condensation control necessitate a higher rate. Atmospheric humidity does not ordinarily become a significant factor in effective environmental temperature until the air temperature approaches the temperature of the animal's surface, in which case the animal will depend almost entirely on evaporative heat loss to maintain thermal equilibrium with the environment.

The use of fans to promote air movement can be beneficial during hot weather if there is too little natural air movement. Direct wetting is effective in decreasing heat stress on cattle and pigs; however, it can cause the death of poultry. Wetting is best accomplished by water sprinkled or dripped directly on the animals. Misters and evaporative coolers specifically designed to reduce air dry-bulb temperature are also used to reduce heat stress on agricultural animals.

Correctly designed and maintained sunshades protect animals from heat stress by reducing solar radiation load. Trees, if available, are ideal sunshades. Artificial, roofed shades are acceptable.

Mechanical ventilation requires proper design and operation of both air inlets and fans for proper distribution and mixing of the air and thus for creating uniform conditions throughout the animal living space. Mechanical ventilation, with fans creating static pressure differences between inside and outside the house, brings in fresh air and exhausts air that has picked up heat, water vapor, and air pollutants while passing through the building. Mechanical ventilation, if properly designed, provides better control of air exchange for enclosed, insulated animal houses in colder climates than does natural ventilation. The effectiveness of natural ventilation in cold climates will depend on the design and orientation of the enclosure, as well as the species and number of animals housed and the stage of their life cycle.

Natural ventilation uses thermal buoyancy and wind currents to vent air through openings in outside walls or at the ridge of the building. Natural ventilation is especially effective for cold animal houses (i.e., houses in which no heat is supplied in addition to animal heat) in moderate climates; however, insulated walls, ceilings, and floors are often recommended to minimize condensation. The air exchange rate needed to remove the water vapor generated by animals and evaporation of water from environmental surfaces often brings air temperature inside such houses down to values near those outdoors. If waterers and water pipes are protected from freezing, the practical low operating temperature is the point at which manure freezes, although this temperature would be too cold for some species or stages of the life cycle. Automatic curtains or vent panels, insulated ceilings, and circulating fans help to regulate and enhance natural ventilation systems.

During cold weather, ventilation in houses for neonatal animals should maintain acceptable air quality in terms of water vapor and other pollutants without chilling the animals. Air speed should be less than 0.25 m/s (50 ft/min) past very young animals. There should be no drafts on young poultry or pigs.

During hot, warm, or cool atmospheric conditions, ventilation of animal houses should maintain the thermal comfort of the animal to the extent possible. Ideally, the ventilation rate should be high enough to prevent indoor temperature from exceeding outdoor temperature (temperature rise limit; Curtis, 1983) by more than 3°C (5°F) when the atmospheric temperature is above 32°C (90°F) for small animals and above 25°C (78°F) for larger ones. In arid and semi-arid regions where the potential for evaporative heat loss is great, air temperature may peak at over 43°C (110°F) for 1 or 2 d or longer without affecting animal well-being if animals have been acclimatized by chronic exposure.

Ventilation system design should be based on building construction and the rates of water vapor and heat production of the animals housed (Curtis, 1983; Hinkle and Strombaugh, 1983). The frame of reference is the animal microenvironment. For example, the outdoor calf hutch is a popular accommodation for dairy replacement heifer calves in most parts of the continental United States. Although the hutch provides a cold microenvironment for calves during winter in northern latitudes, the calf is nonetheless comfortable if cared for correctly (MWPS, 1995). In closed houses during hot periods, additional ventilation capacity (up to 60 or more air changes/hour) may be necessary.

In enclosed animal houses, both environmental temperature and air quality depend on the continuous functioning of the ventilation system. An automatic warning system is desirable to alert animal care and security personnel to power failures and out-of-tolerance environmental conditions (Clark and Hahn, 1971), and consideration should be given to having an on-site generator for emergency use.

The relative air pressures between animal areas and service areas of a building housing animals should be considered when the ventilation system is designed to minimize the introduction of airborne disease agents or air pollutants into the service area. Advice of a qualified agricultural engineer or other specialist should be sought for the design of and operating recommendations for ventilation equipment.

Air Quality

Air quality refers to the nature of the air with respect to its effects on the health and well-being of animals and the humans who work with them. Air quality is typically defined in terms of the air content of certain gases, particulates, and liquid aerosols, including those carrying microbes of various sorts.

Good ventilation, waste management, and husbandry usually result in acceptable air quality. Ammonia, hydrogen sulfide, carbon monoxide, and methane are the pollutant gases of most concern in animal facilities (Curtis, 1986). In addition, OSHA (1995) has established allowable exposure levels for human workers with 8 h of exposure daily to these gases. The concentration of ammonia to which animals are exposed ideally should be less than 10 ppm and should not exceed 25 ppm, but a temporary excess should not adversely affect animal health (Von Borell et al., 2007). Comparable concentrations for hydrogen sulfide are 10 and 50 ppm, respectively. The concentration of carbon monoxide (arising from unvented heaters) in the air breathed by animals should not exceed 150 ppm, and methane (which is explosive at certain concentrations in air) should not exceed 50,000 ppm. Special ventilation is required when underfloor waste pits are emptied because of the potentially lethal hazards to animals and humans from the hydrogen sulfide and methane gases that are released.

Many factors affect airborne dust concentration, including relative humidity, animal activity, air velocity, and type of feed. Dust concentration is lower at higher relative humidities. High animal activity and air velocities stir up more particles and keep them suspended longer. Fat or oil added to feed reduces dust generation (Chiba et al., 1985). Microbes and pollutant gases may attach to airborne dust particles.

The allowable dust levels specified by OSHA (1995) are based on exposure of human workers for 8 h daily without facemasks; allowable dust levels are 5 mg/m3 for respirable dust (particle size of 5 μm or less) and 15 mg/m3 for total dust. Although animals can tolerate higher levels of inert dust with no discernible detriment to their health or well-being (Curtis and Drummond, 1982), the concentration of dust in animal house air should be minimized.

Concentrations of microbes in the air should be minimized. Dust and vapor pressure should be controlled. The ventilation system should preclude the mixing of air from infected microenvironments with that from microenvironments of uninfected animals.

Lighting

Lighting should be diffused evenly throughout an animal facility. Illumination should be sufficient to aid in maintaining good husbandry practices and to allow adequate inspection of animals, maintenance of the well-being of the animals, and safe working conditions for personnel. Guidelines are available for lighting systems in animal facilities (MWPS, 1987b).

Although successful light management schemes are used routinely in various animal industries to support reproductive and productive performance, precise lighting requirements for the maintenance of good health and physiological stability are not known for most animals. However, animals should be provided with both light and dark periods during a 24-h cycle unless the protocol requires otherwise. See Chapters 6 through 11 for references on lighting and photoperiod in individual species. Red or dim light may be used if necessary to control vices such as feather-pecking in poultry and tail-biting in livestock.

Provision of variable-intensity controls and regular maintenance of light fixtures helps to ensure light intensities that are consistent with energy conservation and the needs of animals (as they are understood), as well as providing adequate illumination for personnel working in animal rooms. A time-controlled lighting system may be desirable or necessary to provide a diurnal lighting cycle. Timers should be checked periodically to ensure their proper operation.

Excreta Management and Sanitation

A complete excreta management system is necessary for any intensive animal facility. The goals of this system are as follows:

- To maintain acceptable levels of worker health and animal health and production through clean facilities;
- To prevent pollution of water, soil, and air;
- To minimize generation of odors and dust;
- To minimize vermin and parasites;
- To meet sanitary inspection requirements; and
- To comply with local, state, and federal laws, regulations, and policies.

The planning and design of livestock excreta management facilities and equipment are discussed by MWPS (1993).

A plan should be followed to ensure that the animals are kept reasonably dry and clean and are provided with comfortable, healthful surroundings. Good sanitation is essential in intensive animal facilities, and principles of good sanitation should be understood by animal care personnel and professional staff. Different levels of sanitation may be appropriate under different circumstances, depending on whether manure packs, pits, outdoor mounds, dirt floors, or other types of excreta management and housing systems are being used. In some instances, animals may be intentionally exposed to excreta to enhance immunity. A written plan should be developed and implemented for the sanitation of each facility housing agricultural animals. Building interiors, corridors, storage spaces, anterooms, and other areas should be cleaned regularly and disinfected appropriately.

Waste containers should be emptied frequently, and implements should be cleaned frequently. It is good practice to use disposable liners and to wash containers regularly.

Animals can harbor microbes that can be pathogenic to humans and other species. Hence, manure should be removed regularly unless a deep litter system or a built-up manure pack is being employed, and there should be a practical program of effective disinfection to minimize pathogens in the environment.

For terminal cleaning, all organic debris should be removed from equipment and from floor, wall, and ceiling surfaces. If sanitation depends on heat for effectiveness, the cleaning equipment should be able to supply water that is at least 82°C (180°F). When chemical disinfection is used, the temperature of wash water may be cooler. If no machine is available, surfaces and equipment may be washed by hand with appropriate detergents and disinfectants and with vigorous scrubbing.

Health and performance of animals can be affected by the time interval between successive occupations of intensive facilities. Complete disinfection of such quarters during the unoccupied phase of an all-in, all-out regimen of facility management is effective for disease management in some situations.

Programs of pasture-to-crop rotation for periodically resting the pasture and programs that permit grazing by other animal species can aid in the control of soil-borne diseases and parasites. Spreading of manure on pastures as fertilizer is a sound and acceptable management practice but may spread toxic agents and infectious pathogens (Wray and Sojka, 1977). Caution should be exercised with manure of animals infected with known pathogens, and other methods of waste disposal should be considered.

Animal health programs should stipulate storage, handling, and use criteria for chemicals designed to inactivate infectious microbes and parasites. There should be information about prevention, immunization, treatment, and testing procedures for specific infectious diseases endemic in the region.

Where serious pathogens have been identified, the immediate environment may need to be disinfected as part of a preventive program. Elimination of moist and muddy areas in pastures may not be possible, but prolonged destocking is an available option. Drylot facilities may need to be scraped and refilled with uncontaminated materials. Thorough cleaning of animal housing facilities may be followed by disinfection. Selection of disinfection agents should be based on knowledge of potential pathogens and their susceptibilities to the respective agents (Meyerholz and Gaskin, 1981a,b).

Some means for sterilizing equipment and supplies (e.g., an autoclave or gas sterilizer) is essential when certain pathogenic microbes are present and for some specialized facilities and animal colonies. Except in special cases (e.g., specific-pathogen-free animals), routine sterilization of equipment, feed, and bedding is not necessary if clean materials from reliable sources are used. In areas where hazardous biological, chemical, or physical agents are being used, a system for monitoring equipment should be implemented.

FEED AND WATER

Animals must be provided with feed and water in a consistent manner, on a regular schedule, in accordance with the requirements established for each species by the NRC (1985, 1988, 1994, 2001, 2007) and as recommended for the geographic area. When exceptions are required by an experimental or instructional protocol, these must be justified in the protocol and may require approval by the Institutional Animal Care and Use Committee (**IACUC**). Feeders and waterers must be designed and situated to allow easy access without undue competition (NRAES, 1990; Lacy, 1995; Pirkelmann, 1995; Taylor, 1995).

Sufficient water must be available to meet the animals' daily needs under all environmental conditions. Water troughs, bowls, or other delivery devices must be cleaned as needed to ensure adequate intake and to prevent transmission of microbial- or contaminant-associated disease. Non-municipal water sources should be periodically tested for quality by an approved agency or laboratory.

Large supplies of feed should be stored in appropriate, designated areas (MWPS, 1987a). Bulk feed storage containers and feed barrels must be well maintained and the lids kept securely in place to prevent entry of pests, water contamination, and microbial growth. Containers should be cleaned as needed to ensure feed quality. The area around the containers such as the auger boot area should be cleaned regularly. Feed in sacks should be stored off the floor on pallets or racks, and each sack should be labeled with the contents and manufacture date or use-by date. All feedstuffs should be maintained in such a manner as to prevent contamination by chemicals and/or pests. For example, open feed sacks should be stored in closed containers, and mixing devices and utensils, feed delivery equipment, and feeders/feeding sites should be cleaned regularly to ensure adequate feed intake and prevent transmission of microbial- or contaminant-associated disease. Feed placed in carts or in other delivery devices should be fed promptly or covered to avoid attracting pests. An effective program of vermin control should be instituted in feed storage areas. Animal care personnel should routinely inspect feed to identify gross abnormalities such as mold, foreign bodies, or feces; such feed should not be fed until the abnormal components are removed or the feed is determined to be safe. Toxic compounds (Osweiler, 1985) should be stored in a designated area away from feed and animals to avoid accidental consumption.

Social Environment

Agricultural animals are social by nature and social isolation is a stressor (Gross and Siegel, 1981; Marsden and Wood-Gush, 1986). Agricultural animals that normally live in herds or flocks under natural conditions that are used in research and teaching should be housed in pairs or groups when possible. Considerations involved in implementing social housing for agricultural animals are discussed by Mench et al. (1992). If social housing is not feasible because of experimental protocols or because of unpreventable injurious aggression among group members, singly housed animals should be provided with some degree of visual, auditory, and (or) olfactory contact with other members of their species. Socialization to humans and regular positive human contact is also beneficial (Gross and Siegel, 1982; Hemsworth et al., 1986, 1993). In some instances, one species can be used as a companion for another species (e.g., goats and horses; Gross and Siegel, 1982; Hemsworth et al., 1986, 1993). Temporary isolation is sometimes required for an animal's safety (e.g., during recovery from surgery), but the animal should be returned to a social setting as soon as possible.

Separation by Species

Agricultural animals of different species are typically kept in different enclosures to reduce interspecies conflict, meet the husbandry and environmental needs of the animals, and facilitate research and teaching. However, some research protocols or curricula require species to be co-housed. Facility design and husbandry practices influence whether this can be accomplished in a manner that assures the well-being of the animals. Mixing of compatible species (e.g., sheep and cattle) can often be accomplished more easily in extensive production situations than in intensive housing situations. Some species can carry subclinical or latent infections that can be transmitted to other species that are housed in close proximity, causing clinical disease or mortality. Therefore, a qualified veterinarian or scientist should recommend appropriate health and biosecurity practices if species are to be co-housed.

Separation by Source or Age

Animals obtained from different sources often differ in microbiological status. It is usually desirable to keep these animals separated, at least until microbiologic status is determined (e.g., serologic testing, microbiologic culture, fecal flotation) or steps (e.g., vaccination, deworming, treatment, culling) are taken to protect against disease transmission. Separation of animals of different ages may also be advisable to reduce disease transmission and control social interactions. Placing animals in groups of similar age or size may allow more uniform access to feed and reduce injuries. All-in, all-out schemes are examples of age-group separation that are designed to minimize disease risk. However, mixed-group housing is acceptable if disease risk is low, husbandry practices are good, and social interaction is acceptable or necessary (e.g., calves nursing cows). A qualified veterinarian and animal facility manager should work together to devise housing configurations and husbandry practices that assure animal health and well-being while also meeting research and (or) teaching goals.

HUSBANDRY

Animal Care Personnel

The principal scientist or animal management supervisor should make all animal care personnel aware of their responsibilities during both normal work hours and emergencies. A program of special husbandry procedures in case of an emergency should be developed.

It is the reserach facility management's responsibility to ensure that personnel caring for agricultural animals used for research or teaching are appropriately qualified or trained. This responsibility may be delegated to an IACUC. Qualification by experience and (or) training must be documented. The animal facility manager must ensure that all animal care personnel are aware of their responsibilities during and outside normal work hours. Protocols for emergency care must be developed and made available to all personnel.

Observation

Animals in intensive accommodations should be observed and cared for daily by trained and experienced caretakers. Illumination must be adequate to facilitate inspection. In some circumstances, more frequent observation or care may be needed (e.g., during parturition, postsurgical recovery, confinement in a metabolism stall, or recovery from illness). Under extensive conditions, such as range or pasture, observations should be frequent enough to detect illness or injury in a timely fashion, recognize the need for emergency action, and ensure adequate availability of feed and water. A disaster plan must be developed for observing animals and providing care during emergency weather or health situations. Regardless of accommodations, animal observations should be documented and husbandry or health concerns reported to the animal facility manager or attending veterinarian as appropriate.

Emergency, Weekend, and Holiday Care

There must be a means for rapid communication in case of an emergency. In emergencies, facility security and fire personnel must be able to contact staff members responsible for the care of agricultural animals. Names and contact information for those individuals should be posted prominently in the animal facility and provided to the security department or telephone center. If posting names and contact information poses privacy or security issues, a contact number for a security or command center should be used instead. The institution must ensure that emergency services can be contacted at any time by staff members.

The institution must assure continuity of daily animal care, to encompass weekends, holidays, unexpected absences of assigned personnel, and emergency situations. Staff assigned to weekends and holidays must be qualified to perform assigned duties. Cross-training of staff and establishment of standard operating procedures is encouraged to assure consistent, high-quality care. Emergency veterinary care must be readily available after daily work hours, on weekends, and on holidays.

In the event that weather conditions or natural disasters make feeding temporarily impossible, every attempt should be made to provide animals with a continuous supply of water. Absence of feed for up to 48 h should not seriously endanger the health of normal, well-nourished juvenile or adult cattle, sheep, goats, horses, poultry, or swine. Feed should be provided within 24 h to very young animals that are not nursing their dams.

Emergency Plans

A site-specific emergency plan must be developed to care for agricultural animals that are used for research and teaching. The goal for a plan should be to provide proper management and care for the animals regardless of the conditions. However, some conditions may be so unusual and extreme that it will not be possible to provide immediate care for the animals and to simultaneously ensure employee safety. Thus, emergency plans should define proper animal management and care and parameters to ensure employee safety.

Emergency plans should name employees or positions that are considered essential for providing proper animal management and care. Those employees should a priori understand that responding to emergencies is a condition of employment and that they will be held accountable should they fail to care properly for the animals. Plans should focus on emergencies that are most likely to occur in the specific geographic area or the research or teaching facility (e.g., heavy snow, blizzard, ice, high wind, tornado, hurricane, fire, flood, breach of physical security that disrupts care, and breach of biosecurity that threatens the animals). Emergency plans should include animal evacuation plans specific to the research or teaching facility and actions to be taken if transportation is interrupted.

Animal Identification and Records

Animals should be permanently identified by a method that can be easily read. Identification of individual animals is desirable, but, in some circumstances, it is acceptable to identify animals by group, cage, or pen. Individual birds may be wing-banded or leg-banded. Ear-notching, ear tattooing, electronic transponders, and branding may be used for individual identification of other species, and each has its advantages and disadvantages. Ear notches and tattoos are permanent and effective, but notching constitutes elective surgery and tattoos generally cannot be read without restraining animals. Electronic transponders require special sensor units or stations, but should be considered when possible. Cattle and horses are most consistently identified using freeze-branding on the hip, shoulder, rear leg, or side. In addition, when freeze branding is used on more than one breed of horse, branding is performed under the mane. Some states require that cattle be permanently identified by branding with a hot iron; however, this procedure is more stressful than freeze-branding (Lay et al., 1992). Ear and neck chain tags, although readable at some distance, can become lost and are therefore not necessarily permanent. In addition, neck chains and straps should be avoided in situations in which the animal could become entangled in a fence, rock outcropping, or other feature of the environment. Any associated pain and distress should be considered when determining the method of identification. In some cases, it may be necessary to identify animals in multiple ways (e.g., as a transgenic animal and by individual identification).

Individual records are needed for most animals. These records should include information about the animal (e.g., birth date, sex, pedigree), its source and location, its productivity (e.g., body weight, milk or egg production, milk composition on specific dates), its reproductive performance (e.g., breeding and birthing dates, young produced, semen collection dates), protocols the animal is assigned to, and its ultimate disposition. Records for individual animals or groups should also include dates of vaccination, parasite control measures used, blood testing dates and results, and notations as to whether castration, spaying, or other elective procedures have been performed. Applicable veterinary data to be recorded include dates of examination/treatment, clinical information/diagnosis, names of medications and amounts and routes of administration, descriptions of surgical procedures, and resolution of surgical procedures or illnesses. Principal scientists or animal facility managers may wish to record nutritional information. Research protocols often dictate that additional information be recorded. Refer to Chapters 6 to 11 for species-level information on species-specific identification and record keeping.

Vermin Control

Programs should be instituted to control infestation of animal facilities by vermin (e.g., flies, mosquitoes, lice, mites, ticks, grubs, rodents, skunks, and pest birds such as starlings, pigeons, and sparrows). The most effective control in facilities prevents entry of vermin into the facility by screening openings and ceilings; sealing cracks; eliminating vermin breeding, roosting, and refuge sites; and limiting access of vermin to feed supplies and water sources. Building openings should be screened with 1.3-cm (0.5-in) mesh, and ceilings with ridge vents should be screened with 1.9-cm (0.75-in) mesh to minimize rodent and bird entry. Smaller mesh sizes are recommended where they will not interfere with airflow. Mesh may need to be installed along foundations below ground level, especially with wood foundations.

Pesticides should be used only as approved (Hodgson, 1980). Particular caution should be exercised with respect to residues in feedstuffs, which could injure animals and (or) eventually pass into the meat, milk, or eggs (Willett et al., 1981). Pesticides should be used in or around animal facilities only when necessary, only with the approval of the scientist whose animals will be exposed to them, and with special care. A pesticide applicator or a commercial service may be used.

In some regions, wildlife (e.g., skunks, raccoons, and foxes) and stray cats and dogs may spread zoonotic diseases, including rabies, to agricultural animals. In high-risk locations, institutions should implement an educational program that includes training scientific and animal care personnel to recognize the signs of rabies in both wildlife and agricultural species and to handle and report potentially rabid animals. Inoculation may be advisable for humans who may come into contact with animals in regions where rabies is endemic.

Many agricultural institutions keep cats for pest-control purposes. Although the use of free-roaming cats is a traditional form of pest control for agricultural facilities, cats may limit the ability for baiting and may present hygiene or accident risks or serve as disease vectors (Van't Woudt, 1990; Van Sambeek et al., 1995; Vantassel et al., 2005). However, when cats are present, proper veterinary care and oversight should be provided to these animals. Veterinary care should include vaccinations, parasite control, and neutering.

STANDARD AGRICULTURAL PRACTICES

Sometimes procedures that result in temporary distress and even some pain are necessary to sustain the long-term welfare of animals or their handlers. These practices include (but are not limited to) comb-, toe-, and beak-trimming of chickens; bill-trimming of ducks; toenail removal, beak-trimming, and snood removal of turkeys; dehorning and hoof-trimming of cattle; tail-docking and shearing of sheep; tail-docking, neonatal teeth-clipping, hoof-trimming, and tusk-cutting of swine; and castration of males and spaying of females in some species. Some of these procedures reduce injuries to humans and other animals (e.g., cannibalism, tail-biting, and goring). Castration, for example, reduces the chances of aggression against other animals. Bulls and boars also cause many serious injuries to humans (Hanford and Fletcher, 1983). Standard agricultural practices that are likely to cause pain should be reviewed and approved by the IACUC. Recommendations regarding these practices for the different species are found in Chapters 6 through 11. The development and implementation of alternative procedures less likely to cause pain or distress are encouraged. Overall, best practices for pain prevention and control should be followed.

Sick, Injured, and Dead Animals

Sick and injured animals should be segregated from the main group when feasible, observed thoroughly at least once daily, and provided veterinary care as appropriate. Incurably ill or injured animals in chronic pain or distress should be humanely killed (see Chapter 2 and Chapters 6 through 11) as soon as they are diagnosed as such. Dead animals are potential sources of infection. Their disposal should be accomplished promptly by a commercial rendering service or other appropriate means (e.g., burial, composting, or incineration) and according to applicable ordinances and regulations. Postmortem examination of fresh or well-preserved animals may provide important animal health information and aid in preventing further losses. When warranted and feasible, waste and bedding that have been removed from facilities occupied by an animal that has died should be moved to an area that is inaccessible to other animals. More information regarding sick, injured, and dead animals is available in Chapter 2: Agricultural Animal Health Care.

HANDLING AND TRANSPORT

Additional details on the handling, restraint, and transportation of animals are given in Chapter 5: Animal Handling and Transport.

SPECIAL CONSIDERATIONS

Noise

Noise from animals and animal care activities is inherent in the operation of any animal facility. Although differences exist in perceived loudness of the same sound (Algers et al., 1978a,b), occupational noise limitations have been established for workers, and employees should be provided appropriate hearing protection and monitored for their effects (Mitloehner and Calvo, 2008).

Noise ordinarily experienced in agricultural facilities generally appears to have little permanent effect on the performance of agricultural animals (Bond, 1970; NRC, 1970), although Algers and Jensen (1985, 1991) found that continuous fan noise disrupted suckling of pigs. Sudden loud noises have also been reported to cause hysteria in various strains of chickens (Mills and Faure, 1990).

Metabolism Stalls and Other Intensive Procedures

Animals that are subjected to intensive procedures requiring prolonged restraint, frequent sampling, or other procedures experience less stress if they are trained to cooperate voluntarily with the procedure. Cattle, pigs, and other animals can be trained with food rewards to accept and cooperate with various procedures, such as jugular venipuncture (Panepinto, 1983; Calle and Bornmann, 1988; Grandin, 1989; Grandin et al., 1995).

Many studies of the nutrition and physiology of agricultural animals use a specialized piece of equipment, the metabolism stall. Successful designs have been reported for various species (Mayo, 1961; Welch, 1964; Baker et al., 1967; Stillions and Nelson, 1968; Wooden et al., 1970). These stalls give animal research and care personnel easy access to the animal and its excreta.

The degree of restraint of animals housed in metabolism stalls is substantially different from that of other methods that restrict mobility (e.g., stanchions and tethering). Animals in metabolism stalls are often held by a head gate or neck tether and are restricted in their lateral and longitudinal mobility. These differences may exacerbate the effects of restriction on animals housed in metabolism stalls (Bowers et al., 1993). Metabolism stalls should be used only for approved studies, not for the purpose of routine housing. Researchers should consider appropriate alternatives to metabolism stalls (such as determination of digestibility by marker methods) if such alternatives are available.

There should be a sufficient preconditioning period to ensure adequate adjustment and comfort of the animal to the metabolism stall before sample collection starts. The length of the preconditioning period should be subject to approval of the IACUC. At least enough space should be provided in the metabolism stall for the animal to rise and lie down normally. When possible, metabolism stalls should be positioned so that the animal is in visual, auditory, and olfactory contact with conspecific animals to minimize the effects of social isolation.

Thermal requirements of animals may be affected when they are placed in metabolism stalls. For example, the lower critical environmental temperature of an animal held individually in a metabolism stall is higher than when residing in a group because the single animal cannot obtain the heat-conserving benefits of huddling with group-mates.

Animals in metabolism stalls should be observed more frequently than those in other environments, and particular attention should be paid to changes in behavior and appetite and the condition of skin, feet, and legs. The length of time an animal may remain in a metabolism stall before removal for exercise should be based on professional judgment and experience and be subject to approval by the IACUC. The species and the degree of restraint imposed by particular stall types should be taken into consideration in making such judgments. Recommendations for particular species can be found in the appropriate chapters of this guide.

BIOSECURITY

The term biosecurity in an agricultural setting has historically been defined as the security measures taken to prevent the unintentional transfer of pathogenic organisms and subsequent infection of production animals by humans, vermin, or other means (i.e., bioexclusion). Biosecurity is also applied in the same context to agricultural animals used in the field of agricultural research, teaching, and testing. With the advent of bioterrorism and the designation of select agents, the term biosecurity has acquired new definitions, depending on the field to which it is applied. Biosecurity is now used to define national and local policies and procedures that address the protection of food and water supplies from intentional contamination and is additionally used to define measures required to maintain security and accountability of select agents and toxins. It is important to understand these concepts when using the term and to clarify that in this section we are using the term biosecurity in the context of preventing the unintentional transfer of pathogens to animals and humans through appropriate facility design, training, and precautions (i.e., immunizations). For example, personnel working in swine and poultry facilities should be immunized against influenza and receive training related to potential cross-contamination of agents between animals and humans. The USDA has published voluntary guidelines and a checklist as a resource to help the agricultural producer reduce security risks at the farm level (USDA, 2006). This publication is designed to prevent both intentional and unintentional introduction of pathogens at the farm level. A list of references and resources is also provided in this document on a variety of farm biosecurity issues. Other sources of information include reviews of biosecurity basics and good management practices for preventing infectious diseases and biosecurity of feedstuffs (Buhman et al., 2000; BAMN, 2001). All of these publications offer information and suggestions that could be evaluated for their impact on the design of an animal facility.

It is essential that the agricultural animal care staff maintain a high standard of biosecurity to protect the animals from pathogenic organisms that can be transferred by humans. Good biosecurity begins with personal cleanliness. Showering or washing facilities and supplies should be provided, and personnel should change their clothing as often as necessary to maintain personal hygiene. Disposable gear such as gloves, masks, coats, coveralls, and shoe covers may be required under some circumstances. Personnel should not leave the work place in protective clothing that has been worn while working with animals. Personnel should not be permitted to eat, drink, apply cosmetics, or use tobacco in animal facilities. Visitors should be limited as appropriate, and institutions should implement appropriate precautions to protect the safety and well-being of the visitors and the animals.

Preventing the introduction of disease agents is a continuous challenge, particularly when teaching and research facilities allow public access. Herd health and sanitation programs should be in place to minimize exposure to pathogens.

Animal care personnel in research and teaching facilities should not be in contact with livestock elsewhere unless strict biosecurity precautions are followed. To reduce inter-building transmission of pathogenic microorganisms, careful attention should be given to traffic patterns of inter-building personnel and disease organisms in feed and transport vehicles. Barriers to microorganism transmission should be considered for personnel who move between houses, including showering in, changing clothes, and the use of disinfectant footbaths as personnel move between rooms and buildings. Establishing a barrier between animals and visitors requires visitors to do some or all of the following: shower in/shower out (including washing hair), wear clean footwear (i.e., plastic boots), change to on-site clothes, and wear only on-site clothes. In addition, if personnel need to go back and forth between different phases of production, it is critical that they work from clean to dirty phases of the farm.

Boot Cleaning and Disinfection

The use of boot baths can prevent or minimize mechanical transmission of pathogens among groups of pigs. Visible organic material may be removed from boots using water and a brush or specific boot cleaning station. Boots may be disinfected by soaking in a clean bath of an appropriate disinfectant following the manufacturer's guidelines for dilution rate and exposure time. Personnel should step into and scrub their boots in the boot bath upon entry and when leaving the room/facility. It is important to frequently empty, clean, and refill the boot bath to prevent it from being contaminated with organic matter. Disposable boots may be used.

BIOCONTAINMENT

High-consequence livestock pathogens (e.g., tuberculosis, foot and mouth disease) or the vectors (e.g., mosquitoes, ticks) responsible for transmission of disease cause high morbidity and mortality, and can have a significant regional, national, and global economic impact. The use of these pathogens in agricultural research brings several challenges when designing and operating an animal facility. The design of this type of facility should strive for flexibility, effective containment of pathogens, and minimizing the risk of exposure to personnel when zoonotic agents are utilized. The use of agricultural animals in high-consequence livestock pathogen research requires a thorough understanding of a variety of regulatory requirements and the concept of risk assessment. The USDA provides a list of livestock, poultry, and fish pathogens that are classified as "pathogens of veterinary significance" in Appendix D of the book *Biosafety in Microbiological and Biomedical Laboratories* (**BMBL**; CDC, 2007). The use of these pathogens requires facilities to meet specific criteria for design, operation, and containment features, which are described in the BMBL. For the listed agents, criteria may include utilizing containment levels designated as Animal Biosafety Level (**ABSL**)-2, enhanced ABSL-3, BSL-3-Ag, or ABSL-4. Requirements for BSL-3-Ag facilities must be met when any of the listed pathogens are used in animals and the room housing the animals provides the primary containment (i.e., animals are loose-housed in the room). When the studies can be accomplished in smaller species in which animals are housed in primary containment devices, which allows the room to serve as the secondary barrier, then enhanced ABSL-3 requirements can be utilized. Enhancements to ABSL-3 should be determined on a case-by-case basis, using risk assessment, and in consultation with the Animal and Plant Health Inspection Service (**APHIS**) of the USDA. In addition to the BMBL, facility design standards have been published by the USDA to guide the design of Animal Research Service (**ARS**) construction projects and contain useful information on the design of containment facilities for agricultural research. These standards include information on containment design that addresses hazard classification and choice of containment, containment equipment, and facility design issues for the different levels of biocontainment (ARS, 2002). Although published to provide guidance for National Institutes of Health (**NIH**)-funded construction projects and renovations for biomedical research facilities, the *NIH Design and Policy Guidelines* (NIH, 2003) contain useful information on construction of BSL-3 and ABSL-3 facilities. The use of recombinant DNA molecules in agricultural research can introduce additional considerations when designing an animal facility. Published guidelines provide recommendations for physical and biological containment for recombinant DNA research involving animals (NIH, 2002). These guidelines include a supplement published in 2006 that provides additional information specific to the use of lentiviral vectors (NIH, 2006). The Agricultural Bioterrorism Protection Act of 2002 required the propagation of regulations that address the possession, use, and transfer of select agents and toxins that have the potential to pose a severe threat to plants or animals, and their products. The USDA/APHIS published the implementing regulation covering animals and animal products, which identifies those select agents and toxins that are a threat solely to animals and animal products (VS select agents and toxins) and overlap agents, or those agents that pose a threat to public health and safety, to animal health, or to animal products (CFR, 2005). Overlap select agents and toxins are subject to regulation by both APHIS and the Centers for Disease Control and Prevention (CFR, 2002). The regulations implemented by both agencies reference the BMBL and the NIH *Guidelines for Research Involving Recombinant DNA Molecules* as sources to consider when developing physical structure and features, and operational and procedural safeguards. Other issues discussed in some of these references may not directly affect containment of pathogens or safety of personnel, but should be considered as they may affect the design of a facility. For example, the use of select agents requires certain security measures to be in place that restrict access to areas where select agents or toxins are used or stored. This can include laboratories, animal rooms, and storage freezers, resulting in a significant impact on how a research facility is designed. A thorough understanding of the references cited in this section is advised before initiating the design of new biocontainment facilities or renovation of existing facilities to accommodate research with hazardous agents or toxins requiring containment.

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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 post-parturient 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 minimize 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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Chapter 5: Animal Handling and Transport

Handling refers to how agricultural animals are touched, moved, and interacted with during husbandry procedures. Transport means when agricultural animals are moved by vehicles or vessel from one place to another.

Performance standards during handling include careful, considerate, respectful, calm, human interactions with animals in as positive a manner as is possible. Animals handled in a respectful manner will be calmer and easier to handle than animals handled in a rough or disrespectful manner.

Whenever possible, animals should be moved at a normal walking speed, and acclimating the animals to handling and close contact with people will reduce stress (Grandin, 1997a; Fordyce, 1987; Boandl et al., 1989). Research clearly shows that animals that are handled in a negative manner and fear humans have lower weight gains, fewer piglets, and give less milk and reduced egg production (Hemsworth, 1981; Barnett et al., 1992; Hemsworth et al., 2000). Cattle that become agitated during restraint in a squeeze chute or exit from the squeeze chute rapidly have lower weight gains, poorer meat quality, and higher cortisol levels compared with calmer animals (Voisinet et al., 1997a,b; King et al., 2006).

Socialization of agricultural animals with humans should be done when feasible when small numbers of animals are used for research. Socialization and gentling can be carried out with relative ease by frequent exposure to kind, gentle care. Even brief periods of handling, beginning at the youngest possible age, confer advantages for ease of handling of birds and increase feed efficiency, body weight, and antibody responses to red blood cell antigens (Gross and Siegel, 2007). For example, Gross and Siegel (1982a,b) and Jones and Hughes (1981) 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. When large numbers of animals are housed under commercial conditions, socialization may not be possible, but the flightiness can be reduced if a person either walks through the flock herds or groups of animals or walks by their cages on a daily basis.

Calm animals will also provide more accurate research results that are less confounded by handling stress. Handling and restraint stresses can significantly alter physiological measurements. Beef cattle not accustomed to handling had significantly higher cortisol levels after restraint compared with dairy cattle that were accustomed to handling (Lay et al., 1992a,b). Prolonged 6-h restraint of sheep where they could not move resulted in extremely high cortisol levels of >110 ng/mL (Apple et al., 1993). Aggressive handling should never be used for farm animals. Multiple shocks with an electrical prod more than doubled the levels of lactate and glucose in pigs compared with careful handling without electric prods (Benjamin et al., 2001; Brundige et al., 1998). Transportation performance standards include movement of animals with minimal risk of injury or death to animal or handler. Transportation is only performed when necessary. Making the transport experience more comfortable for each species should be a priority for animal handlers.

BIOMEDICAL VERSUS AGRICULTURAL RESEARCH REQUIREMENTS

For research results to be applicable to commercial agriculture, the animals have to be handled and housed in conditions similar to those on commercial farms. In these situations, many of the animals may not be accustomed to close contact with people, and commercial handling equipment such as cattle squeeze chutes and other specialized equipment will be required. In another type of research, an agricultural animal may be used for biomedical research and housed in small indoor pens that are not similar to commercial conditions. Biomedical researchers have conditioned and trained animals to cooperate with injections, restraint, and other procedures. Primates, pigs, and sheep can be easily trained to voluntarily enter a restraint device or hold out a limb for various procedures (Panepinto, 1983; Grandin, 1989a; McKinley et al., 2003; Schapiro et al., 2005). Hutson (1985) reported that providing food rewards to sheep made them more willing to move through a handling facility in the future. Training animals to cooperate greatly improves welfare, and removes some effects of restraint stress on physiological data. Low levels of cortisol and glucose were obtained from unsedated antelopes that had been conditioned to enter a restraint box and voluntarily stand still for blood tests (Phillips et al., 1998).

Training animals to voluntarily cooperate with injections, blood sampling, and other procedures is definitely recommended for biomedical settings where a few animals are used for medical experiments. However, it is often not practical for agricultural research in which large numbers of animals are handled.

FLIGHT ZONE AND BEHAVIOR PRINCIPLES

People who are handling cattle, bison, sheep, horses, and other grazing animals should have knowledge of flight zone principles (Grandin, 1987, 2007a; Smith, 1998; Cote, 2003; Figure 1). The flight zone concept does not apply to animals that are trained to lead with a halter or otherwise conditioned to close human handling. The flight zone varies depending on whether cattle or other livestock have been extensively or intensively raised. Extensively raised cattle may have flight zones up to 50 m, but intensively raised cattle (e.g., feedlot) may have flight zones only 2 to 8 m (Grandin, 1989b, 2007a). The size of an alley can change flight zones. Sheep in a 2-m (6-ft)-wide alley had a smaller flight zone than sheep in a 4-m (13.5-ft)-wide alley (Hutson, 1982). An approximation of the flight zone can be made by approaching the animal and noting at what distance the animal moves away. When the handler is outside of the flight zone, cattle will turn and face the handler. Flight zones can be exploited by handlers to move cattle and other livestock efficiently and quietly. For example, handlers should be positioned at the edge of the flight zone and behind the point of balance (located at the shoulder) to move cattle forward. A common mistake made by many handlers is to stand in front of the shoulder and attempt to make an animal go forward by poking its rear. This gives the animal conflicting signals. To move the animal forward, the handler should be behind the point of balance (Kilgour and Dalton, 1984; Grandin, 1987, 2007a); Figure 1 presents the concept of flight zone and point of balance. Figure 2 shows how to move an animal forward in a chute by walking quickly past the point of balance at the shoulder in the opposite direction of desired movement (Grandin, 1998, 2007a,b; Grandin and Deesing, 2008). To cause cattle to stop or back up, handlers should be positioned ahead of the point of balance. Too deep a penetration of the flight zone may cause extensively raised cattle to bolt or run away or rear up in a chute. Animals will often stop rearing if the handler backs up and gets out of the flight zone. Personnel working with cattle should be trained to use flight zones correctly.

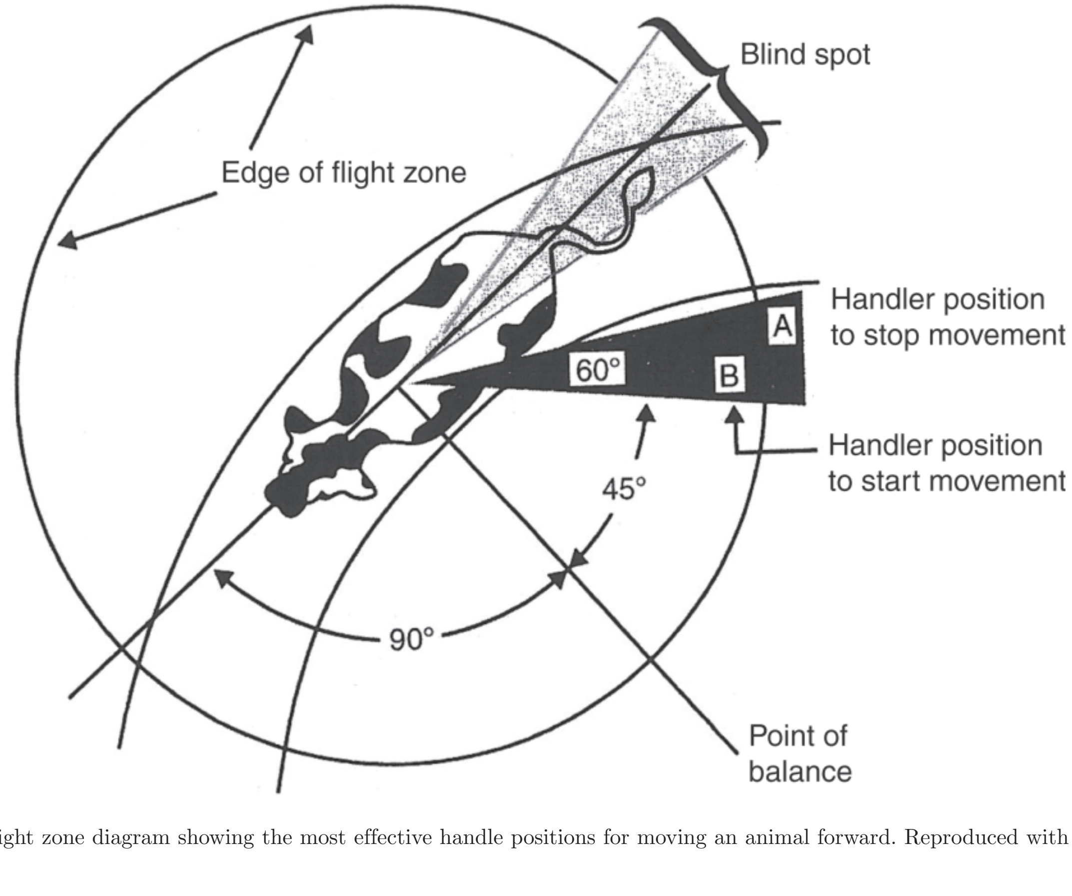

Figure 1. Flight zone diagram showing the most effective handle positions for moving an animal forward. Reproduced with permission of T. Grandin.

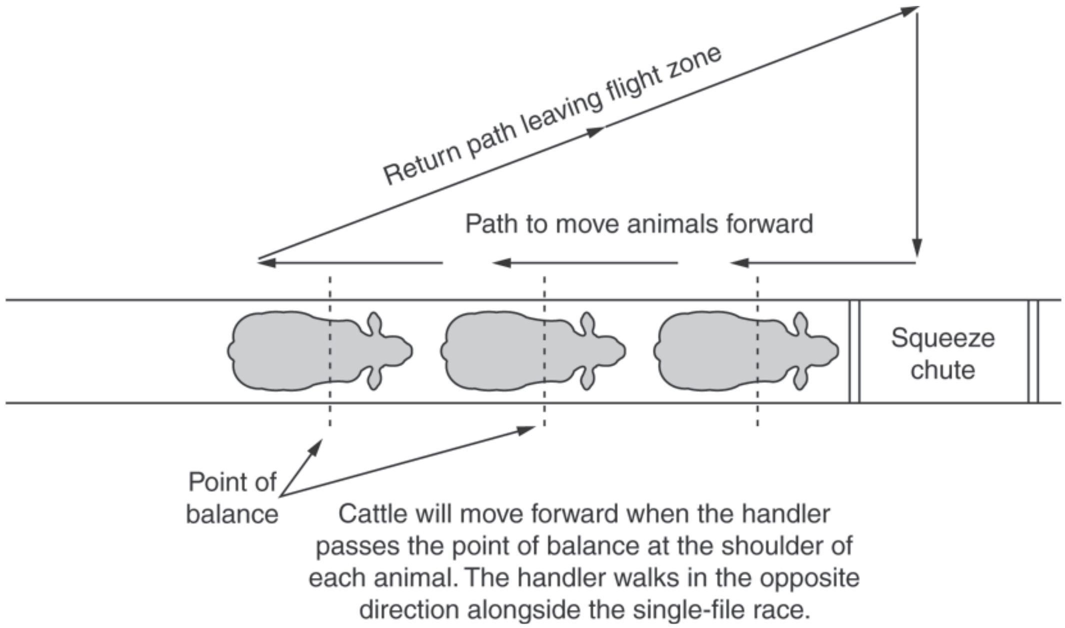

Figure 2. Handler movement pattern to induce cattle to move forward in a race. Reproduced with permission of T. Grandin.

Extensively raised grazing animals that arrive at a research facility may have a large flight zone. The size of the flight zone will gradually diminish if they are handled calmly and have frequent contact with people. Farm animals are social and a lone animal separated from its herdmate often becomes severely agitated. Many injuries to both people and animals occur when a single lone animal runs into a fence or charges. An agitated lone animal can be calmed by putting some other animals in with it.

Cattle and sheep will follow a leader (Arnold, 1977; Dumont et al., 2005). When one of the animals starts to move, the others will follow. Natural following behavior can be used to facilitate calm movement of animals. If animals are calmly moving in the desired direction, the handler should back up and stop putting pressure on the flight zone. Continuous pressure on the flight zone may cause animals to start running, which is undesirable.

AIDS FOR MOVING ANIMALS

Animals in properly designed facilities may be moved using their natural behavior and without the use of any aids. The goals of movement should be to minimize stress to each individual animal, reduce fear, and maintain calmness in all animals. All handlers should be trained in the natural behavior of the species including their flight zone and in proper handler movement and interaction, and be able to recognize any signs of distress, anxiety, or behaviors that may result in injury or stress to the animals. When necessary, nonelectrical driving aids such as paddles, flags, and panels may be an adjunct with the use of natural behavior and handling skills. Handlers should be trained in the proper and effective use of each driving aid, which is appropriate to the species.

An electric prod should only be picked up and used in a specific situation where it is needed and then put away. Handlers have a better attitude toward the animals when electric shocks are not used (Coleman et al., 2003). Data collected at meat plants indicate that most cattle and pigs could be moved throughout an entire handling system without electric prods (Grandin 2005). On a ranch or feedlot, the use of electric prods should be limited to 10% or less of the cattle (NCBA, 2007).

When an electric prod needs to be used, it should be applied to the hindquarters of the animal. Usually 1 to 3 brief shocks are needed. If the animal does not respond, the use of the electric prod should be discontinued immediately. It should never be applied to sensitive areas of the animal such as the eyes, ears, genitals, udder, or anus. Battery-operated prods are recommended because they administer a localized shock between 2 prongs. Electric prods should not be used on newborn animals, debilitated weak animals, nonambulatory downed animals, or emaciated animals. Electric prods are highly stressful to pigs. Repeated shocks greatly increased the percentage of nonambulatory pigs (Benjamin et al., 2001). Multiple shocks and aggressive handling significantly increased blood lactate and other indicators of metabolic stress compared with gentle handling (Ritter et al., 2009). Pigs that become nonambulatory because of fatigue or porcine stress syndrome should not have electric prods used on them.

Some examples of the use of an electric prod as a last resort or if human or animal safety is in jeopardy are listed below:

Table 5-1. Visual distractions that may cause animals to balk and refuse to move[1]

- Sudden changes in floor structure or surface such as drain grates, objects on the floor or change in flooring material.
- Shadows, puddles, and shafts of light; seeing light through a slatted floor.
- Animals may refuse to enter a dark place. Use indirect lighting to facilitate movement toward the light. Animals tend to move from a darker place to a more brightly illuminated place, but they will not move into blinding light.
- Reflections on a wet floor or shiny metal. Move lights to eliminate the reflection or use non-reflective surfaces.
- Moving people in front of approaching animals. People should stand where approaching animals do not see them.
- Jiggling chains, coats on a fence, flapping plastic, or swinging ropes. Remove these distractions.
- Animals see people, moving objects such as vehicles or objects with high color contrasts outside of the chute. Improve movement by installing solid sides.

[1]This table is adapted from information in Kilgour (1971), Lynch and Alexander (1973), Hutson (1981), Grandin (1980a,b, 1982–1983, 1996), van Putten and Elshof (1978), Kilgour and Dalton (1984), Tanida et al. (1996), Grandin and Johnson (2005), and Grandin and Deesing (2008).

1. To move an animal after repeated attempts with nonelectrified driving aids such as a plastic bag on the end of a stick, flags, slappers, rattle paddles, or streamers tied to the end of a stick have failed; the use of an electric prod is preferable to beating, ragging, pushing, or hard tail twisting of animals. If excessive slapping or electric prodding is required routinely, then the personnel involved may be too anxious or inadequately trained in proper animal handling or the facility may need modifications. Smaller animals may be gently lifted or rolled onto a transport mechanism.
2. To get a downed (fallen) animal in a truck that is located at a truck stop on the side of a highway. In this situation, opening up the truck gates or unloading the animals is not possible.
3 For cattle that are choking in a head stanchion or headgate or become jammed in a chute or other equipment.

Animal Perception

Hearing. All species of grazing animals have sensitive hearing. Cattle and horses have hearing that is more sensitive compared with humans to high-pitched sounds (Heffner and Heffner, 1983). The human ear is most sensitive at 1000 to 3000 Hz and cattle are most sensitive to 8000 Hz (Ames, 1974; Heffner and Heffner, 1983). Handlers should not yell or shout at cattle because shouting may be just as aversive as an electric prod (Pajor et al., 2003). In another experiment, the sounds of people yelling caused a greater increase in heart rate than the sounds of gates clanging (Waynert et al., 1999).

Intermittent or high-pitched sounds caused greater behavioral reactions and increased heart rate in pigs compared with steady or low-pitched sounds (Talling et al., 1998). Intermittent sounds and rapid movements are also more likely to cause cattle to react (Lanier et al., 2000). Handlers should be observant of the position of an animal's ears. Horses and cattle will point their ears directly toward things that attract their attention (Grandin, 2007a).

Vision. Cattle, sheep, and horses have wide-angle vision and they can see all around themselves without turning their heads (Prince, 1970; Hutson, 1980; Kilgour and Dalton, 1984). Grazing animals have depth perception when they are standing still with their heads down (Lemmon and Patterson, 1964). Depth perception is probably poor when the animals are moving with their heads up. This explains why they stop and put their heads down when they see a shadow on the floor.

Grazing animals are dichromats (i.e., have partial color-blindness). The retinas of cattle, sheep, and goats are most sensitive to yellowish-green; (552–555 nm) and bluish-purple light (444–455 nm) (Jacobs et al., 1998). The dichromatic vision of the horse is most sensitive at 428 and 539 nm (Murphy et al., 2001). Dichromatic vision and the absence of a retina receptor for red may explain why livestock are so sensitive to sharp contrasts of light and dark such as shadows or shiny reflections on handling equipment.

Poultry appear to have excellent vision. Chickens and turkeys possess 4 cone-cell types in the retina giving them tetrachromatic color vision, compared with the human trichromatic vision based on 3 cone-cell types (Lewis and Morris, 2000). Moreover, the spectral sensitivity of chickens is greater than that of humans from 320 to 480 nm and 580 to 700 nm. Their maximum sensitivity is in a similar range (545–575 nm) to humans (Prescott and Wathes, 1999). The broader spectral sensitivity of poultry may make them perceive many light sources as being brighter than a human would see. Poultry may be more docile during handling in blue light spectra (Lewis and Morris, 2000). Lighting conditions have a large effect on chicken behavior when the birds are shackled for slaughter (Jones et al., 1998). During handling of poultry, the occurrence of flapping should be minimized. Changes in lighting may be used as one tool to keep birds calmer during handling.

Effects of Visual Distractions and Handling

Livestock of all species will often refuse to move through a chute or other handling facility if they see distractions such as shadows, reflections, or people ahead of them. Removing distractions that cause animals to balk and stop will facilitate animal movement (Kilgour and Dalton, 1984; Grandin, 1996; Grandin and Johnson, 2005; Grandin, 2007a). A calm animal will stand and point its eyes and ears toward distractions that attract its attention. If the leader is allowed to stop and look at a distraction, it will often move forward and the other animals will follow. If the animals are rushed, they may turn back and refuse to move forward when they see a distraction. Distractions are most likely to cause balking or other handling problems if the animals are not familiar with the facility. Experienced dairy cows will often ignore a distraction such as a floor drain, but new, inexperienced heifers will balk at it. Table 5-1 contains a list of distractions that may cause animals to balk and refuse to move. This list can be used as a guide for modifying handling facilities where excessive use of electric prods is occurring. In facilities where animals move easily and quietly and electric prods are seldom used, removal of distractions may not be needed.

Facility Design Principles for all Species

Flooring. For all species, nonslip flooring is essential (Grandin 1990, 2007b; Albright, 1995; Grandin and Deesing, 2008). Animals often become agitated when they start slipping. Handling and restraint will be safer and animals will remain calm if animals have nonslip flooring (e.g., grooved concrete, rubber mats, or metal rod grids). Handling facilities should have nonslip floors and good drainage.

Equipment Maintenance. Surfaces that contact the animals must be smooth and free of sharp edges that could injure animals. Sharp edges will cause bruises (Grandin, 1980c) and injury. Managers should routinely inspect equipment and have a program of regular maintenance based on use. Special attention should be paid to latches on restraint devices.

Sanitation. Managers should regularly inspect facilities to ensure cleanliness. When new facilities are being designed, ease of cleaning is an important part of the design. Concrete curbs can be used to direct manure to a drain. Hoses, shovels, and other tools that are needed for cleaning should be readily available. Sanitation equipment should be removed after routine cleaning.

Animal handling facilities should be regularly cleaned after use and maintained in good working condition. Injuries and accidents can happen to animals and handlers from equipment lockup or other problems that can occur with build-up of filth, breakage, or wear and tear. Managers should routinely inspect the facilities to ensure cleanliness and to maintain a regular maintenance schedule based on use.

GENERAL PRINCIPLES OF RESTRAINT AND HANDLING

Training of animal care personnel in handling procedures should include consideration of the well-being of the animals. During the handling and restraint of animals, care should be exercised to prevent injury to animals or personnel. Animals should be handled quietly but firmly. Properly designed and maintained facilities operated by trained personnel greatly facilitate efficient movement of animals.

Prolonged restraint of any animal must be avoided unless such restraint is essential to research or teaching objectives. The following are important guidelines for the use of animal restraint equipment:

- Animals to be placed in restraint equipment ordinarily should be conditioned to such equipment before initiation of the project, unless the preconditioning itself would increase the stress to the animals.
- The period of restraint should be the minimum required to accomplish the research or teaching objectives.
- Electrical immobilization must not be used as a method of restraint. It is highly aversive to cattle and sheep (Grandin et al., 1986; Lambooy, 1985; Pascoe and McDonnell, 1985; Rushen, 1986). Electrical immobilization must not be confused with electrical stunning that causes instantaneous insensibility or electric prod use that does not immobilize animals.
- Restraint devices should not be considered normal methods of housing, although they may be required for specific research and teaching objectives.
- Attention should be paid to the possible development of lesions or illness associated with restraint, including contusions, knee or hock abrasions, decubital ulcers, dependent edema, and weight loss. Health care should be provided if these or other serious problems occur, and, if necessary, the animal should be removed either temporarily or permanently from the restraint device. Animals should be handled and restrained in facilities and by equipment appropriate for the species and procedure.

Some aggressive behaviors of larger farm animals pose a risk to the health and well-being of both herdmates and human handlers. These behaviors may be modified or their impact reduced by several acceptable restraint devices (e.g., hobbles, squeeze chutes, and stanchions) and practices. Only the minimum restraint necessary to control the animal and to ensure the safety of attendants should be used. Care should be exercised when mixing animals to minimize fighting, especially when animals are grouped together for the first time.

Animals should be handled and restrained in facilities and by equipment appropriate for the species and procedure. For cattle, for example, a chute facility should be available (particularly one suited to obstetrical procedures, if appropriate). Unless they are very young or tame, calves restrained for routine procedures should be handled by means of a calf chute equipped with a calf cradle.

PRINCIPLES TO PREVENT BEHAVIORAL AGITATION DURING RESTRAINT FOR ALL SPECIES

The following guidance is provided to prevent behavioral agitation:

- Nonslip flooring should be provided (Grandin, 1990; Albright, 1995). Repeated small rapid slips may cause agitation.
- Avoid sudden jerky motion of either people or equipment. Smooth movements will keep animals calmer (Grandin, 1992).
- When an animal is raised off the ground, during restraint, it will usually remain calmer if its body is fully supported.
- Even pressure over a wide area of the body has a calming effect (Ewbank, 1968). The Panepinto sling for small pigs and cattle squeeze chutes use this principle (Panepinto, 1983; Grandin, 2007b).
- A calm, confident tone of voice will help keep livestock calmer.
- Optimum pressure—not too loose and not too tight. An animal needs to be held tight enough to feel the feeling of restraint, but not so tight that it feels pain. Excessive pressure will cause struggling (Grandin, 1992).
- Blocking vision: using a blindfold made from a completely opaque material will often keep cattle and horses with a large flight zone calmer (Mitchell et al., 2004). Solid sides on cattle chutes or a fully enclosed dark box have a calming effect (Grandin, 1980a,b, 1992; Muller et al., 2008; Pollard and Littlejohn, 1994).

RECOMMENDATIONS FOR EACH SPECIES

Beef Cattle Handling

Animals that are extensively raised and have large flight zones may become agitated if people stand close to the chutes and pens in the handling facility. If this occurs, solid fences may need to be installed so the animals do not see the people that are deep in their flight zone. Further information on facility design is in Grandin (1990, 1997b, 2007b) and Grandin and Deesing (2008).

There are many different designs of restraining (squeeze) chutes. Squeeze chutes should permit all animals to stand in a balanced position and the squeeze sides are applied evenly on both sides. Squeeze chutes may be hydraulic or manual models. Settings of pressure relief valves for hydraulic restraint chutes should be adjusted to prevent excessive pressure from being applied (Grandin, 1989b). The chute should automatically stop squeezing at a reasonable pressure even if the operator continues to pull on the squeeze lever. A separate pressure control is required on chutes that have a hydraulic device for restraining the head. To avoid animal injury, this device must be set at a lighter pressure than other parts of the chute. Pressure should be applied slowly to avoid exciting the animal. Excessive pressure can cause injury and incite cattle to fight the restraint. If cattle bellow the moment pressure is applied by a hydraulic device, this is an indicator of excessive pressure (Grandin, 2001). Bellowing during restraint is associated with higher cortisol levels (Dunn, 1990). Cattle should be able to breathe normally during restraint. The head gate can be self-catching or manually operated. Self-catching head gates are generally not recommended for use with horned cattle unless they are operated manually. Unless they are very young or tame, calves restrained for routine procedures should be handled by means of a calf chute equipped with a calf cradle.

Roping of cattle is necessary under certain conditions (e.g., in pastures when an animal needs treatment and no restraining facility is conveniently available). However, roping should be performed by trained and experienced personnel and in a manner that minimizes stress to both the individual and the total herd. For head restraint of cattle in a squeeze chute, a properly fitted rope halter is recommended. Nose tongs may be used on fractious animals in conjunction with other means of cattle restraint (e.g., squeeze chute), but nose tongs can slip and tear out of the nose, causing injury to both animal and personnel, and therefore are not recommended as a sole means of restraint. Nose tongs are aversive and cattle may resist the attachment of the tongs in the future. For repeated procedures that require head restraint, a rope halter is strongly recommended. Electroimmobilization must not be used as a method of animal restraint; cattle and sheep find this procedure very aversive (Pascoe and McDonnell, 1985; Grandin et al., 1986; Rushen, 1986).

Plastic streamers or a grocery bag tied to the end of a stick is an effective device for moving cattle and changing their direction (Grandin, 2007a). Cattle temperaments vary among individuals and among breeds (Tulloh, 1961; Grandin, 1993; Curley et al., 2006). Handling should be adjusted for genetic and phenotypic differences.

Dairy Cattle Handling

Mature milking dairy cows can be handled in head stanchions or a management rail (Albright and Fulwider, 2007). A complete squeeze chute is not required. Diagrams and pictures in Sheldon et al. (2006) illustrate methods for restraining tame dairy cows when they are held in a head stanchion. Young dairy heifers that are not accustomed to close contact with people are often handled most efficiently and safely in beef-type facilities with a squeeze chute.

Disturbances by veterinarians and other visitors can reduce milk yield (King, 1976). If the cows are accustomed to many people walking through the milking parlor, there may be no effect because the frequent visitors have become part of their normal routine. Dairy animals are able to discriminate between people who have handled them in a negative manner and people who handled them in a positive manner (dePassillé et al., 1996). They were most likely to avoid the negative handler when he was seen in the same location where the aversive events occurred.

Dairy bulls are usually more dangerous than beef bulls. Bull attacks are a major cause of fatalities when people are working with livestock. One of the reasons beef bulls are safer is that they are reared in a social group on a cow. Price and Wallach (1990) found that beef bulls attacked more often when they were raised in individual pens. A dairy bull calf raised to maturity alone in a pen is more likely to be dangerous than a bull that was always kept with other animals. If a bull is going to become dangerous, he is most likely to show aggression toward people at 18 to 24 mo. Handlers must learn to recognize signs of aggression that precede an attack such as the broadside threat. The bull will turn sideways to show how big he is before he attacks. Good descriptions are in Albright and Arave (1997) and Albright and Fulwider (2007). Bulls that show aggressive tendencies toward people should be culled or transferred to a secure facility.

Horse Handling

Teaching and research horses are usually handled using halters and lead ropes, and extra control may be achieved by using the chain of a lead shank placed over the horse's nose. Only trained horses should be tied and only to solid objects that will not give way if the horse pulls back. Lead ropes attached to the halter should be tied with quick release knot. Horses should never be tied with a chain looped across the top of the nose. Cross-ties attached to each side of the halter should be equipped with panic-snaps or safety releases. A twitch may be applied to the horse's upper lip as a short-term restraint procedure (Sheldon et al., 2006). The movement of a horse may be restrained in stocks and chutes. An equine stock or chute may be as simple as a rectangular structure with a nonslip floor. Other methods of restraint that may be applied by experienced individuals include front foot hobbles, sideline or breeding hobbles, or leg straps, but should be carefully considered depending on the training of the individual horse and the degree of restraint necessary.

Chemical restraint can be effective and should be administered by a qualified person. With some drugs, an apparently sedated horse may react suddenly and forcefully to painful stimuli (Tobin, 1981). General or local anesthesia should be administered by a qualified person, preferably a veterinarian, for painful procedures such as castration.

Swine Handling

Snaring by the nose is a common method for holding swine for blood testing and other procedures. Good descriptions are in Battaglia (1998) and Sheldon et al. (2006). Snaring is probably stressful for pigs because they will attempt to avoid the snare after they have experienced snaring. For biomedical research, small pigs can be trained to enter the Panepinto sling (Panepinto, 1983). The animal is fully supported in a sling and its legs protrude out through leg holes. A panel is the best device for moving pigs (McGlone et al., 2004). Nonelectric driving aids such as cattle paddles and flags can also be used by properly trained people. Guidelines on electric prod use are in the section on driving aids. Previous experiences with handling and the amount of contact with people will affect the ease of pig movement. Pigs with previous experiences of being calmly moved may be easier to move in the future (Abbott et al., 1997; Geverink et al., 1998). Calm, nonthreatening movements of people will reduce stress levels in pigs and make them more willing to approach people (Hemsworth et al., 1986).

Sheep and Goat Handling

Sheep and goats show strong flocking behavior in pens as well as on pasture. Breed, stocking rate, topography, vegetation, shelter, and distance to water may influence flocking behaviors. Isolation of individual sheep or goats usually brings about signs of anxiety. Separations from the flock, herd, or social companions are important factors that cause sheep and goats to try to escape. Sheep and goats tend to follow one another even in activities such as grazing, bedding down, reacting to obstacles, and feeding (Hutson, 2007). When handling sheep and goats, these characteristic behaviors should be considered and used advantageously and, more importantly, for the best interest of the animal's health and welfare.

Transportation of sheep and goats should take into consideration the climatic conditions and productive stage (e.g., late pregnancy or dams with young offspring) of the animals. Care should be exercised in the transport of animals, and special consideration should be given during conditions of temperature extremes and high humidity. Measures such as increasing the supply of nutrients immediately before long-distance transport that may reduce the risk of pregnancy toxemia and transport tetany in sheep and goats should be considered. Except for short distances when hauling is less physically taxing than trailing, transportation of ewes and does during late gestation should be avoided. When possible, animals should be gated off into smaller groups during transport to prevent pileups and death losses. Additionally, temperature extremes or exposures should be considered and adequate and appropriate crating provided. Preventative or prophylactic medicinal agents (e.g., antibiotics and pre-transport vaccinations) may also be administered in an effort to minimize diseases that are associated with shipping.

The Sheep Production Handbook (American Sheep Industry Association, 2002) and *Sheep Care Guide* (Shulaw, 2005) contain detailed information about handling facilities and transportation. Sheep can be easily trained to enter a squeeze tilt table (Grandin, 1989a). The Panepinto sling can also be used for sheep. Some restraint devices are more aversive than others. Well-designed restrainers support the animal's body and do not have sharp pressure points. Both sheep and goats can be easily trained to enter head stanchions. Sheldon et al. (2006) and Battaglia (1998) have illustrated guides on manual methods for holding sheep and goats. Designs for sheep races and corrals can be found in Barber and Freeman (2007) and American Sheep Industry Association (2002).

Poultry Handling

Poultry are handled in many experimental and teaching situations. Examples include wing- or leg-banding, immunization by intramuscular and subcutaneous injections, intranasal or intraocular application of drops and wing-web puncture, and removing or placing birds in different groups, cages, or holding and transportation crates. Injured, diseased or birds for transport should be euthanized on the farm. They should not be placed in transportation crates. People handling birds should be adequately trained so that stress to birds is minimal.

Poultry that are not familiarized to humans tend to struggle vigorously when caught. They can easily be injured if grasped improperly or subjected to excessive force. All poultry tend to flap their wings when caught, inverted, or caused to struggle for balance or footing. This tendency leads to risk of joint dislocation, bone fracture, or bruises when wings strike objects or other birds. The risk is particularly great for modern varieties of market-weight meat-type birds, which have powerful breast muscles but relatively weak joints due to their youth, or for caged light hybrid (White Leghorn) laying hens, which have fragile wing bones. Poultry should be handled in ways that minimize wing-flapping or its harmful consequences. Care should be taken to prevent birds from striking their wings on door edges when placing them into or pulling them from cages or compartments. Particular care should be exercised in handling caged laying hens, which are prone to osteoporosis (Rennie et al., 1997; Webster, 2004). To minimize the risk of bone fracture, hens should be held by both legs when removing them from the cage (Gregory and Wilkins, 1989; Gregory et al., 1993). The manner in which a bird is carried can affect its fearfulness and stress. Broilers carried even briefly in the inverted position by the legs show a greater corticosterone response than do birds carried in an upright position, and the response lasts for about 3 h (Kannan and Mench, 1996). Therefore, birds should be carried upright whenever possible. Birds struggle less if they have been socialized, the body is fully supported in an upright position with wings restrained, the environment is relatively quiet, and the lighting is subdued.

Poultry should not be picked up or moved by one wing unless the wing is grasped near the base of the wing close to the body. They should quickly be released from such a hold, as when transferring birds from a coop to a floor pen.

They should be shifted to a hold that firmly grasps both wings at their bases or that supports the body to minimize struggle and chance of a limb injury. Ducks should not be caught by the leg because they are prone to leg injury if handled in this way.

Large, strong birds such as turkey toms can be difficult to control by grasping a limb. They can also deliver punishing blows with their wings when struggling against capture. To pick up a very large turkey such as breeder tom, grasp one wing near the base of the body and then grasp the leg on the opposite side and set the bird's breast on the floor. Finally, proceed with restraining the bird by grasping both legs. For intermediate-sized turkeys, the base of the wing and then both legs can be grasped simultaneously while lifting the turkey off the floor. Turkeys and ducks can be driven, so catching and handling of individual birds can be minimized by judicious use of alleys, ramps, and driving techniques when flocks must be relocated. However, some birds such as older turkeys will not walk on different surfaces and therefore may have to be moved by individual handling.

In many experimental and teaching situations, newly hatched birds or relatively small numbers of older birds need to be handled. In those cases, individuals can be easily caught and manipulated. Examples included wing- or leg-banding; immunization by intranasal or intra-ocular application of drops and wing-web puncture; and removing or placing birds in different groups, cages, and holding crates. Trained and experienced scientists and caretakers know that birds struggle less if they have been socialized, if the environment is relatively quiet, and if the body is fully supported in an upright position (Gross and Siegel, 2007). More complex procedures; for example, obtaining blood samples,

Table 5-2. Recommended minimum area allowances in transportation accommodations for groups of animals used in agricultural research and teaching[1]

	Average BW		Area per animal			
Species	(kg)	(lb)	(m^2)		(ft^2)	
Cattle (calves)	91	200	0.32		3.5	
	136	300	0.46		4.8	
	182	400	0.57		6.4	
	273	600	0.80		8.5	
			Horned		Hornless	
			(m^2)	(ft^2)	(m^2)	(ft^2)
Cattle (mature fed cows and steers	364	800	1.0	10.9	0.97	10.4
	455	1,000	1.2	12.8	1.1	12.0
	545	1,200	1.4	15.3	1.4	14.5
	636	1,400	1.8	19.0	1.7	18.0
Small pigs	4.54	10	0.060	0.70		
	9.07	20	0.084	0.90		
	13.60	30	0.093	1.00		
	22.70	50	0.139	1.50		
	27.20	60	0.158	1.70		
	31.20	70	0.167	1.80		
	36.30	80	0.177	1.90		
	40.80	90	0.195	2.10		
			Winter		Summer	
Market swine and sows	45	100	0.22	2.4	0.30	3.0
	91	200	0.32	3.5	0.37	4.0
	114	250	0.40	4.3	0.46	5.0
	136	300	0.46	5.0	0.55	6.0
	182	400	0.61	6.6	0.65	7.0
			Shorn		Full fleece	
Sheep	27	60	0.20	2.1	0.21	2.2
	36	80	0.23	2.5	0.24	2.6
	45	100	0.26	2.8	0.27	3.0
	55	120	0.30	3.2	0.31	3.4
			Dimensions		Area	
			(m)	(ft)	(m^2)	(ft^2)
Loose horses	250 to 500	550 to 1100	0.7 × 2.5	2.3 × 8.2	1.75	18.8
Foals <6 mo			1.0 × 1.4	3.3 × 4.6	1.4	15.2
Young horses 6–24 mo			0.76 × 2.0	2.5 × 6.6	1.2	16.5
			1.2 × 2.0	3.9 × 6.6	2.4	25.8

[1]Adapted from data of Grandin (1981, 2007c); Cregier (1982); Whiting and Brandt (2002); Whiting (1999); ILAR Transportation Guide (2006); and National Pork Board (2008) *Trucker Quality Assurance Handbook.*

intraperitoneal and venous puncture, and artificial insemination, often require at least 2 experienced persons. Skilled operators should adequately train personnel in such handling procedures so that stress to birds is minimal. Particular care should be exercised in handling caged layers to minimize the risk of bone fractures (Gregory and Wilkins, 1989).

When large numbers of birds housed under commercial conditions are to be moved or treated, handling methods need to be compatible with the housing systems involved (Weeks, 2007). A source of major concern should be the manner in which individual birds are caught, carried, and placed in new quarters or crates. In many situations, birds are at risk of injury because they are caught and moved by grasping a single wing with subsequent exertion of excessive force in moving the bird. No types of poultry should be picked up by one wing. Gregory and Wilkins (1989) found that when laying hens were caught by one leg and removed from cages at the end of lay, the incidence of broken bones was 12.7%; the incidence was only 4.6% when both legs were used in removing hens from the cages. On commercial broiler farms, the chickens are usually picked up by a single leg. Leg breakage can be reduced if the birds are carried a short distance to the transport cage. When research is done under commercial broiler farm conditions, it is acceptable to pickup broiler chickens in this manner.

TRANSPORT

The transport of livestock involves a complex series of operations including handling, loading and unloading, unfamiliar environments, and, in some cases, isolation, social disruption, confinement, loss of balance, fluctuations in environmental temperature and humidity, exposure to pollutants (e.g., truck exhaust), feed and water deprivation, and other factors. Hence, it is often difficult to determine with precision which component or combination of components is most responsible for transportation stress. Therefore, it becomes important to pay attention to all components and the potential for cumulative effects on the well-being of the animals to be transported. In-depth reviews and research on space allowances for each species of livestock have been published for cattle (Eldridge et al., 1988; Tarrant et al., 1992; Knowles, 1999; Eicher, 2001; Swanson and Morrow-Tesch, 2001; Fike and Spire, 2006), sheep (Cockram et al., 1996; Knowles et al., 1998), pigs (Guise et al., 1998; Warriss, 1998; Whiting and Brandt, 2002; Ritter et al., 2006; Sutherland et al., 2009), and horses (Stull, 1999; Whiting, 1999; Friend, 2000a,b). In addition, the National Academy of Sciences published recommendations (ILAR Transportation Guide, 2006) for the transport of research animals that include space requirements during transport that are consistent with the guide. In the absence of data supporting specific space requirements of farm animals during transport, formulae from ILAR Transportation Guide (2006) may be useful in determining space allowances during transport. The minimum areas per animal for animals of different weights when shipped in groups are given in Table 5-2.

The safety and comfort of the animal should be the primary concerns in the transportation of any animal. Nonambulatory or weak, debilitated animals must not be loaded or transported unless necessary for medical attention. Animals that are nearing the time of parturition should not be transported. The only exception to this is when moving an animal a short distance to the place where it will give birth or to a hospital facility. If animals become injured or nonambulatory during the course of transport, appropriate steps should be taken immediately to segregate such animals and attend to their needs. Specialized carts and sleds, canvas tarpaulins, or slide boards are recommended for offloading nonambulatory animals. Animals must not be dragged, hoisted, or dropped from transport vehicles. If the animal cannot be removed with the use of recommended devices, then the animal should be euthanized by trained personnel using acceptable methods established by the AVMA (2007). Non-ambulatory animals in research and teaching facilities must be euthanized using approved procedures unless they are receiving medical treatment (see Chapters 2 and 6 through 11) before removal (Grandin, 2007c; *Humane Slaughter Act Regulations*).

If young or newborn calves are to be transported, individual care and colostrum should be provided within 2 to 3 hours after birth. Calves should always have a dry hair coat, dry navel cord, and be able to walk easily without assistance before being transported. They only exception to this recommendation is when calves are transported a short distance to a specialized calf rearing facility. In all species, weak newborns, emaciated animals, animals with severe injuries or animals that have great difficulty walking must never be transported to livestock auctions or markets.

When animals are transported, they should be provided with proper ventilation and a floor surface that minimizes slipping. When possible, animals should be shipped in groups of uniform weight, sex, and species. Stocking densities affect stress-related plasma constituents and carcass bruising as well as behavioral parameters of cattle (Tarrant et al., 1988, 1992). Similar results have been found for swine (Lambooy and Engel, 1991; Knowles and Warriss, 2007) and sheep (Cockram, 2007).

Animal injuries, bruises, and carcass damage can result from improper handling of animals during transport. Grandin (1980c) identified rough handling, mixing of animals of different sexes, horned animals, and poorly designed, maintained, and broken equipment as major causes of carcass damage in cattle. Recommendations for facility design, loading and unloading trucks, restraint of animals, and animal handling in abattoirs have been published (Grandin, 1980a,b, 1982–1983, 1990, 2007d). Good driving practices such as smooth acceleration and no sudden stops will help reduce injuries from animals being thrown off balance.

Table 5-3. Truck set-up procedures during temperature extremes for pigs[1]

		Side slats	
Air temperature, °C (°F)	Bedding	Closed, %	Open, %
<−12 (<10)	Heavy	90	10[2]
−12 to −7 (10 to 20)	Medium	75	25[2]
−7 to 4 (20 to 40)	Medium	50	50
4 to 10 (40 to 50)	Light	25	75
>10 (>50)	Light[3]	0	100

[1]Source: National Pork Board (2008) *Trucker Quality Assurance Handbook*.

[2]Minimum openings are needed for ventilation even in the coldest weather.

[3]Consider using sand or wetting bedding if it is not too humid and trucks are moving.

Thermal Environment on the Vehicle

Transport and handling stresses can be aggravated greatly by adverse weather conditions, especially during rapid weather changes. Hot weather is a time for particular caution. The Livestock Weather Safety Index is used as the basis for handling and shipping decisions for swine during periods of weather extremes. The values for cattle are conservative especially for heat-tolerant Brahman and Brahman crosses (Grandin, 1981, 2007c).

Animals should be protected from heat stress while in transit. For all species, heat will build up rapidly in a stationary vehicle unless it has mechanical ventilation. Arriving vehicles should be promptly unloaded and vehicles should start moving promptly after loading. If a loaded truck has to be parked during hot weather, fans or water misters should be provided to keep animals cool. Chickens and pigs are especially prone to heat stress. Banks of fans beside which a loaded truck can park are used extensively in the pork and poultry industries. Further information on the thermal environment can be found in the National Research Council's *Guidelines for Humane Transportation of Research Animals* (ILAR Transportation Guide, 2006). The thermal neutral zones for different animals can be found in Robertshaw (2004). Means of protection include shading, wetting, and bedding with wet sand or shavings when livestock are at high density (e.g., on a truck) and air speed is low (e.g., the truck is parked) during hot weather.

During transportation, animals should also be protected from cold stress. Wind protections should be provided when the effective temperature in the animal's microenvironment is expected to drop below the lower critical level. Recommendations for protecting animals from cold stress are in Grandin (2007c) and the National Pork Board (2008) *Trucker Quality Assurance Handbook* (Table 5-3). Adequate ventilation is always necessary. During cold weather, trucks transporting livestock should be bedded with a material having high thermal insulative properties (such as chopped straw) if the animals will spend more than a few minutes in the transport vehicle. This is especially important for pigs to reduce death losses (Sutherland et al., 2009). Currently there are no trucking quality assurance recommendations for space allowance of weaned pigs during transport in the United States. A space allowance of 0.06 and 0.07 was preferable to 0.05 m^2/pig when transporting weaned pigs between 60 and 112 min in summer (28.4 ± 1.2°C) and winter (10.5 ± 6.15°C) based on neutrophil:lymphocyte ratio and behavior (Sutherland et al., 2009). However, the effect of space allowance on the welfare of weaned pigs may differ when for transport durations longer than 112 min. Sufficient bedding must be provided so that it stays dry.

Table 5-4. Recommended dimensions of transportation accommodations for horses and ponies used in agricultural research and teaching

Trailer or van dimension	(m)	(ft)
Ceiling for horse height		
Up to 1.5 m (15 hands[1])	1.7–2.0	5.6–6.5
1.5–1.6 m (15 to 16 hands)	2.0–2.2	6.5–7.0
Width		
Single or tandem	1.2	4
Two horses abreast	1.7–2 × 1.8–3.1	5.6–6.6 × 5.9–10.2

[1]One hand is about 10 cm (4 in).

Vehicle Recommendations

Truck beds for livestock transport should be clean, dry, and equipped with a well-bedded, nonslippery floor. Animals should be loaded and unloaded easily and promptly. Chutes should be well designed for the animals being handled (Grandin, 1990). Animals should be transported at appropriate densities to reduce the chances of injury. The type of transport vehicle is also important with regard to differences between and within species of livestock. For example, depending on breed type, horses often have special transport requirements (Houpt, 2007). Livestock should not be transported on trucks that do not have sufficient clearance to accommodate their height, as would be the case for horses transported on doubled-decked cattle trucks (Grandin et al., 1999; Stull, 1999; Houpt, 2007).

Many teaching and research activities require the frequent transport of animals for short distances. Careful loading and unloading will reduce stress. On short trips, loading and unloading is the most stressful part of the journey. On short trips, pigs remain standing (Guise et al., 1998) and they can be stocked at a higher density than on longer trips where the animals will need more space to lie down. For heavy (129-kg) pigs, increasing the floor spaces from 0.39 to 0.48 m2/pig reduced transport deaths from 0.88 to 0.36% on trips lasting approximately 3 h (Ritter et al., 2006). Vehicles should be of adequate size and strength for the animals carried and have adequate ventilation. Stock trailers and pickup truck beds fitted with stock racks are the most frequently used vehicles for short-distance transport. The inside walls and lining of the vehicles should have no sharp edges or protrusions that would be likely to cause injury. Animals may be transported either loose in these vehicles or may be haltered and tied in the case of cattle, sheep, and horses. Only animals that have been previously trained to a halter and that are of a quiet disposition should be tied when transported. Animals should be tied with a quick-release knot to the side of the vehicle at a height that is approximately even with the top of the shoulder (withers). The tie should be short enough so that animals cannot step over the lead.

The condition of the animals should be checked periodically during transit. Drivers should start and stop the vehicle smoothly and slow down for curves and corners.

Loading and Unloading Ramps for Livestock

A ramp is not required when the animals are transported in a low stock trailer. A well-maintained ramp with a nonslip surface is essential for loading animals onto trucks with beds taller than an animal's ability to step up onto the vehicle. Loading ramps must provide nonslip footing to prevent slipping and falling or damage to the dew claws (van Putten and Elshof, 1978; Grandin, 1983, 1990, 2007b; Phillips et al., 1988). On concrete ramps, stair steps provide good footing (Grandin, 1990). For cattle, each step should be 10 cm (4 in) high with a 30 cm (12 in) tread width. For all species, if the animals are not completely tame, the ramp should have solid sides.

Horse Transport

The typical vehicles designed to transport horses by road are vans, trailers, and trucks. The capacity of these vehicles ranges from transporting a single horse or multiple horses. During transportation, attempts should be made to minimize the trauma and anxiety of the horse. Considerations include the loading procedures, manner of driving, interior space, footing, ventilation, noise, lighting, duration of transit, mixing of unfamiliar or aggressive horses, fitness to travel, and handling (Grandin et al., 1999).

Horses are sometimes transported in small groups, and sorting horses for compatibility is important to minimize stress and injuries. Considerations for sorting may include size, sex, and behavior. Horses should not be placed in double-deck conveyances designed for cattle because these trailers are too limited in the height from floor to ceiling for most horses and injuries are prevalent (Grandin et al., 1999; Stull, 1999). All vehicles should be examined before each trip for safety and maintenance. The floor planking and metal floor braces should be of sufficient strength to bear twice the weight of any horse being transported. Door latches, tiers, and hitches should be inspected before the start of the trip and repaired if needed because these deteriorate with use and exposure.

Trailers. The required dimensions of a trailer depend on the size of the horses being hauled (Table 5-4). Horse trailers with individual stalls should have a butt chain or bar to prevent the exiting of a horse from the trailer. The rear doors may either be hinged (horse steps up into the trailer) or have a loading ramp, or both, with a strong fastening device to prevent the doors from opening during transit. In horse vans, full, solid partitions are often used between horses to form small box stalls. A partial partition located at the height of the middle of the horse's body should be used to separate horses in trailers and between cross-tied horses in vans. These partial partitions allow the horse to spread its legs enough to achieve proper balance in a limited area. The flooring should not be slippery. Sand, bedding, or rubber matting may provide better footing, which reduces anxiety and potential injuries. Legs wraps, tail wraps, bell boots, or padded halters are not necessary, but may be beneficial in preventing or minimizing injuries for some horses during transit. Lighting at night in the trailer and loading areas facilitates safe handling and loading of horses.

Table 5-5. Space requirements for lairage[1]

Species	Weight, kg (lb)	Space, m^2 (ft^2)
Cattle	545 (1,200)	1.87 (20)
Pigs (market weight)	113 (250)	0.55 (6)

[1]Further information on the design of lairage facilities and welfare at the slaughter plant can be found in the American Meat Institute Recommended Animal Handling Guidelines and Audit Guide (Grandin, 2007c,d).

Horses traveling together in small groups are usually not tied during transport and may exhibit limited movement depending on the loading density within the compartment. Excessive movement of horses during transit may indicate a problem and should be assessed by the driver. Horses in trailers and vans may be tied in transit to prevent turning around and interaction with other horses and should be tied using either a quick-release knot or panic-snaps. Tying horses limits the movement of the head and neck. The elevation of the horse's head above the withers during transit compromises the immune system and may predispose the horse to respiratory disorders (Raidal et al., 1997). Respiratory problems can be avoided by ensuring the head is not elevated above the point of the shoulder at least every 12 h, usually by feeding hay below chest level during transit or by taking breaks to allow the horse to lower its head (Racklyeft and Love, 1990; Stull and Rodiek, 2002).

Horses may need to be watered during the trip, preferably every 12 h and more often during hot weather conditions. Many horses traveling in trailers or vans are provided with hay while in transit. Horses without access to feed during transit should be fed at least every 24 h. Horses should not be expected to travel more than 24 h at one time without experiencing fatigue and dehydration, especially in extreme (hot or cold) environmental conditions (Stull, 1999; Friend, 2000b; Stull and Rodiek, 2002).

Regulation of air movement through the transport vehicle is essential to avoid thermal stress or excessive exposure to exhaust fumes. Adequate ventilation is especially crucial during extremely hot or cold weather. In hot weather, horses should not be left in parked trailers because heat stroke is likely; in cold weather, horses in moving trailers may need to be provided with blankets, especially if air flow cannot be controlled (as in stock trailers that are not fully loaded).

Poultry Transport

Unlike the loading ramp and chute system used for livestock, poultry on commercial farms are caught manually and loaded into transport crates that are then stacked on an open bed truck. Special attention to developing skilled staff for the catching, loading, and transport of poultry is important. Increased fear (Jones, 1992), leg breakage (Gregory and Wilkins, 1989), and mortality have been associated with poor catching and loading techniques (Weeks, 2007). Also, poorly feathered birds have greater body heat loss than well-feathered birds. The thermal neutral zone ranges from 8 to 18°C and 24 to 28°C for well-feathered chickens and poorly feathered chickens, respectively, under typical transit conditions of low air movement and high humidity (Webster et al., 1992). Increased time in transit, feed and water deprivation, and fatigue can cause increased death loss and stress. Therefore, these factors should be minimized.

Transport Distance and Duration

Most of the animals transported for use in research and teaching will be transported short distances for durations less than 6 h. In these situations, the amount of time on a transport vehicle does not become a welfare issue. A high percentage of the animals will be transported for less than 2 h. United States regulations specify that livestock have to be unloaded, fed, and watered after 28 h on a vehicle without food or water during interstate transport. The US *Humane Slaughter Act* requires that livestock in the lairage (stockyards) of a slaughter plant must have access to water in all of the holding pens. People who use agricultural animals in research and teaching need to keep the time that livestock or poultry are on vehicles as short as possible. There may be situations where research has to be conducted on a commercial farm, feedlot, or slaughterhouse when the researcher has no control over the transport conditions.

Regulatory Requirements for Transport

Transporters must comply with all county, state, and federal animal health regulations and identification requirements before transporting livestock and poultry. When animals are transported across state lines or from foreign countries, federal regulations for vaccinations, veterinary inspections, and health certificates must be complied with. There are different regulations for each species, and each state may also have regulations for health certificates. State animal health laws apply to all animals transported within a state. Some western states have brand inspection laws that require certificates of ownership and inspection of the livestock by an inspector. In some states animals transported short distances must have certificates. Transporters should be knowledgeable of regulatory requirements. International regulations for transporting animals have recently been summarized (ILAR Transportation Guide, 2006).

Lairage Recommendations Before Slaughter

After the animals are unloaded from the transport vehicle, lairage pens should be provided. There must be sufficient space for all of the animals to lie down at the same time without being on top of each other. Table 5-5 lists some examples of recommended space requirements (Grandin, 2007c).

Emergency Procedures for the Research Facility and Transporters

Both research facilities and people transporting animals should have a list of emergency contact phone numbers. The following numbers should be on the list. For the contacts other than the police, fire, and ambulance, phone numbers for work, home, and mobile should be listed.

- Police (telephone number)
- Fire (telephone number)
- Ambulance (telephone number)
- Emergency contact 1 and emergency contact 2

Transporters should have numbers they can call if they have an accident. Some of the contacts that should be included are persons who can bring portable panels, loading ramps, or other equipment for reloading escaped animals after an accident.

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Chapter 6: Beef Cattle

Beef cattle includes all animals of the genus *Bos* and their close relatives that are raised primarily for meat production. *Bos* animals that are utilized for milk are covered in Chapter 7: Dairy Cattle. As ruminants, beef cattle are capable of utilizing a wide range of feedstuffs and consequently are maintained in an array of situations ranging from extensive grazing to confined feedlot pens and intensive laboratory environments. Regardless of the housing system, basic needs for food, water, shelter, and comfort should be met.

FACILITIES AND ENVIRONMENT

Ideal Thermal Conditions

Under most environmental conditions, temperature represents a major portion of the driving force for heat exchange between the environment and an animal. However, moisture and heat content of the air, thermal radiation, and airflow also affect total heat exchange. Thus, a combination of environmental variables contributes to the conditions (effective or apparent temperature) to which an animal responds.

Under conditions in which relative measures and comparisons of the effect of different environmental variables could be determined, the apparent ambient temperature at which animals can cope has been defined with a reasonable degree of accuracy; however, variation does exist among animals. Environmental conditions that provide maximum comfort (thermal comfort zone, **TCZ**) and require little or no energy expenditure for maintenance depend on cattle age, metabolic size, and/or body mass and surface area. The TCZ generally ranges between 15 to 25°C for most cattle less than 1 mo old; between 5 and 20°C for a mature beef cow consuming a maintenance diet; and between −10 and 20°C for yearlings with ad libitum access to energy-dense feedlot diets. Based on physiological responses (Beatty et al., 2006) and heat load thresholds (Gaughan et al., 2008), *Bos indicus* and some heat-tolerant *Bos taurus* cattle breeds (Gaughan, et al., 1999) have a TCZ at least 5°C greater than typical *Bos taurus* cattle.

Encompassing the TCZ is the thermoneutral zone (**TNZ**). Within the TNZ, an animal can maintain homeostasis through normal physiological and metabolic processes, which may require minimal expenditure of energy when the animal is exposed to conditions outside the TCZ (Hahn, 1985; Young, 1985). The TNZ generally ranges between 10 and 30°C for most cattle less than 1 mo old; between −15 and 28°C for a mature beef cow consuming a maintenance diet; and between −35 and 25°C for yearlings with ad libitum access to energy-dense feedlot diets. Even though the upper end of the TNZ for most *Bos taurus* cattle is between 25 and 30°C, for high-producing cattle with high intakes of metabolizable energy the upper limit may be closer to 20°C on sunny days when little or no wind is present (Brown-Brandl et al., 2006). When given sufficient time, cattle acclimate and adapt to colder or hotter conditions. It should be noted that cattle that are adapted to −35°C may be uncomfortable (show signs of heat stress) at 10°C. Thus, the TCZ and TNZ serve only as guidelines to describe the limits within which cattle are comfortable and can adapt to, respectively. Independent of these guidelines, performance standards that indicate a problem with the thermal environment include, in cold weather, shivering, huddling, and loss of body condition/weight; and in hot weather, panting, sweating, and a reduction in feed intake. Primary factors that affect thermal comfort include feed/energy intake and body condition/fat cover.

Thermal Indices

At the present time, the temperature-humidity index {**THI**; THI = 0.8 × ambient temperature + [(% relative humidity/100) × (ambient temperature − 14.4)] + 46.4} has become the de facto standard for classifying thermal environments in many animal studies and selection of management practices during seasons other than winter (Hahn et al., 2003). The THI, first proposed by Thom (1959), has been extensively applied for moderate to hot conditions, even with recognized limitations related to airspeed and radiation heat loads (NOAA, 1976). A THI between 70 and 74 is an indication to producers that the potential for heat stress in livestock exists (LCI, 1970). In particular, when THI values are above 70 by 0800 h, it is recommended that managers of confined cattle that have high metabolic heat loads (e.g., feedlot cattle) initiate or prepare to initiate heat-stress management strategies before cattle become exposed to the excessive heat load (Mader et al., 2000). A THI of 84 or above can cause death, especially in feedlot cattle that are within 45 d of slaughter and consuming high-energy finishing diets.

Modifications to the THI have been developed to overcome the shortcomings related to the lack of airflow and radiation heat load in the index (Mader et al. (2006). Eigenberg et al. (2005) also developed similar adjustments based on predictions of respiration rates using ambient and dew point temperature, windspeed, and solar radiation. These models have merit in that the combined effects of multiple environmental factors can be taken into account when determining animal comfort.

Gaughan et al. (2008) developed a more extensive index as a guide to the management of feedlot cattle during hot weather. The heat load index (**HLI**) incorporates black globe temperature (Buffington et al., 1981), relative humidity, and windspeed. A threshold (HLI = 86), above which cattle are less efficient at dissipating heat was developed for a reference animal (healthy black, predominantly Angus, steers without access to shade, 100 to 150 d on feed, and a summer hair coat). The threshold for a full-blood Brahman steer is 96. Also, adjustments to the threshold are possible for use of shade, clean dry pens, cattle coat color, and days on feed. The thresholds are lowered if cattle are sick (−5) or not acclimated to summer conditions (−5).

Very limited data exist for assessing environmental effects on reproduction. However, Amundson et al. (2006) found THI and daily minimum temperature to be equally good predictors of pregnancy rate at 42 d into the breeding season. However, the combination of wind speed and THI had the greatest correlation (R^2 = 0.63) to pregnancy rate.

Indices for cold stress are not as well defined as for heat stress. The wind chill index (**WCI**) has traditionally been used to derive an apparent temperature for humans. In 2001, the National Weather Service (NWS, 2008) released a new WCI that may have merit for assessing effects of wind on domestic livestock (see Chapter 3: Husbandry, Housing, and Biosecurity for discussion).

Range and Pasture Systems

Acceptable systems for grazing beef cattle on pasture and rangeland vary widely. Cow body condition is an excellent performance standard for monitoring the well-being and nutritional status of range cattle (NRC, 1996). Special consideration needs to be given to environmental factors that affect grazing beef cattle. In areas where heat stress is common, provision of shade (including man-made or natural vegetation) to decrease the solar heat load is the most practical intervention in pasture and range systems. The need for artificial shade should be assessed after careful consideration of the adequacy of naturally occurring sources. Heat stress is evidenced when respiration rates begin to increase. Prolonged increases in body temperatures will result in decreased feed intake, body condition, and weight (Robertshaw, 1987; Hahn, 1995). In areas where exposure to extreme cold is likely, provision of shelter for grazing beef cattle may be desirable. Grazing beef cows decrease grazing time and forage intake as ambient temperature decreases below 0°C (Adams et al., 1986), although such changes are small in adapted beef cows (Beverlin et al., 1989). Cattle use windbreaks to decrease wind chill and prevent exposure to blowing snow, although it has not been clearly established that windbreaks improve animal performance (Krysl and Torell, 1988). Supplementary feed should be provided during periods of heavy snow cover that preclude grazing.

An adequate supply of forage should be available to grazing cattle. Intake and performance may be decreased when the amount of standing forage is lacking (NRC, 1987), but the appropriate quantity of forage dry matter per hectare varies with the pasture or range type and the stocking rate. Guidelines for acceptable amounts of standing forage per unit of body weight at given stocking rates (herbage allowance) are available (NRC, 1987), but additional research is needed with a variety of pasture and range types. Grazing beef cattle should be provided with supplements for nutrients that are known to be deficient in pasture and range forage in particular localities. In almost all grazing environments, range cattle require free-choice access to supplemental salt as a source of supplemental sodium. Typically, these salt-based, free-choice mineral supplements will also be fortified with trace minerals.

Observation and monitoring of range cattle often occur less regularly than for other livestock. When supplemental feed is provided, cattle are usually observed at least 2 or 3 times weekly. Unsupplemented cattle on open range may be observed less frequently. However, it is recommended that range cattle be observed at least once per week. In certain areas, grazing beef cattle may be affected by predators and poisonous plants. Careful attention should be given to such problems, and efforts should be made to decrease or eliminate these adverse conditions.

Availability of fresh, unfrozen water is critical for grazing beef cattle, and distance to water should be given consideration in pasture and range systems. If cattle are required to travel long distances to water in hot, dry climates, animal performance and utilization of pasture forage can be affected (Fusco et al., 1995). Holechek et al. (1995) recommended that distance to water be no greater than 1.6 km (1 mi) in rolling, hilly country and in undulating, sandy terrain. This recommendation was decreased to 0.8 km (0.5 mi) in rough country, increased to 2.4 km (1.5 mi) in smooth, sandy terrain, and increased to 3.2 km (2 mi) in areas with flat terrain. Thus, the distance to water for grazing cattle should not exceed 3.2 km, and every animal should have the opportunity to drink ad libitum at least once per day.

Feedlot and Housing Systems

Beef cattle used in research or teaching may be housed in intensive management systems, either indoors or in open lots, with or without shelter. Facilities for beef cattle should provide cattle with opportunities for behavioral thermoregulation (e.g., access to a windbreak, sunshade, mound, or roofed shelter). Management of dairy beef is similar to other cattle, although, some feeding, housing, and marketing regimens are unique to Holsteins (NCR 206, 2005).

Proper airflow and ventilation are essential in intensive facilities. In feedlots, cable or wire fencing has minimal effect on natural airflow in summer. However, high airflow rates are undesirable during periods of low temperature, and tree shelterbelts and other types of windbreak can decrease the rate of airflow past the cattle. An 80% solid windbreak 3 m (10 ft) high (minimum recommended height) decreases wind speed by half for about 45 m (150 ft) downwind and controls snow for about 8 m (25 ft); a similar windbreak 4 m (13 ft) high decreases wind speed by half for about 65 m (200 ft) downwind and controls snow for about 10 m (30 ft). A windbreak is recommended in mounded, south-sloping feedlots in the northern United States to provide dry resting areas with low air velocities. Caution should be exercised when placing cattle in sheltered areas in the summer because of the adverse effects of restricted airflow on cattle reared in hot environments (Mader et al., 1999).

During potentially stressful heat episodes (nighttime THI do not fall below 70), panting scores (1 = elevated respiration rate, 2 = drool or saliva present on side of mouth, 3 = open mouth breathing observed, and 4 = tongue and neck extended with open mouth breathing) can be utilized as an excellent indicator of stress levels experienced (Mader et al., 2006). When cattle are beginning to experience panting scores of 2 or greater some means of cooling may be needed. Cattle learn to take evasive action to alleviate heat stress and such competition for cooler areas in a pen or around the water trough increases even during cooler days in which heat alleviation methods (e.g., sprinkling) are not utilized (Mader et al., 2007). When this occurs evidence of crowding is observed, which exacerbates the heat stress problems. Wetting the ground or floor of holding facilities can be an effective method of cooling cattle managed in unshaded, outdoor units where surface vegetation is sparse or nonexistent (Mader, 2003; Mader and Davis, 2004). Direct wetting of cattle during extreme heat is also an effective practice and is often used as an emergency measure. Benefits of sprinkling are enhanced if sprinkling is started in the morning, before cattle experience high heat loads (Davis et al., 2003). Generally, a daily application of 0.5 to 1.0 cm of water is sufficient to cool pen surfaces. However, applying 1.25 to 1.50 cm every other day is acceptable and will not sufficiently contribute to mud build-up in normally dry pens. In areas with high evaporation rates (>1.0 cm of water/day), additional water may be needed, which can serve to cool pen surfaces as well as eliminate potential dust problems. The size of the area needed to be sprinkled would be similar to the shade area recommendations. As a routine protective practice, wetting can be efficiently accomplished by utilizing a timer to provide 5 to 10 min of spray during each 20- to 30-min period. Fogger nozzles are often mistakenly recommended for wetting animals. Fogger nozzles are less effective than sprinkler nozzles because of the barrier formed by the fine droplets (mist). These droplets adhere to the outer hair coat of the animal, causing the heat for evaporation to come from the air rather than from the body. Mitlöhner et al. (2001) reported that misting cattle was not as effective as shade in decreasing heat stress, and in some cases, caused respiration rate to increase compared with nonmisted cattle.

Shade for cattle can provide the margin of survival for animals that are unconditioned to a sudden heat wave with high solar radiant loads in central and southern regions of the United States. Mader et al. (1999) found limited performance benefits of utilizing shade in the north-central region of the United States, in contrast to the findings of Mitlöhner et al. (2001) where shade was effective in southern regions. Also, use of shade in northern climates may be costly and logistically prohibitive because of snow load requirements (unless shade is taken down after summer), potential mud problems under shade (low evaporation rates), and the low percentage of time that cattle may actually benefit from using the shade. However, benefits of using shade for maintaining animal comfort will almost always be found in any area or location in which abnormally hot or hot and humid conditions arise or persist, including northern climates, and when cattle have not had the opportunity to acclimate. Mitlöhner et al. (2001, 2002) found excellent results when shades were provided for feedlot cattle reared in the south-central region of the United States, an area where more consistent benefits of shade would be expected to be realized. For optimum benefits shades should be 3.6 to 4.2 m (12 to 14 ft) high in areas with clear, sunny afternoons (e.g., southwestern United States) to permit maximum exposure to the relatively cool northern sky, which acts as a radiation sink. In areas with cloudy afternoons (e.g., eastern United States), shades 2.1 to 2.7 m (7 to 9 ft) in height are more effective, as they limit the diffuse sky radiation received by animals beneath the shades. The amount of shade required for young cattle is 0.7 to 1.2 m^2 (7.5 to 13 ft^2) per animal, whereas larger cattle need 1.8 to 2.5 m^2 (19.4 to 27 ft^2) per animal. Shades are strongly recommended for sick cattle or for animals in hospital pens.

Cold housing can be provided for beef cattle. Open sides of any cattle building need to face away from prevailing winds. Such structures are ventilated by natural airflow, and the resultant winter temperatures are typically 2 to 5°C above outdoor conditions as a result of body heat. Totally enclosed housing requires ventilation to maintain the air temperature at acceptable levels and to minimize the accumulation in the air of water vapor, noxious gases, other odorous compounds, and dust. Ventilation systems may be either natural or mechanical.

Type of pen surface affects dustiness during hot dry weather and mud or manure build-up during wet periods. Good drainage of outside pens is imperative. Dirt pens should be regularly cleaned of animal waste residues and maintained to minimize accumulation of water. A hard surface apron in front of the feed bunks and around water troughs and shelters should be considered in dirt pens. Mounds should be provided in dirt pens for cattle to lie on during inclement weather (Table 6-1). Accumulation of mud in a pen or on the cattle can influence maintenance requirements and thermal balance. Properly designed pens with adequate slope are extremely important for minimizing mud and related health and behavior problems. In areas where slope or drying conditions are limited, adding mounds is very useful for keeping cattle clean and dry. Under hot-humid conditions, mounds aid in preventing animal crowding and improve exposure to airflow for the animals that utilize them. Additional information on feedlot/drylot pen design and layout has been published by Pohl (2002) and Henry et al. (2007).

For hard-surfaced pens, materials should be durable, slip-resistant, and impervious to water and urine; easily cleaned; and resistant to chemicals and corrosion from animal feed and waste. Concrete floors should be scored or grooved during construction to improve animal footing. Properly designed slotted floors are self-cleaning. Fences, pen dividers, walls, gates, and other surfaces must be strong enough to withstand the impact of direct animal contact. Configuration and treatment of contact surfaces must minimize or eliminate protrusions, changes in elevation, and sharp corners to minimize bruising and injuries and to improve the efficiency of cattle handling.

Proper lighting permits inspection of animals in feedlots and other cattle housing systems and provides safer working conditions for animal care personnel. Maintenance of facilities (e.g., repair of fences and equipment) should be timely and ongoing.

FEED AND WATER

Diets for beef cattle should be formulated according to the recommendations of the NRC (1996). Formulation of diets should consider factors such as environmental conditions, breed or biological type, sex, and production demands for growth, gestation, or lactation.

Feed and water should be offered to cattle in ways that minimize contamination by urine, feces, and other materials. Feed bunks should be monitored daily and contaminants or spoiled feed should be removed. In most situations, feed should be available at all times. However, restricted feeding of high-energy diets may be practiced to meet maintenance requirements or targeted levels of production. When restricted feeding is practiced, feed must be uniformly distributed in the bunk to allow all cattle to have simultaneous access to the diet. When high-energy diets are fed, increased attentiveness should be given to possible occurrence of diet-related health problems such as grain overload, lactic acidosis, and bloat. Abrupt changes in diets should be avoided. Feed deprivation for more than 24 h should be avoided, and feed deprivation for any length of time must be justified in the animal use protocol.

Cattle can vary considerably in body weight and condition during the course of grazing and reproductive cycles. Feeding programs should allow animals to regain the body weight that is lost during the normal periods of negative energy balance. Confined cattle should have continuous free access to a source of water, except before surgery or weighing if the research or animal care protocol requires such restriction. When continuous access to water is not possible, water should be available ad libitum at least once daily and more often if hot weather conditions exist or cattle have high levels of metabolizable energy intake for purposes of achieving high output (growth or milk). Under winter range conditions, Degen and Young (1990a, b) found that snow can be used as a water source for beef cows and growing calves. However, there was evidence that the snow resulted in reduced water intakes as evidenced by compensatory water intake when water was reintroduced following 84 d of consuming water in the form of snow. When snow was the only source of water, total water intake reductions averaged approximately 10% among the cattle groups.

The quantity and, possibly, quality of water available will influence animal comfort, especially under hot conditions. Evaporation of moisture from the skin surface (sweating) or respiratory tract (panting) is the primary mechanism used by the animals to lose excess body heat in a hot environment. Estimates of daily water requirements for beef cattle are reported in NRC (1996). During summer months, in particular, waterer space available and water intake per animal becomes extremely important. Under these conditions, Mader et al. (1997) found that as much as 3 times the normal waterer space (7.5 vs. 2.5 cm of linear space per animal) may be needed to allow for sufficient room for all animals to access and benefit from available water. Additional waterer space recommendations are provided by MWPS (1987).

Table 6–1. Floor or ground area and feeder space recommendations for beef cattle used in agricultural research and teaching[1,2,3]

Area or space	Calves, 180 to 380 kg (400 to 800 lb)		Finishing cattle, 360 to 545 kg (800 to 1200 lb)		Bred heifers, 360 kg (800 lb)	
	m^2	ft^2	m^2	ft^2	m^2	ft^2
Floor or ground area						
Open lots (no barn)						
Unpaved lots with mound (includes mound space)	14.0 to 28.0	150 to 300	23.2 to 46.5	250 to 500	23.2 to 46.5	250 to 500
Mound space, 25% slope	1.9 to 2.3	20 to 25	2.8 to 3.3	30 to 35	2.8 to 3.3	30 to 35
Unpaved lot, 4 to 8% slope, no mound	28.0 to 55.8	300 to 600	37.2 to 74.4	400 to 800	37.2 to 74.4	400 to 800
Paved lot, 2 to 4% slope	3.7 to 4.7	40 to 50	4.7 to 5.6	50 to 60	4.7 to 5.6	50 to 60
Barns (unheated cold housing)						
Open front with dirt lot	1.4 to 1.9	15 to 20	1.9 to 2.3	20 to 25	1.9 to 2.3	20 to 25
Enclosed, bedded pack	1.9 to 2.3	20 to 25	2.8 to 3.3	30 to 35	2.8 to 3.3	30 to 35
Enclosed, slotted floor	1.1 to 1.7	12 to 18	1.7 to 2.3	18 to 25	1.7 to 2.3	18 to 25
Feeder space when fed:	cm	in	cm	in	cm	in
Once daily	45.7 to 55.9	18 to 22	55.9 to 66.0	22 to 26	55.9 to 66.0	22 to 26
Twice daily	22.9 to 27.9	9 to 11	27.9 to 33.0	11 to 13	27.9 to 33.0	11 to 13
Free choice grain	7.6 to 10.2	3 to 4	10.2 to 15.2	4 to 6	10.2 to 15.2	4 to 6
Self-fed roughage	22.9 to 25.4	9 to 10	25.4 to 27.9	10 to 11	27.9 to 30.5	11 to 12
	Cows, 455 kg (1,000 lb)		Cows, 590 kg (1,300 lb)		Bulls, 680 kg (1,500 lb)	
	m^2	ft^2	m^2	ft^2	m^2	ft^2
Floor or ground area						
Open lots (no barn)						
Unpaved lots with mound (includes mound space)	18.6 to 46.5	200 to 500	28.0 to 46.5	300 to 500	46.5	500
Mound space, 25% slope	3.7 to 4.2	40 to 45	3.7 to 4.2	40 to 45	4.7 to 5.6	50 to 60
Unpaved lot, 4 to 8% slope, no mound	32.5 to 74.3	350 to 800	32.5 to 74.3	350 to 800	74.3	800
Paved lot, 2 to 4% slope	5.6 to 7.0	60 to 75	5.6 to 7.0	60 to 75	9.3 to 11.6	100 to 125
Barns (unheated cold housing)						
Open front with lot	1.9 to 2.3	20 to 25	2.3 to 2.8	25 to 30	3.7	40
Enclosed, bedded pack	3.3 to 3.7	35 to 40	3.7 to 4.7	40 to 50	4.2 to 4.7	45 to 50
Enclosed, slotted floor	1.9 to 2.3	20 to 25	2.0 to 2.6	22 to 28	2.8	30
Feeder space when fed:	cm	in	cm	in	cm	in
Once daily, limited feed access	61.0 to 76.2	24 to 30	66.0 to 76.2	26 to 30	76.2 to 91.4	30 to 36
Twice daily, limited feed access	30.5 to 38.1	12 to 15	30.5 to 38.1	12 to 15	—	—
High-concentrate diet, ad libitum	12.7 to 15.2	5 to 6	12.7 to 15.2	5 to 6	—	—
High-forage diet, ad libitum	30.5 to 33.0	12 to 13	33.0 to 35.6	13 to 14	—	—

[1]Primarily based on MWPS (1987).
[2]Values are on a per-animal basis in a pen environment.
[3]In favorable (e.g., dry) climates, area accommodations may be less than indicated in this table.

HUSBANDRY

Adequate care of cattle and calves is especially important for establishing and maintaining optimal immune system function. Good husbandry can minimize health problems and infectious diseases. The risk of disease and mortality in young calves is related to immune status (Postema and Mol, 1984; McDonough et al., 1994). It is critical that newborn calves nurse or ingest colostrum soon after birth. Additional information on the care of the newborn calf can be obtained from Chapter 7: Dairy Cattle.

The health of young growing cattle should be assessed regularly pre- and postweaning. Animal care personnel should be taught to recognize signs of illness and external parasites. Alert caretakers should have the ability to perceive appropriate behavior and posture (Albright, 1993). A system of monitoring calves through critical stress periods such as weaning should be established. Any sick or injured calves should be treated promptly. Daily records should be kept (e.g., calves treated and treatment). For cattle reared in close confinement (e.g., cattle in feedlots) assessments should be done at least once daily and more often if cattle have been stressed or potentially exposed to conditions in which their health could be compromised. In general, confined feedlot cattle, especially new incoming cattle, require more frequent observations than nonconfined cattle (i.e., on range or pasture) because of the greater probability of animal health being compromised due to comingling, dehydration, digestive problems, respiratory problems, and interaction of any of these factors with environmental stress. Signs of healthy calves are alert ears and clear eyes, no signs of diarrhea, and, upon arising, resumption of a normal standing posture after stretching. For feedlot cattle provided energy-dense diets, caretaker knowledge of acidosis and management regimens necessary to minimize digestive problems are essential.

Appropriate medication and vaccination programs should be used to reduce the incidence of disease and mortality, improve cattle health and performance, and ensure that no illegal residues occur in the carcass (Wilson and Dietrich, 1993). Treatment and vaccination schemes should be based on veterinary advice and experience.

Weaning

In typical beef cow/calf production systems, calves are artificially weaned from their dams by physical separation. This process, albeit important to the efficiency of the cowherd, can be stressful to both the cow and calf. The most common weaning procedure involves an abrupt separation of cows and calves resulting in increased walking and vocalization and decreased eating and resting (Veissier and le Neindre, 1989). An alternative to abrupt weaning and permanent separation is a period (approximately 7 days) of fenceline contact between cows and calves in adjacent but separate pastures. This weaning management alternative has been shown to decrease vocalization and walking (or pacing) and increase the time spent resting and grazing (Price et al., 2003). This fenceline weaning procedure may also decrease the incidence of calf illness (Boyles et al., 2007). Within the weaning pasture or pen, a mature cow can be included in the group of freshly weaned calves. This "trainer" cow can assist in introducing the weaned calves to the location and facilitating consumption of feed and water (Gibb et al., 2000). Despite the weaning process selected, it is important that weaned calves be provided access to clean water and a source of feed and/or forage. To encourage intake, highly palatable forage and feed sources are recommended until calves become accustomed to the separation from their dams. Additionally, feed and water sources should be placed close to the perimeter of the fenceline, because calves will typically spend a majority of their time in these areas as they seek to reunite with their dams.

Social Environment

Cattle are social animals. Each individual in the group should have sufficient access to the resources necessary for comfort, adequate well-being, and optimal performance. Mixing, crowding, group composition, and competition for limited resources are part of the social environment and in some circumstances, may be social stressors for certain cattle. Generally, cows from similar environments but from different social groups can be mixed with little or no long-term adverse effect on performance (Mench et al., 1990); however, because introduced cows may be the recipients of aggression, the number of mixing episodes should be minimized. Mixing of older cattle, especially bulls, results in more fighting than occurs when younger cattle are mixed (Tennessen et al., 1985). Fighting and mounting can be a problem associated with keeping bulls in social groups and can present a significant welfare problem if not managed carefully (Fraser and Broom, 1990; Mounier et al., 2005). Attempts should be made to keep bulls in stable social groups and to minimize mixing.

When feed, water, or other resources critical for comfort or survival are limited, or when large differences exist among cattle in size or other traits related to position in the social order, some animals may be able to prevent others from gaining access to resources. In properly designed facilities, all individuals should have sufficient access to feed, water, and resting sites to minimize the correlation between position in the social order and productive performance (Hafez, 1975; Strickland and Kautz-Scanavy, 1984; Fraser and Broom, 1990).

Proper animal care includes observation of groups and of individuals within groups to ensure that each individual has adequate access to the resources necessary for optimal comfort, welfare, and performance.

Floor or Ground Area

Area recommendations for open lots and barns are listed in Table 6-1. Every animal should have sufficient space to move about at will, adequate access to feed and water, a comfortable resting site, and the opportunity to remain reasonably dry and clean. These suggested recommendations alone do not ensure that an ideal environment exists; however, in some cases these conditions can be met with less than the recommended area. The area required is affected by type and slope of floor or soil surface, amount of rainfall, amount of sunshine, season, group size, and method of feeding.

Open feedlot pens need to be sloped to promote drainage away from feed bunks, waterers, pen dividers, and resting areas. Space allocations are related directly to slope. In temperate Midwestern climates, the following relationships have been found to be workable (MWPS, 1987): 2% slope or less: 37 to 74 m^2 (400 to 800 ft^2) per animal; 2 to 4% slope: 23 to 37 m^2 (250 to 400 ft^2); and 4% or greater slope: 14 to 23 m^2 (150 to 250 ft^2). Space allocations can be less in drier regions of the country. In the Southwest, at 0% slope, typical allocations are 14 to 23 m^2 (150 to 250 ft^2) per animal. In other regions, space allocations may need to be increased above Midwestern norms in consideration of such factors as soil type and rainfall distribution.

The area requirements for cattle are greatly influenced by group size. One animal housed separately in a pen requires the greatest amount of floor area on a per-animal basis. As group size increases, the amount of area required per individual decreases. When an animal is housed individually, the minimum pen width and length should be at least equal to the length of the animal from nose tip to tail head when the animal is standing in a normal erect posture.

Acceptable indoor pen floor surfaces for beef cattle include unfinished concrete, grooved concrete, concrete slats, expanded metal, plastic-covered metal flooring, and rubberized mat. The floor surface in stanchions and metabolism stalls may be concrete, expanded metal, wood, rubberized mat, or a combination of materials that provides support for the animals' bodies; does not damage hooves, feet, legs, and tails; and can be cleaned.

STANDARD AGRICULTURAL PRACTICES

For beef cattle, management procedures may be performed by properly trained, nonprofessional personnel. These include, but are not limited to, vaccinating, dehorning and castrating young cattle, horn-tipping, ear-tagging, branding, weighing, implanting, use of hydraulic and manual chutes for restraint, roping, hoof-trimming, routine calving assistance, ultrasound pregnancy checking, feeding, and watering.

Other husbandry and health practices used in beef cattle research and teaching that similarly may be performed by properly trained, nonprofessional personnel, but that require special technical training and advanced skill levels, include artificial insemination, electroejaculation, pregnancy palpation, embryo flushing and transfer, nonroutine calving assistance and dystocia treatment, emergency cesarean section, retained placenta treatment, and dehorning and castration of older cattle.

One of the main animal husbandry concerns is that of pain and distress, especially pain inflicted from standard husbandry procedures. Dehorning, castration, and branding are husbandry procedures that can cause pain and discomfort; nevertheless, these procedures are justified as a management tool to minimize injuries or other problems associated with confining horned cattle and commingling bulls. Additional guidelines outlining veterinary oversight of these practices, other animal health issues, and related institutional policies are covered in Chapters 1 and 2.

Dystocia Management

Matings should be planned to lessen the genetic probability of dystocia. When dystocia does occur, proper care and assistance at calving can decrease injury or death of both calves and heifers/cows.

Parturition without complication is common in beef cows. Therefore, before administering assistance to a cow experiencing difficulty with calving, personnel should be familiar with the stages associated with approaching parturition and the signs of normal delivery. As a general rule, females should be examined within 30 to 60 min following presentation of feet, nose, or fetal membranes if delivery of the calf does not appear imminent. However, heifers or cows exhibiting signs of a malpresentation, oversized fetus, fetal anomaly, or other obvious complication must be assisted immediately.

Facilities should be provided that are designed for restraint of cows and heifers experiencing dystocia. Because many animals, especially heifers, lie down during the obstetrical procedure, sufficient space should be provided to permit adequate freedom of movement. It is important that the obstetrical restraint facility be fitted with side gates, both of which are hinged at the head end, so that the animal can become fully recumbent and the obstetrical procedure can be performed with safety and efficiency.

In dystocia cases where fetal presentation appears to be compromised or there appears to be a disparity between the size of the fetus and the diameter of the birth canal, assistance of the delivery by personnel appropriately trained in the judicious use of a fetal extractor may be attempted. In general, if more than slight traction is required on the fetal extractor, the procedure should be stopped and a veterinarian called immediately to perform a caesarean section or fetotomy. Use of excessive force can damage the calf and/or dam and lead to suffering and/or death. Strict sanitation should be used with all obstetrical procedures.

Vaccinations and Drug Administration

Vaccinations are a key component to any herd health program. Care should be taken to ensure the proper use, handling, and storage of vaccines and approved or investigational drugs. The preferred site of injection is the neck for either intramuscular or subcutaneous injections; however, for investigational drugs used in research, alternate sites of administration may be required or preferred as dictated by the research protocol. Investigators and animal care staff should utilize best management practices associated with the use of syringes and handling needles. Use and regular replacement of disposable syringes and needles is highly recommended to avoid excessive trauma and disease transmission.

Castration

Castration of male beef cattle is performed to reduce aggressiveness, prevent physical danger to other animals in the herd and to handlers, enhance reproductive control, manage genetic selection, and satisfy consumer preferences regarding taste and tenderness of meat. Accordingly, castration of young bulls is a necessary management practice in beef production.

Several methods for castrating cattle are acceptable, including surgical removal of the testicles using a knife or scalpel to open the scrotum and cutting or crushing the spermatic cords with an emasculatome or emasculator. Bloodless procedures utilizing specialized rubber rings or surgical tubing bands (applied with specially designed instruments) are available to create devitalization and eventual sloughing of the tissues below the ring or band. High-tension banding systems may be used with appropriate veterinary supervision and/or training in those situations where surgical castration may predispose to postsurgical complications or when surgical castration is not appropriate because of its effect on research protocol. The castration method used should take into account the animal's age and weight, the skill level of the technician, environmental conditions, and facilities available as well as human and animal safety. Whatever the method of castration, the procedures should be conducted by, or under the supervision of, a qualified, experienced person and carried out according to castration equipment manufacturer recommendations and accepted husbandry practices (Battaglia and Mayrose, 1981; Ensminger, 1983).

Surgical castration is normally a short-term event with short-term duration of pain-associated responses. Bloodless castration has been associated with lower short-term pain indicators but longer chronic pain indicators (Moloney et al., 1995; Thuer et al., 2007). Bloodless castration should be used when surgical castration may predispose to postsurgical complications or when surgical castration is not appropriate because of its effect on the research protocol. Castration is least stressful when performed at or shortly after birth, but lower stress is reported if performed before 2 or 3 months of age or before animals reach a body weight of 230 kg (Farm Animal Welfare Council, 1981). It is strongly recommended that calves be castrated at the earliest age possible.

It may be desirable to inject local anesthetic in the scrotum of calves heavier than 230 kg when surgical methods of castration are used or when the spermatic cords are crushed. Topical local anesthetics may also be used on open wounds. Improved animal performance, as one potential indicator of improved animal welfare, has not been observed in animals locally anesthetized at the time of castration (Ting et al., 2003; Wildman et al., 2006; Rust et al., 2007). It should be recognized that the effect of anesthetic agents is short-lived. Nevertheless, procedures should be implemented to minimize pain and discomfort, especially in older cattle. Castration of older, heavier bulls should be performed only by skilled individuals. When it is necessary to castrate these heavier bulls, techniques and procedures to control bleeding must also be used. No advantage to use of anesthesia is apparent when bloodless castration is practiced (Chase et al., 1995).

The possibility of infection should be given additional consideration after castration. Equipment should be sterilized, and facilities should be clean and sanitized. Infection following castration can be minimized by keeping the animals in a clean area and away from excessive mud or contaminants following the procedure until the wound is healed. If tetanus is a common disease associated with the premises, or if a bloodless castration method is utilized, the herd health veterinarian should schedule a prophylactic tetanus immunization program.

Dehorning

Horns on cattle can cause bruises and other injury to other animals, especially during transport and handling. Horns on adult cattle also can be a hazard to humans. Hornless cattle require less space in the feedlot and at the feed bunk. Polled breeds should be used whenever possible.

Disbudding and dehorning of cattle in the United States is not currently regulated. The Canadian Veterinary Medical Association recommends that disbudding be performed within the first week of life (CVMA, 1996). In the United Kingdom, disbudding with a hot iron is preferred to dehorning and it is advised that this should be performed before cattle reach the age of 2 mo. In Australia, dehorning without local anesthesia or analgesia is restricted to animals less than 6 mo old (La

Fontaine, 2002). Calves suffer less pain and stress, have less risk of infection, and have better growth rates when dehorning is performed at a very young age (Newman, 2007). Stafford and Mellor (2005) found that the use of local anesthetics virtually eliminated the escape behavior of calves associated with the dehorning process and that a 2-h delay was observed in the cortisol response to horn amputation. Whenever possible, the use of a local anesthetic is encouraged when dehorning. Additional information on dehorning can be found in AVMA (2008) guidelines on castration and dehorning, and in Chapter 10: Sheep and Goats.

When horned breeds of cattle are selected, dehorning (removal of horns) should be performed under the supervision of experienced persons using proper techniques (Ensminger, 1970; Battaglia and Mayrose, 1981). The horn buds should be removed at birth or within the first month after birth by several means, including hot cauterizing irons, cauterizing chemicals, a sharp knife, or commercially available mechanical devices. It is strongly recommended that calves be dehorned at the earliest age possible.

When it is necessary to remove horns from older cattle, methods that minimize pain and bleeding and prevent infection should be employed. Dehorning should be performed by a person knowledgeable and experienced in the appropriate procedures. Appropriate restraint and local anesthesia to control pain should be used when cattle older than 1 mo of age (>50 kg) are dehorned. Cattle should be monitored for hemorrhage and infection following dehorning. Adult cattle should be dehorned if aggressive behavior is displayed toward herd mates or humans. Dehorning may temporarily depress the growth of cattle (Loxton et al., 1982).

In the event that bunk and pen space are ample (e.g., 2 times recommended space requirements), then tipping the horn (removing the tip only) may be considered as an alternative to minimize potential bruising or injury of pen mates. However, Ramsay et al. (1976) reported that, after transport, carcass bruises were as common among tipped cattle as among horned ones.

Identification Methods

Proper animal identification is essential to research, facilitates record keeping, and aids in the routine observation and repeat identification of cattle. Methods of identification include skin color markings, ear tagging, tattooing, hot branding, freeze branding, and electronic identification. Ear tags are best used in conjunction with a more permanent form of identification such as a tattoo or brand, as ear tags are sometimes lost. Hot branding the hide is utilized as a means of identification; however, loss in hide value and studies indicating that freeze branding is less painful than hot branding (Lay et al., 1992; Schwartzkopf-Genswein et al., 1997) have begun to minimize the use of hot branding. Alternatives to hot branding should be considered. However, skin and hair color in addition to a limited access to liquid nitrogen or dry ice in extensive range operations may affect the ability to achieve a quality freeze brand. At some locations, branding is required by law. Both hot branding and freeze branding should be performed by trained personnel to minimize skin contact with the branding device to only that required to achieve a useful brand. Advent of a national animal identification system (NAIS) in the form of visual (flap tags) or radio frequency identification (RFID) ear tags serve as an additional means of identification. As this system will become standard for all cattle as part of a national program, managers of beef cattle as part of resident herds used in research should comply with the established guidelines.

Implanting

Implanting of cattle is a management practice for the administration of growth promotants and potentially as a means of delivery of investigational compounds used in research. For proper absorption and maximum response, implants should be placed correctly and in the correct location. Traditionally, implants are placed beneath the skin on the back side of the middle third of the ear; however, alternate implantation sites may be required as designated by the research protocol. Proper disinfection of the implant site is required to prevent infection. Care should be taken not to injure major blood vessels or the cartilage of the ear when implanting in the ear location. Utilization of best management practices associated with the use of the implant device and correct needle-handling procedures are required by suitably trained personnel.

ENVIRONMENTAL ENRICHMENT

Refer to Chapter 4: Environmental Enrichment for information on enrichment of beef cattle environments.

HANDLING AND TRANSPORT

Refer to Chapter 5: Animal Handling and Transport for information on handling and transportation of beef cattle.

SPECIAL CONSIDERATIONS

Intensive Laboratory Facilities

Some research and teaching situations require that beef cattle be housed under intensive laboratory conditions. Cattle may be kept in metabolism stalls, stanchions, respiration chambers, or environmental chambers. Housing cattle in such facilities should be avoided unless required by the experimental protocol (e.g., complete urine or fecal collection, frequent sampling, or environmental control) and then should be for the minimum amount of time necessary to accomplish the teaching or research objective. Cattle that are held or penned temporarily in crowded areas, frequently disturbed, or come into close contact with humans, or exposed to unfamiliar conditions or laboratory/teaching settings should have calm dispositions and be adapted to frequent contact with animal care personnel and to those conditions that could result in the animal having an adverse reaction. In some cases, it may be advantageous to train such animals to a halter. Time spent preparing cattle for use in a laboratory improves the quality of research and the safety of both the animals and the humans. Cattle should not be housed in isolation unless approved by the Animal Care and Use Committee for specific experimental requirements. Whenever possible, cattle should be able to maintain visual contact with others.

Unless the experimental protocol has special requirements for lighting, all animal rooms should be designed to minimize variation in light intensity. During light periods, the minimum light intensity for intensively housed cattle is 70 lx (Manser, 1994). If possible, a diurnal light-dark cycle should be used and a standard daily schedule established (Wiepkema, 1985).

Excreta should be removed from enclosed laboratories at least once daily. Pens or stalls should be washed thoroughly at the beginning of every trial. If excreta or other foreign materials such as wasted feed cannot be adequately removed through daily cleaning, additional washing may be needed during a trial. The method of collection of feces and urine from cattle in metabolism stalls, stanchions, and chambers depends on the design and construction of the unit. Additional management may be needed to keep animals clean when they are housed in stalls or stanchions. Cattle may need to be washed and curried regularly to maintain cleanliness and to avoid fly infestations. Pens, stalls, and stanchions should be large enough to allow cattle to stand up or lie down without difficulty and should be long enough to allow cattle to maintain a normal standing position.

Because of the operating costs associated with single-pass ventilation systems in controlled environmental facilities, partial recirculation (up to 80%) of exhaust air from animal rooms is common and acceptable in many studies. In facilities designed to recirculate even a small part of the exhausted air, treatment is necessary to remove odorous compounds, gases, and particulate matter.

Cattle maintained in some laboratory environments have their activity restricted more than cattle in production settings. The length of time that cattle may remain in stanchions, metabolism stalls, or environmental chambers before removal to a pen or outside lot for additional exercise should be no longer than that necessary for conducting the study. Opportunities for regular exercise should be considered if they do not disrupt the experimental protocol; care must be taken in moving animals from the laboratory to the outside environment for exercise when a large temperature differential exists. If cattle are to be housed in such laboratory environments for more than 3 wk then particular attention should be given to alertness of the animal; appetite; fecal and urinary outputs; and condition of the feet, legs, and hock joints. Rubber mats or suitable alternatives should be used to increase the comfort of cattle maintained for lengthy periods on hard surfaces.

Care of Genetically Engineered and Cloned Beef Cattle and Use of Beef Cattle in Biomedical Research

Relative size, cost of maintaining beef cattle, and the use of alternate animal models in biomedical research have largely minimized the use of beef cattle in this regard. Nevertheless, beef cattle have played a role in understanding such maladies as lysosomal storage diseases (e.g., mannosidosis) and hemochromatosis (iron overload), among others, which have similarities to diseases, often genetically based, found in humans; therefore beef cattle may serve as highly valuable biomedical models in some cases. In addition, the potential use of cattle (albeit more often dairy cattle than beef cattle) as bioreactors for the production of human gene products or pharmaceuticals ("pharming") in milk, blood, urine, or tissues may further extend the use of beef cattle for biomedical applications. Standards for the care and welfare of beef cattle used in biomedical research should be the same as that applied to all beef cattle. However, institutional or biomedical funding agencies may require more specific disease entry testing requirements for cattle used in biomedical research, in addition to having more stringent procedures with respect to adherence to alternate oversight committee guidelines for reporting, housing, observation and care procedures (e.g., federal assurance statement guidelines, institutional biohazard committees, lab animal vs. production animal designations that may dictate care practices) than might be utilized or generally accepted under typical agricultural research and production systems.

In some cases, in which in vitro reproductive technologies are used for the production of beef cattle in research (genetically engineered, cloned, or otherwise), maturation, fertilization, manipulation, and/or culture, differences can exist in fetal morphology, physiology, and in the expression of developmentally important genes (Farin et al., 2004) that may require alteration in management strategy (e.g., increased frequency of observation at calving). For example, cattle produced in this manner may exhibit "large calf syndrome" and therefore may require extra assistance at calving (see Dystocia Management section).

The animal biotechnology sector continues to grow, with significant advancements being made that may directly (genetic engineering) and indirectly (e.g., vaccine development) affect beef cattle research (Jain, 2008), and it is important to recognize that alterations through the genetic engineering of beef cattle may similarly require alterations in beef cattle care practices. With respect to genetic engineering, unanticipated results from genetic modifications have been observed in several genetically engineered species (e.g., consequences to genetic engineering for double muscling in beef cattle: Rollin, 1996) that require diligence on the part of the researcher and animal care staff in assessing animal welfare (Rollin, 1996). However, the general standards of care associated with genetically engineered and cloned beef cattle should be the same as that applied to all beef cattle unless the specific genetic modification requires an alteration in management within the research environment to specifically facilitate animal welfare. Additional considerations regarding the use of genetically engineered animals are outlined in Chapters 1 and 2.

EUTHANASIA

According to the USDA and Food Safety and Inspection Service (FSIS) *Humane Slaughter of Livestock* regulations (USDA-FSIS, 2003), floors of livestock pens, ramps, and driveways of harvest facilities shall be constructed and maintained so as to provide good footing for livestock (CFR, 2006). Animals shall have access to water in all holding pens and, if held longer than 24 h, access to feed. Also, for animals held overnight there shall be sufficient room in the holding pens for the animals to lie down (CFR, 2006).

The AVMA *Guidelines on Euthanasia* (AVMA, 2007; current guidelines at http://www.avma.org/) lists several methods of euthanasia that are appropriate for ruminants. Intravenous administration of barbiturates, potassium chloride used in conjunction with general anesthesia, and penetrating captive bolt are acceptable means of euthanasia in all cases. Other conditionally acceptable methods include intravenous administration of chloral hydrate (following sedation), gunshot to the head, and electrocution. In all cases, euthanasia should only be performed by trained individuals.

Agents that result in tissue residues cannot be used for the euthanasia of ruminants intended for human or animal food, unless those agents are approved by the Food and Drug Administration. Carbon dioxide is the only chemical currently used in euthanasia of food animals (primarily swine) that does not lead to tissue residues. Use of carbon dioxide is generally not recommended for euthanasia of larger animals. The carcasses of animals euthanized by barbiturates may contain potentially harmful residues, and such carcasses should be disposed of in a manner that prevents them from being consumed by humans or animals.

Dying, diseased, and disabled livestock shall be provided with a covered pen sufficient to protect them from adverse climatic conditions (CFR, 2006). Incurably ill or injured animals in chronic pain or distress should be humanely euthanized as soon as they are diagnosed as such and according to AVMA (1993) recommended procedures. Their disposal should be accomplished promptly by a commercial rendering service or other means (e.g., burial, composting, or incineration) according to applicable ordinances and regulations.

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Chapter 7: Dairy Cattle

Dairy cattle include replacement heifer calves and yearlings, dry cows, lactating cows, and breeding bulls used for research and teaching purposes related to milk production. The basic requirements for safeguarding the welfare of dairy cattle are an appropriate husbandry system that meets all essential needs of the animals, and high standards of handling (Agriculture Canada, 1990).

FACILITIES AND ENVIRONMENT

Physical accommodations for dairy cattle should provide a relatively dry area for the animals to lie down in and be comfortable (Cook et al., 2005) and should be conducive to cows lying for as many hours of the day as they desire. Recent work indicates that blood flow to the udder, which is related to the level of milk production, is substantially higher (28%) when a cow is lying than when a cow is standing (Metcalf et al., 1992).

Criteria for a satisfactory environment for dairy cattle include thermal comfort (effective environmental temperature), physical comfort (injury-free space and contact surfaces), disease control (good ventilation and clean surroundings), and freedom from fear. Cattle can thrive in almost any region of the world if they are given ample shelter from excessive wind, solar radiation, and precipitation (Webster, 1983). Milk production declines as air temperature exceeds 24°C (75°F; West, 2003) or falls below −12°C (10°F) for Holstein and Brown Swiss cows or below −1°C (30°F) for Jerseys (Yeck and Stewart, 1959; Young, 1981).

Heat stress affects the comfort of cattle more than does cold stress. Milk production can be increased during hot weather by the use of sunshades, sprinklers, misters, and other methods of cooling (Roman-Ponce et al., 1977; Bucklin et al., 1991; Armstrong, 1994; Armstrong and Welchert, 1994) as well as by dietary alterations (NRC, 1981). Temperatures that are consistently higher than body temperature can cause heat prostration of lactating cows, but additional energy intake (+1%/°C) and greater heat production by the cow can compensate for lower temperatures, even extremely low ones. Consideration also needs to be given to humidity levels and wind chill factors in determining effective environmental temperatures. Adaptation to cold results in a thicker haircoat and more subcutaneous fat, which also reduces cold stress (Curtis, 1983; Holmes and Graves, 1994). Because dairy animals adapt well to cold climates, maintaining indoor air temperature equal to or slightly above outdoor air temperature is quite tolerable to housed animals. Coincidentally, providing the ventilation rate necessary to maintain this minimum temperature difference leads to good air quality (Bickert, 2003b). Protecting the animal from extreme drafts, providing dry lying places that contribute to a dry, fluffy, erect haircoat, meeting the nutritional needs of the animal, and allowing the animal sufficient freedom of movement are essential.

The newborn dairy calf has a lower critical temperature of 8 to 10°C (50°F) (Webster et al., 1978). The intake of high-energy colostrum permits rapid adaptation to environmental temperatures as low as −23°C (−9°F) and as high as 35°C (95°F) in dry, individual shelters with pens (Erb et al., 1951) or in hutches (Jorgenson et al., 1970; Rawson et al., 1989; Spain and Spiers, 1996).

Calves may be housed individually in outdoor hutches or inside buildings in bedded pens or elevated stalls. If calves are exposed to low temperatures, they should be provided with dry bedding and protected from drafts. Proper ventilation is critical in closed buildings with multiple animals. Hutches should be sanitized by cleaning, followed by moving the hutch to a different location or leaving the hutch vacant between calves (Bickert et al., 1994). In hot climates or during hot summer weather, calf hutches need to be environmentally modified or shaded to ensure that the calf does not experience severe heat stress.

Housing and handling systems vary widely, depending on the particular use of the cattle in research and teaching (Albright, 1983, 1987). Recommended facilities for dairy cattle range from fenced pastures, corrals, and exercise yards with shelters to insulated and ventilated barns with special equipment to restrain, isolate, and treat the cattle (Bickert, 2003a). Generally, headlocks (one per cow), corrals, and sunshades are used in warm semi-arid regions. Pastures and shelters are common in warm humid areas. Naturally ventilated barns with free stalls are used widely in both warm and cold regions.

To a lesser extent, insulated and ventilated barns with tie stalls are used in colder climates.

Early research showed an economic advantage in providing housing for dairy cows during the winter instead of leaving them outside (Plumb, 1893). During good weather, to enrich the environment and to improve overall health and well-being, cows should be moved if possible from indoor stalls into the barnyard, where they can groom themselves and one another (Wood, 1977), stretch, sun themselves, exhibit estrous behavior, and exercise (Albright, 1993b). Exercise decreases the incidence of leg problems, mastitis, bloat, and calving-related disorders (Gustafson, 1993).

Keeping cows out of mud and manure increases their productivity and reduces endoparasitic and foot infections. Current trends and recommendations favor keeping dairy cows on unpaved dirt lots in the southwestern United States and on concrete in the northern United States throughout their productive lifetimes. Concrete floors should have a surface texture that provides good footing but does not cause injury (Albright, 1994, 1995a). The concrete surface should be rough but not abrasive, and the microsurface should be smooth enough to avoid abrading the feet of cattle. Scraping a new concrete surface tends to remove microprojections formed during finishing

Data are limited on the long-term effects of intensive production systems; however, concern has been expressed about the comfort, well-being, behavior, reproduction, and udder, foot, and leg health of cows kept continuously on concrete. As a safeguard, cows should be moved from concrete to dirt lots or pasture, at least during the dry period. An additional advantage is that the rate of detection and duration of estrus are higher for cows on recommended dirt lots or pastures than for cows on concrete (Britt et al., 1986).

Exercise during the dry period does not adversely affect milk production, but does result in cows that are fit. Forced exercise after parturition reduces energy intake and milk production; therefore, forced exercise is not recommended (Lamb et al., 1979).

For recommendations for housing cattle in intensive laboratory environments (e.g., lighting, excreta collection, and metabolism or environmental chambers), refer to Chapter 3: Husbandry, Housing, and Biosecurity.

Area

Between and within breeds, ages, and body conditions, critical dimensions of dairy cattle vary less with weight than with age. Body length and hip width are relatively uniform (±5%) across breeds at weights between 180 and 450 kg (400 and 1,000 lb; ASAE, 1987). More than 94% of the dairy cattle in the United States are Holsteins, and area recommendations for female calves and heifers are usually related to age groupings for Holsteins (Woelfel and Gibson, 1978; Graves and Heinrichs, 1984; Heinrichs et al., 1994; MWPS, 1995). Average normal growth curves relate heart girth and live weight to age (Woelfel and Gibson, 1978; Graves and Heinrichs, 1984; Heinrichs et al., 1994; MWPS, 1995).

The length of individual stalls should be a little longer than the length of the animal, defined as the distance between the pin bones and the front of the shoulders (ASAE, 1987) or between the pin bones and the brisket (Irish and Merrill, 1986). For stanchions and tie stalls, stall width to length ratio should be at least 0.7 (MWPS, 1985). The width of free stalls should be twice the hip width (Irish and Merrill, 1986). These dimensions have been taken into account for the recommendations for Holsteins shown in Tables 7-1 and 7-2.

Dairy cows prefer larger, more comfortable stalls and use free stalls 9 to 14 h daily (Schmisseur et al., 1966; Irish and Martin, 1983). Free-stall systems may be adapted for feeding trials utilizing electronic gates. Free stalls are recommended for dairy cattle used in teaching, extension, and research programs throughout much of the United States. The range of effective dimensions of stalls for mature Holstein cows (Graves, 1977; MWPS, 2000) is presented in Tables 7-1 and 7-2.

Bedding

Resting dairy cattle should have a dry bed. Stalls ordinarily should have bedding to allow for cow comfort and to minimize exposure to dampness or fecal contamination. When handled properly, many fibrous and granular bedding materials may be used (MWPS, 2000), including long or chopped straw, poor-quality hay, sand, sawdust, shavings, and rice hulls. Inorganic bedding materials (sand or ground limestone) provide an environment that is less conducive to the growth of mastitis pathogens. Sand bedding may also keep cows cooler than straw or sawdust. Regional climate differences and diversity of bedding options should be considered when bedding materials are being selected. Bedding should be absorbent, free of toxic chemicals or residues that could injure animals or humans, and of a type not readily eaten by the animals. Bedding rate should be sufficient to keep the animals dry between additions or changes. Any permanent stall surfaces, including rubber mats, should be cushioned with dry bedding (Albright, 1983). Bedding material added on top of the base absorbs moisture and collects manure tracked into the stall, adds resiliency, makes the stall more comfortable, and reduces the potential for injuries (MWPS, 2000).

Bedding mattresses over hard stall bases such as concrete or well-compacted earth can provide a satisfactory cushion. A bedding mattress consists of bedding material compacted to 8 to 10 cm (3 to 4 in) and enclosed in a fabric (heavyweight polypropylene or other similar material). Shredded rubber may be used and is recommended as a mattress filler (Underwood et al., 1995). Small amounts of bedding (chopped straw) on

Table 7-1. Recommended options and sizes[1] for pens and stalls for dairy cattle used in agricultural research and teaching

Component	Option	Size	
Individual calves	Hutches and yard or tether	1.5 to 3 m^2/head	6 to 12 ft^2/head
Until 2 mo [to 91 kg (to 200 lb)]	Bedded pen	2.2 to 3 m^2/head	24 to 32 ft^2/head
Until 7 mo [to 182 kg (to 400 lb)]	Stall[2]	0.6 to 0.8 × 1.5 to 1.8 m^2/head	10 to 15 ft^2/head
Groups[3] of weaned calves	Movable shed (super calf hutch)	2 m^2/head	21 ft^2/head
[182 kg (<400 lb; 3 to 12/group)]	plus yard		
	Inside pen	2.3 to 2.8 m^2/head	25 to 30 ft^2/head
	Bedded pack	3.1 × 4.9 to 6.1 m	10 × 16 to 20 ft
	Scraped alley	3.1 × 2.4 to 3.1 m	10 × 8 to 10 ft
Groups[3] of heifers in pens, 6 to 20/group	With free stalls	(see Table 7-2)	
181 to 454 kg (400 to 1,000 lb)	With bedded pack	8 to 12 m^2/t	4 to 6 ft^2/cwt
34 to 136 kg (75 to 300 lb)		1.5 to 5.6 m^2/head	16 to 60 ft^2/head
		5. to 8 m^2/t	2.5 to 4 ft^2/cwt
	With slatted floor[4]	1.5 to 2.3 m^2/head	16 to 25 ft^2/head
	With counterslope		
	Floors and litter alley	6 to 8 m^2/t	3 to 4 ft^2/cwt
		1.5 to 3 m^2/head	16 to 30 ft^2/head
Dry cows and heifers	Bedded pack and paved alley	8 to 12 m^2/t	4 to 6 ft^2/cwt
[454 kg (>1,000 lb)]		4 to 9 m^2/head	40 to 96 ft^2/head
Maternity or isolation pens (5% of cows)[5]	With bedded nonslip floors	9.3 to 14.9 m^2/head	100 to 160 ft^2/head
		3.1 × 3.1 to 3.7 × 4.3 m	10 × 10 to 12 × 14 ft
Individual mature bulls	Rugged pens	13 to 22.3 m^2/head	140 to 240 f^{t2}/head
		3.1 × 4.3 m	10 × 14 ft or larger
	Tie stalls	1.4 × 2.5 to 2.6 m	54 × 97 to 102 in
		to 1.8 × 360 m	to 72 × 188 in
Milking cows	Free stalls	(see Table 7-2)	
	Tie stalls	(see Table 7-2)	
	Paved lots	9 m^2/head	100 ft^2/head
	Unpaved corrals	46 m^2/head	500 ft^2/head

[1]Sizes exclude access for feeding and cleaning.
[2]Research protocol may require the use of individual stalls for calves.
[3]Different sources use different age groups. Weight variation increases with age.
[4]Space decreases with age. Spacing between slats is 3.18 cm at 169 kg, 3.82 cm at 170 kg, and 4.45 cm at 250 to 500 kg (1.25 in at 374 lb, 1.5 in at 375 lb, and 1.75 in at 550 to 1,100 lb; Woelfel and Gibson, 1978).
[5]In addition to maternity pens, treatment and handling facilities are recommended (Anderson, 1983; Anderson and Bates, 1983; Bates and Anderson, 1983; Graves, 1983; Veenhuisen and Graves, 1994; MWPS, 1995).

top of the mattress keep the surface dry and the cows clean (MWPS, 2000).

Ventilation

Ventilation permeates all aspects of the animal environment (Bickert, 2005). Most often, ventilation is associated with respiratory health of animals: the quality of the air that animals breathe directly influences animal health and disease. Nevertheless, ventilation—directly and indirectly—affects many other aspects of animal health as well. Good ventilation in the lying area of lactating animals helps to keep bedding dry, a factor in favor of good mammary health. Good ventilation along alleys helps to keep walking surfaces dry, a condition that contributes to healthy feet and a reduction in falling accidents. Good ventilation may lead to greater productivity; for example, maintaining air movement in the area of the eating area makes animals more comfortable, which is especially important during hot weather as an aid to maintaining dry matter intake. A comfortable, well-ventilated lying area encourages animals to lie down, an important contribution to many aspects of animal health (rumination, mammary blood supply).

During ventilation, outside air is brought into a barn where it collects moisture, heat, and other contaminants, all produced by the animals. Air is then exhausted to the outside. Ventilation is an air exchange process—contaminated air inside the barn is exchanged for fresh outside air. To determine ventilation rates, we focus on the moisture content of the air, as measured by relative humidity. But moisture is only one aspect; ventilation removes other undesirable contaminants as well.

Ventilation is truly a process of dilution. Air moved through a barn actually serves to dilute the inside air and, very importantly, to dilute all of its components. Dilution reduces concentrations of moisture and heat. Dilution also reduces concentrations of airborne disease organisms, harmful gases and dust, and undesirable odors. The dilution rate of ventilation is often expressed in air changes per unit time. For example, a ventilation rate of 4 air changes per hour implies that the entire volume of the ventilated space (e.g., a barn) is replaced every hour. In fact, some of the air may bypass the occupied zone in the barn, depending upon geometry of the space, the design of diffusers controlling inlet air, and so on. Thus, the effectiveness of ventilation is not often 1.0, but something less, perhaps 0.65.

When ventilation is reduced below recommended levels—usually in a misguided effort to warm the barn using animal heat—less moisture is removed. Sometimes the consequences of the resulting moisture buildup and lack of proper ventilation—usually condensation—are masked by 1) insulating the barn, 2) using a greenhouse effect, 3) providing supplemental heat, or 4) dehumidifying the inside air. For example, adding heat to the air reduces relative humidity, without the need for air exchange. It is quite possible to have substantial quantities of moisture added to the air and, if accompanied by heating of the air, have the relative humidity remain in an acceptable range. Thus, if relative humidity is the only measure of air quality, air quality may be deemed satisfactory. However, even though excess moisture may not be apparent, the reduced dilution does indeed result in increased concentrations of airborne disease organisms, harmful gases and dust, and undesirable odors. If these increases are ignored, animal health problems are inevitable.

Underventilation in winter is one of the most serious threats to the environment of animals. Improper design and improper management of the ventilation may be reasons that wintertime ventilation is lacking, compromising animal health. Problems are most likely during winter, spring, and fall, especially during rainy weather and warmer days coupled with cold nights. Specific recommendations for ventilation system design are available (MWPS, 2000). In general, minimum ventilation is provided by a continuous rate in winter, amounting to at least 4 to 6 air changes per hour. Summer ventilation rates may range up to and above 90 air changes per hour.

Maintaining good air quality is a fundamental aspect of that healthy environment with ventilation providing the key. Through ventilation, the air inside the barn is continually diluted, ensuring that the air the animal breathes has low concentrations of all contaminants that threaten the animal's health.

Housing Types

In colder climates, stanchion and tie-stall barns have served well for herds ranging up to 50 or 60 milk cows. However, stall barns are labor intensive, both for milking and feeding. Comfort or tie stalls are preferred over stanchions. To avoid contamination of the teat and reproductive tract orifices, manure removal must be more regular and thorough when cows are housed in tie stalls. Cow trainers and gutter grates are recommended to ensure cleaner stalls and cows.

Free-stall barns are a type of loose housing with one free stall recommended for each lactating cow. Depending upon provisions for feeding, different groups of cows can be fed differently according to their particular nutritional requirements. This has led to barn arrangements that permit division of milking herds into groups, usually by production.

One free stall is recommended for each lactating cow. The stall base and bedding provide a resilient bed for cow comfort and a clean, dry surface to reduce the incidence of mastitis. Because cows prefer to stand uphill, the stall base should be sloped forward 3 to 4% from rear to front. Commonly used materials for the base include concrete, clay, sand, and stone dust; hardwood planks tend to rot. Rubber tires, if not firmly imbedded, tend to become loose (MWPS, 1995). In an ideal free stall, the stall bed and partition should define the lying position of the cow and accommodate natural lying and rising behavior (McFarland and Gamroth, 1994; MWPS, 2000).

Proper free-stall care includes daily inspection and removal of wet bedding and manure, in addition to adding dry bedding periodically. Neglected free stalls with excessive moisture or accumulations of manure can lead to an increased incidence of mastitis. For stalls with bases that must be replenished such as sand, an upward slope of the base toward the front should be maintained. This upward slope helps position cows more squarely in the stall when lying down, which contributes to cleaner stalls and cleaner cows. Free-stall hardware and other components should be kept in good repair.

Corrals should be scraped as needed and concrete alleys should be scraped or flushed regularly to clean them effectively. Feedbunk areas should be scraped regularly and any leftover feed removed. Shades and corrals should be designed to minimize areas of moisture and mud.

Pastures must be managed to avoid disease transmission. Stocking rates should maximize production per head unless forage supplementation is provided or unless production per unit of pasture area is to be studied. This strategy minimizes the stress that may result from overgrazing and minimizes ingestion of plants from areas immediately surrounding those areas contaminated with excreta, thereby reducing the challenge of potential pathogens and helminth parasites. Some pathogenic microbes may survive more than 6 mo in fecal deposits. Shade should be provided during hot weather.

Special Needs Areas

Cows with special needs are associated with greater risk and thus require special consideration with respect to facilities (Bickert, 2003a):

- Preparturition. Cows that are near the time of calving (2 to 3 wk prepartum) benefit from a clean, dry environment and access to an appropriate dirt lot for exercise. Feeding facilities should be provided to prepare cows for the high-energy ration they will receive upon entering the milking herd. Free-stall housing situated for frequent observation and proximity to the maternity area is a desirable option.

- Maternity. In preparation for calving, cows should be moved to individual pens that are separate from other animals, especially younger calves. The environment should be well ventilated, and the pens should be maintained to be clean, dry, and well bedded. Recommended pen size is 3.7 m × 3.7 m or 3 m × 4.3 m (12 ft × 12 ft or 10 ft × 14 ft). The maternity pen should have a stanchion on one side for cow restraint. A concrete curb between each stall aids sanitation. Deep bedding should be used on concrete floors to prevent cows from slipping. Grooved concrete (e.g., diamond pattern) is also recommended (Albright, 1994, 1995a). Provisions should exist for lifting downer cows. Devices to aid and promote standing include hip lifters (hip clamps), slings (wide belt and hoist), inflatable bags, and warm water flotation systems. Pen location should permit access by a tractor or loader to allow removal of downed cows. All downed cows should be promptly examined by a veterinarian and handled in a humane and appropriate manner. Each pen should be provided with adequate feeding space and fresh, clean water. Depending on local conditions, a calving pen may not be necessary. Cows can calve in a pasture area with lighting situated for observation. A calving pasture should be well sodded and drained, should be large enough to allow cows to move away from others in the group before calving, and should contain an adequate sheltered area. Use of a pasture pen can eliminate footing and bedding problems associated with calving pens.
- Removing calf. Dairy calves are normally removed from their dams as soon as possible following birth. The cow and calf are more difficult to separate after 3 d (Albright, 1987). Therefore, early removal (before 72 h) is recommended (Hopster et al., 1995). To prevent transmission of Johne's disease, follow the National Johne's Education Initiative control program (www.johnesdisease.org; accessed June 16, 2009).
- Postcalving. A cow that has recently calved (from 0 to 7 d postpartum) should be placed in a special area for frequent observation before rejoining the milking herd. Individual feed intake and milk production should be monitored to determine whether the cow is progressing normally. Milk must be withheld from shipment as required by regulations. Free stalls or large, well-bedded pens may be used in this special area. For a larger herd, a special hospital and maternity barn, possibly equipped with a pipeline or portable milker, could house cows in this management category as well as cows that are calving or that have other special needs.
- Treatment. A treatment area in the barn is recommended for confining cows for artificial insemination, pregnancy diagnosis, postpartum examination, sick cow examination, surgery, and for holding sick or injured animals until recovery.
- Dry-off. Cows recently dried off should be separated from the milking herd for feeding purposes. Recommended medical treatments should be performed, and cows should be observed frequently to ensure normal progress.

Lighting

Lighting recommendations for dairy cattle housed in indoor environments are the same as those for beef cattle in intensive environments (see Chapter 6: Beef Cattle).

FEED AND WATER

Except as necessary for a particular research or teaching protocol, dairy cattle should be fed diets that have been formulated to meet their needs for maintenance, growth, production, and reproduction (NRC, 2001; see Chapter 2: Agricultural Animal Health Care). Feed ingredients and finished feeds should be wholesome, carefully mixed, and stored and delivered to the cattle to minimize contamination or spoilage of feeds. To ensure freshness, feeds that are not consumed should be removed daily from feeders and mangers, especially high-moisture feeds such as silage. Feed should be far enough from waterers to minimize wetting of feed.

Space should be adequate for feed and water. Feeders or mangers should be designed with smooth surfaces for easy cleaning and increased feed consumption. The recommended linear space per cow at the feed bunk is 61 to 90 cm (2 to 2.5 ft), which should allow every animal uninterrupted feeding (Malloy and Olson, 1994). Feeder design should permit a natural head-down grazing posture to promote intake, improve digestive function, facilitate normal tooth wear, and decrease feed-wasting behavior (Albright, 1993a). At least one water space or 61 cm (2 ft) of tank perimeter should be provided for every 15 to 20 cows in a group. At least 2 watering locations should be provided for each group of cows. Each cow in tie stalls and stanchions should have its own water bowl or drinking cup (Andersson, 1985; MWPS, 1995).

All calves should consume colostrum in amounts of 8 to 10% of body weight (or 2 to 3 L) within 4 to 5 h after birth always before milk is fed, and another 2 to 3 L within 24 h of birth for a 36- to 45-kg (80- to 100-lb) calf (Stott et al., 1979; Stott and Fellah, 1983; Hunt, 1990; Pritchett et al., 1991; Mechor et al., 1992).

Colostrum should be monitored with a colostrometer for quality (protein and antibody content). Mixed high-quality colostrum pooled from several cows can be better than low-quality colostrum from a particular dam. However, it is currently suggested that individual cows be tested for colostrum quality for the use of their colostrum alone with avoidance of colostrum from known disease-carrying cows (e.g., those with Johne's disease, mycoplasma, or bovine viral diarrhea; Stabel, 2009). Proper handling and storage of the colostrum is essential. Until calves can consume dry feed at an adequate rate, they should be fed liquid feed in amounts sufficient to provide needed nutrients at a rate up to 20% of body weight at birth per day until weaned. Water should be given at times other than when milk or milk replacer is fed to avoid possible interference with curd formation. However, this is not a problem with most milk replacers currently fed. Fresh water should be provided at all times. Replenishment of water should follow milk or milk feeding by at least 15 minutes (Davis and Drackley, 1998). Calves being raised as replacement heifers or for beef should be fed enough dry feed with sufficient fiber preweaning to stimulate normal rumen development (McGavin and Morrill, 1976). Calf research guidelines have been reported that permit uniformity in measuring and reporting experimental data (Larson et al., 1977).

Water intake affects consumption of dry matter (Kertz et al., 1984; Milam et al., 1986) and is itself influenced by individual behavior, breed, production rate, type and amount of feed consumed, water temperature, environmental temperature, atmospheric vapor pressure, water quality, and physical facility arrangement (Atkeson and Warren, 1934; Murphy et al., 1983; Andersson, 1985; Lanham et al., 1986). Nonlactating cows consume 3 to 15 kg of water/kg of dry matter consumed, depending on environmental temperature. Lactating cows consume 2 to 3 kg of water/kg of milk produced plus that required for maintenance (Little and Shaw, 1978).

Water should be available at all times (NRC, 2001); it should be checked daily for cleanliness and monitored regularly to ensure that it is free of contaminants that could potentially put zoonotic agents into the human food chain (Johnston et al., 1986). Water sources should be readily accessible to all stock. Underfoot surroundings in watering areas should be dry and firm. Cattle should not be able to wade in drinking water.

HUSBANDRY

Social Environment

Dairy cattle are social animals that exist within a herd structure and follow a leader (e.g., to and from the pasture or milking parlor). Cows exhibit wide differences in temperament, and their behavior is determined by inheritance, physiology, prior experience, and training. Cattle under duress may bellow, butt, or kick; however, cows are normally quiet and thrive on gentle treatment by handlers. Cows learn to discriminate among people and react positively to pleasant handling. Aversive handling leads to more incidents during handling and transport for calves than positive handling (Lensink et al., 2001). Similarly, heifers and cows exposed to aversive handling took longer to traverse and more force to move than those handled more gently (Pajor et al., 2000). Although the presence of an aversive handler reduced kicking during udder preparation, residual milk was 70% greater than for the control milkings (Rushen et al., 1999a). Cows have higher milk yields if handlers touch, talk to, and interact with them frequently (Albright and Grandin, 1993; Seabrook, 1994).

Cows should have visual contact with one another and with animal care personnel. Handling procedures are more stressful for isolated cattle; therefore, attempts should be made to have several cows together during medical treatment, artificial insemination, or when cows are being moved from one group to another (Whittlestone et al., 1970; Arave et al., 1974). This was verified by increased heart rate, hypothalamic-pituitary-adrenocortical axis activity, and vocalizations. Pain sensitivity is reduced during isolation, suggesting a stress-induced analgesia (Rushen et al., 1999b). Care should be taken to minimize the negative impact of moving cows to new groups by avoiding frequent regrouping and by always moving more than one animal at a time to a new group. The use of a trainer cow can have a positive impact on adjustment to feedlot environments where many heifers are raised (Loerch and Fluharty, 2000). However, dairy calves had few indicators that repeated regrouping and relocations stressed calves. Aggression was rare and the calves seemed to habituate to the repeated mixing (Veissier et al., 2001). Calves from larger groups after weaning (16 compared with 4) had fewer incidences of displacement of other calves from the feed barrier, were more active, and had more positive interactions with familiar calves (Færevik et al., 2007). Calves, like cows, prefer familiar calves to unfamiliar calves during stressful situations, and a familiar companion calf improved cows' reaction to separation (Færevik et al., 2005). Social status can affect health issues such as lameness (Galindo and Broom, 2000). Low-ranking cows spent more time standing and standing half in cubicles (perching) than did middle- and high-ranking cows. Standing half in cubicles correlated positively with the number of soft tissue lesions related to lameness.

Dairy cattle have traditionally been kept in groups of 40 to 100 cows (Albright, 1978), although specific research protocols may require smaller or larger group sizes. Variation in group size—small (50 to 99), medium (100 to 500), and large (500 or more)—does not cause a problem per se. Expansion to a larger herd size, however, can affect management decisions because overcrowding with an insufficient number of headlocks or inadequate manger space per cow, irregular or infrequent feeding, and excessive walking distance to and from the milking parlor have a greater impact on behavior and well-being than does group size (Albright, 1995b).

Cattle of all ages are gregarious. Socially isolated cattle show clear signs of stress: increased heart rate, vocalization, defecation/urination, and cortisol levels (Rushen et al., 1999a; Herskin et al., 2007). In addition, there are benefits of housing cattle together. For example, pairs of calves are more likely to play than isolated calves, a behavior thought to be associated with positive welfare (Jensen, 2004). Young calves should be kept in groups from 2 to 7 animals in order for animals to benefit from social contact, but larger groupings are associated with health problems and morbidity (Losinger and Heinrichs, 1997; Svensson et al., 2003). Management of resources is an important part of reducing aggression and other problems, such as cross sucking, in groups of animals. Adult dairy cattle should have 1 freestall/cow to reduce competition (Fregonesi et al., 2007). Similarly, dairy cattle with more space at the feedbunk (1.0 vs. 0.5 m) engage in fewer aggressive interactions (DeVries et al., 2004), and the reduction of competitive behavior associated with more feeder space is particularly marked in post-and-rail feeder design (Huzzey et al., 2006).

Cross sucking in calves is an undesirable behavior performed in groups. Calves are typically fed 10% body weight during the milk-fed period and there is clear evidence that this feeding level is insufficient (Jasper and Weary, 2002; Khan et al., 2007). A combination of slower milk flow, hay feeding, and access to a nonnutritive artificial teat are also recommended to reduce cross sucking (de Passillé, 2001). Providing additional objects for oral manipulation, such as tires, has also been shown to reduce other problems such as stereotypic tongue rolling in calves (Veissier et al., 1998).

Restraint and Handling

Vaccination schedules that are appropriate for the location and dynamics of the individual herd should be established with the advice of the attending veterinarian. Certain dairy cattle behaviors (e.g., aggression and kicking) put at risk the health and well-being of herdmates as well as the humans handling the cattle. These behaviors can be reduced or modified by implementing principles of low-stress handling and restraint (Grandin 1993) that include appropriate movement of people, well-designed facilities, optimal lighting, nonslip flooring, and smooth, quiet restraint devices. Stanchions, head gates, and squeeze chutes can be modified to function optimally, but acclimation and positive reinforcement by individuals trained in low-stress handling can minimize the need for additional restraint by halters, rope, tail hold, and nose tongs. Hobbles and casting ropes should be used selectively and only when necessary. Chemical sedation is always preferable to excessive use of force or application of electrical prods.

Information about calving management is given by Albright and Grandin (1993). First-calf heifers should be bred to calving-ease bulls and be of appropriate stature and body condition to minimize the chances of dystocia or the need for calving assistance. Optimal calving conditions in a clean, quiet environment with employees appropriately trained to follow calving protocols will result in more live calves and fewer calving injuries and illness. Calving injuries should be assessed immediately so that appropriate footing is provided and proper treatment is implemented. Cows that are unable to stand should be moved to a soft-bedded pack and examined by a veterinarian within 2 to 4 h of calving.

Calves require special handling and care from the time they are born. Colostrum should be fed or ingested within the first 5 h after birth always before milk is fed. Between 1.89 L (2 quarts; for beef-breed calves) and 3.79 L (4 quarts; for most dairy calves) of colostrum are necessary to impart adequate immunity to the calf. In the absence of colostrum, a colostrum replacement product that delivers at least 125 g of immunoglobulin should be given by bottle, bucket, or tube feeder. Colostrum is rich in nutrients and provides the calf with vital immunoglobulins and other important immune factors. Clean navels can be dipped in a dilute chlorhexidine solution (1 part of a 2% chlorhexidine solution mixed in 4 parts water) as soon as possible after birth. Good nutrition as supplied by a combination of milk (or milk replacer), starter grain, and fresh water along with proper handling and close monitoring starts a calf on its way toward a healthy life.

STANDARD AGRICULTURAL PRACTICES

All animals should be individually identified (see Chapter 2: Agricultural Animal Health Care). Heifer calves should have supernumerary teats removed at an early age (Moeller, 1981). Removal may be performed in the first 3 mo of life with a scalpel or sharp scissors. Older calves and heifers close to calving that have supernumerary teats should be examined by a qualified person. The removal of extra teats at this advanced age is necessary if they will later disrupt the milking process or be at risk of becoming infected. If so, they can be removed with proper restraint and use of appropriate anesthesia by a qualified and trained person. Milking procedures should follow National Mastitis Council guidelines (NMC, 2007). Routine breeding programs should include housing and handling facilities that allow for effective implementation of artificial insemination programs.

Castration may be performed on male calves (see Chapter 6: Beef Cattle).

Disbudding and Dehorning

A review of horn anatomy and growth and dehorning and disbudding of cattle was provided by the AVMA (2007b). The AVMA also provides guidance on use of sedation, anesthesia, and analgesia and alternatives to horn removal (AVMA, 2007b). The AVMA policy on dehorning/disbudding should be followed (AVMA, 2008).

Calves should be observed closely for 1 to 2 h following dehorning. No food or water should be offered until the sedation is completely worn off or reversed. Persistence of a depressed attitude, head-pressing, or an abnormal head tilt for more than 2 h should result in a complete examination.

Tail Docking

The bovine tail has several physiological and behavioral functions including dissipation of heat, and facilitation of visual communication among cattle and with human caretakers; the tail often serves as a primary mechanism of fly control (Stull et al., 2002). Removal of the lower portion of a cow's tail is commonly referred to as "tail docking" and the use of tail docking as a routine dairy farm management tool apparently originated in New Zealand. New Zealand farmers responding to a 1999 survey believed removal of tails resulted in faster milking, reduced risks to the operator, and reduced rates of mastitis (Barnett et al., 1999). Similar unsubstantiated claims have been made for the US dairy industry (Johnson, 1991). Several European countries, some Australian states, and California have prohibited tail docking. Both the Canadian and American veterinary medical associations have policy statements that oppose the practice of tail docking for routine management of dairy cattle (AVMA, 2006). The policy statement of the American Association of Bovine Practitioners (**AABP**) indicates that scientific evidence to support tail docking is lacking and recommends that "if it is deemed necessary for proper care and management of production animals in certain conditions, veterinarians should counsel clients on proper procedures, benefits, and risks (AABP, 2005). Scientific studies have been performed to evaluate both the potentially negative and positive aspects of tail docking. Important welfare issues that have been evaluated have included pain caused by tail docking, changes in fly avoidance behavior, immune responses, and changes in levels of circulating plasma cortisol (Petrie et al., 1996; Eicher et al., 2000, 2001, 2006; Eicher and Dailey, 2002; Schreiner and Ruegg, 2002a; Tom et al., 2002). Experiments that have been performed on both calves and preparturient heifers have consistently concluded that the process of tail docking does not induce significant acute or chronic changes in plasma cortisol or other selected physiological measures (Matthews et al., 1995; Petrie et al., 1996; Eicher et al., 2000; Schreiner and Ruegg, 2002a; Tom et al., 2002). Modest changes in general behavior of calves that have been docked using rubber rings or cautery irons have been reported but these changes have not been associated with significant differences in normal feeding, ruminating, or grooming behaviors (Petrie et al., 1995; Schreiner and Ruegg, 2002a; Tom et al., 2002). Likewise, few significant differences in general behavior of docked preparturient heifers have been noted (Eicher et al., 2000; Schreiner and Ruegg, 2002a). However, greater changes have been observed in tail surface temperatures of docked heifers compared with heifers with intact tails, indicating that heifers may experience chronic pain similar to the phantom pain reported by human amputees (Eicher et al., 2006).

Research has demonstrated that tail-docked heifers flick their tails more often and are forced to use alternative behaviors such as rear leg stomps, feed tossing, and head turning to try to rid themselves of flies (Ladewig and Matthews, 1992; Phipps et al., 1995; Eicher et al., 2001). More flies settle on tail-docked cows than on intact cows, and the proportion of flies settling on the rear of the cow increases as tail length decreases (Matthews et al., 1995). In another study (Eicher et al., 2001), there were no significant differences in the numbers of stable flies found on the front legs of cows but docked cows had nearly twice as many flies on their rear legs compared with those with intact tails . Fly avoidance behaviors (such as feed tossing) were increased in the docked animals, whereas tail swinging was increased in the control animals. Foot stamping was identified only in docked animals and, overall, fly numbers and fly avoidance behaviors were increased in docked animals (Eicher et al., 2001). Researchers have been unable to identify improvements in udder health or udder cleanliness for animals in commercial herds that have docked tails (Tucker et al., 2001; Schreiner and Ruegg, 2002b). In one study, the effect of tail docking on cow cleanliness and somatic cell counts (**SCC**) was evaluated over an 8-wk period for lactating cows that were housed in a free-stall facility (Tucker et al., 2001). Standardized cleanliness scores obtained from the rump, midline of the back, or rear udder were not significantly different between docked and intact animals nor was there any significant difference in SCC or the number of teats containing obvious debris (Tucker et al., 2001). In another study, SCC, occurrence of intramammary infections (**IMI**), and udder and leg hygiene scores were evaluated over an 8-mo period for lactating dairy cows (n = 1,250) that had been blocked by farm (n = 8) and randomly allocated to tail-docked or control groups (Schreiner and Ruegg, 2002b). No significant differences were found in SCC or udder and leg hygiene scores. The prevalence of contagious, environmental, and minor pathogens was not significantly different between cows with docked or intact tails. Although current studies do not indicate that the process of tail docking modifies physiological indicators of stress, several studies have documented changes in fly avoidance behavior and recent research has suggested that docked tails have enhanced sensitivity to heat. No benefits to cattle welfare have been associated with tail docking. The routine use of tail docking in research or teaching herds should be discouraged, and alternatives to tail docking (such as trimming switches with clippers or fastening the switch out of the way) are recommended when appropriate. Any use of tail docking, other than for medical reasons, should be reviewed and approved by the IACUC.

Foot Care

Lameness in dairy cattle is a major source of economic loss to the farmer and a serious cause of pain and discomfort to the cow. It is perhaps the most important condition affecting the welfare of cows on dairy farms (Cook, 2003; Espejo et al., 2006; Vermunt, 2007). Lame cows suffer lowered milk production and reduced fertility, and are culled at 2 to 4 times the rate of healthy control cows (Cook et al., 2004). The pain associated with lameness results in changes in the animal's gait that include

1. Arching of the back (in cases of rear limb lameness);
2. Shortening of the stride length on the affected limb (as the cow tries to reduce the time spent weight bearing on the painful limb);
3. Sinking of the dew claws on the unaffected contralateral limb (as the cow transfers weight to the unaffected side);
4. Head bob in a vertical plane (the head is raised as the painful foot strikes the ground, especially with front limb lameness and may be reversed with rear limb lameness);
5. Reduction in walking speed, and frequent stops; and
6. Swinging the affected limb in or out depending on the location of the painful lesion.

These alterations can be used to provide a locomotion score for each animal, and the most commonly used system in North America utilizes a 5-point system of scoring where 1 is nonlame and 5 is severely lame. Herd workers should be taught how to score locomotion so that they can identify cows with scores >2 for treatment by an attending veterinarian or hoof-trimmer (Bicalho et al., 2007).

Around 85% of lameness in dairy cattle is associated with lesions in the rear feet, particularly the outer claw, because of the overgrowth of horn resulting from the redistribution of weight as the cow walks on hard concrete surfaces, with a large udder occupying the space between her rear legs. This overgrowth of the outer claw may be removed and the weight transferred equally between the inner and outer claw by regular hoof-trimming. Trimming to restore a normal toe length along the dorsal hoof wall of around 75 mm (3 in) for mature Holstein cattle, combined with balancing weight between the inner and outer claw, lasts around 4 mo on average. Therefore, it is recommended that cattle be trimmed at 6-mo intervals, typically at the time of dry off and in mid-lactation around 90 to 150 d in milk. Some cows with pre-existing hoof disease may require attention more frequently (every 2–4 mo).

Hoof lesions causing lameness may be broadly classified into 2 groups: infectious and claw horn. Infectious lesions include digital dermatitis (heel warts), interdigital phlegmon (foot rot), and heel horn erosion. These lesions are associated with poor feet and leg hygiene and are a particular problem in free-stall environments, where the cow is exposed to alleyways contaminated with wet manure when she is not occupying a stall. Putative agents such as several species of *Treponema* and *Fusobacterium necrophorum* are involved in the pathogenesis of these conditions, but hydropic maceration of the skin of the interdigital space appears to be a prerequisite for the development of disease (Berry, 2006). Infectious causes of lameness are controlled by improving leg hygiene by removing manure from the walkways and by the use of a topical antibacterial administered either directly to the lesion by a hand-held spray or via a footbath. The frequency of foot bathing is dependent on the degree of manure contamination of the cows, and a variety of chemicals are available for use, such as copper sulfate, zinc sulfate, and formalin. Use of any of these chemicals should be done under veterinary direction.

Claw horn lesions include sole hemorrhage, sole ulcer, toe and heel ulcer, and white line disease (including hemorrhage, fissure, and abscess). These are clinical signs on the surface of the claw that represent the result of several possible causative pathways. Sinking of the third phalanx within the claw horn capsule, due to a breakdown in the connective tissue of the suspensory apparatus, may be caused by hormonal changes at calving time and nutritional events such as subacute ruminal acidosis (Cook et al., 2004). Sinking of the third phalanx compresses the corium below, interrupting the flow of blood and nutrients to the cells responsible for horn growth. As a result, a defect develops that becomes apparent several months later as the sole horn continues to grow.

Excessive removal of sole horn, either through poor hoof trimming or due to excessive wear from walking long distances on rough concrete will also contribute to lesion development. Flooring surfaces should be nonslip, avoid excessive trauma to the claw surface and be dry. Concrete should be grooved to improve traction; a pattern that utilizes parallel grooves 3/4 inch wide and deep, spaced 3 inches on center appears to provide a good compromise between sufficient traction to reduce injury while limiting the amount of wear. For transfer lanes between milking centers and the living accommodation, a 1-m (30-inch)-wide strip of rubber flooring has been used successfully to reduce trauma and wear, and rubber flooring has been used in parlor holding areas to provide cushion for cows that have to stand for long periods of time (Cook and Nordlund, 2009).

The severity of the claw horn lesions that develop is influenced by the time spent standing each day, which results in increased loading of the claw and increased compression of the tissues below the third phalanx. Time spent standing may be increased by 1) poor stall designs that fail to provide surface cushion, room to lunge, and sufficient resting area; 2) overstocking—providing fewer usable stalls than there are cows in a pen; 3) excessively prolonged milking times (>45 min per milking); 4) time spent locked up away from the stalls for management tasks (>2 h); and 5) heat stress—cows may stand more in an attempt to cool off.

In addition, lame cows struggle to use stalls with hard surfaces because the act of rising and lying down becomes more challenging due to foot pain (Cook and Nordlund, 2009). These cows stand more in the stall and fail to gain adequate rest for lesion healing. For this reason, deep sand-bedded stalls provide the gold standard in cow comfort. If sand stalls are unavailable, lame cows should be treated and returned to a bedded pack area for rest and recuperation until normal ambulation returns.

Failure to identify a claw horn lesion early in its course may result in deep digital sepsis. This is a complication caused by infection of the deeper structures of the claw, including the distal interphalangeal joint and tendon sheaths. Such animals are usually severely lame and require euthanasia or extensive surgery (requiring months for recovery). Seeking veterinary assistance is recommended for individual cows that show signs of lameness or if a significant lameness issue exists for the herd.

ENVIRONMENTAL ENRICHMENT

Refer to Chapter 4: Environmental Enrichment for information on enrichment of dairy cattle environments.

HANDLING AND TRANSPORTATION

Refer to Chapter 5: Animal Handling and Transport for information on handling and transportation of dairy cattle.

SPECIAL CONSIDERATIONS

Milking Machine and Udder Sanitation

The milking facility should have a program for regular maintenance of milking machines and follow the recommended mastitis control program of the National Mastitis Council (NMC, 2007). Appropriate equipment and competent personnel should be available for milking. Personnel responsible for milking should receive ongoing training about proper milking procedures as the frequency of training has been associated with adequacy of milking performance (Rodrigues et al., 2005). Animal care facilities should be designed and operated to standards meeting or exceeding those of grade A dairies as defined in the Pasteurized Milk Ordinance (FDA, 2004). Areas where milking takes place (whether in a barn or milking parlor), must be designed and constructed in accordance with the 3-A Sanitary Standards Inc. (2009) Accepted Practices. Cows should be maintained in housing areas that provide for adequate hygiene to ensure that udders are visibly clean. Cows should be milked on a regular schedule that is appropriate for the goals of the herd or specific research project. Written operating procedures should be established to control potential contamination of milk with antibiotics or other pharmaceutical agents. Antimicrobial treatments should be administered based on approved defined protocols. All extra-label treatments must be administered under the supervision of a veterinarian that has an appropriate veterinary-client-parent relationship. Milking machine and udder sanitation are vital to an effective preventive program against mastitis and follow guidelines as established by the NMC (1993). Care should be used to minimize the excessive use of water before and during udder preparation. Emphasis should be placed on ensuring that cows enter the milking parlor with clean, dry teats. Udders, especially teat ends, should be clean and dry when teat cups are applied for milking. The removal of foremilk ("forestripping") before teat disinfection is encouraged as a means to detect mild cases of clinical mastitis. Teat sanitation, predipping, and wiping immediately before machine attachment reduce udder infection caused by environmental pathogens (Bushnell, 1984; Pankey et al., 1987; Galton et al., 1988; Pankey, 1992; Malloy and Olson, 1994; Reneau et al., 1994). Postmilking disinfection of teats is an essential management practice that greatly reduces the incidence of mastitis (Neave et al., 1969; Philpot et al., 1978a,b; Philpot and Pankey, 1978; Pankey, 1992). Milkers handling cows should pay meticulous attention to their own personal hygiene and wash their hands thoroughly before milking and frequently during milking. The use of clean nitrile or latex gloves during milking is highly encouraged to prevent contamination of the udder. Cows with subclinical cases of contagious mastitis should be milked last to reduce the spread of mastitis throughout the herd. Udder hair removal is recommended as a means to improve milking hygiene and udder health. Cleaning of milk handling equipment is accomplished by a combination of chemical, thermal and physical processes and cleaning regimens should be designed to meet appropriate regulatory standards. Recommended cleaning and sanitizing practices are a balance between the cleaning temperatures, cleaning chemical concentration, contact time and mechanical action (Reinemann et al., 2000). Effective cleaning programs for milking machines include use of hot water (typically between 38 and 55°C); use of disinfectant solutions and other chemical agents effective for removing mineral, milk fat, and protein deposits from equipment between milkings; disinfection of teat cups between cows; and flushing of teat cups with warm water, cold water, boiling water, or chemical disinfectant solution. The most common routine in the United States is a combination of prerinse, alkaline detergent, acid rinse (frequency depending on water hardness), and premilking sanitize. Very small herds (<30 cows) may utilize manual cleaning and disinfecting that involves hand-cleaning of some or all of the milk harvesting and storage equipment. Small to medium herds (30 to 500 cows) commonly use automatic washing equipment. This equipment will automatically mix the chemicals with the appropriate water volume and temperature and circulate these solutions through the milking machine. On large farms (1,000 cows or more), an attendant may be present to mix chemical solutions and operate valves for circulation. The effectiveness of milking system cleaning can be evaluated by examination of standard plate counts and laboratory pasteurized counts performed on bulk tank milk samples.

Stray Voltage

The term stray voltage describes a special case of voltage that develops on grounded metal objects on farms. If this voltage reaches sufficient levels, animals coming into contact with grounded devices may receive a mild electrical shock that can cause a behavioral response. At voltage levels that are just perceptible to the animal, behaviors indicative of perception such as flinches may result, with little change in normal routines.

Studies by numerous independent research groups in several countries are in agreement that the most sensitive cows (<1%) begin to react to 50 or 60 Hz electrical current of 2 mA (measured as the root mean square average; rms) applied from muzzle to hooves or from hoof to hoof (Lefcourt, 1991; Reinemann, 2005). This corresponds to a contact voltage level of about 1 V (50 or 60 Hz, rms). As the voltage and current is increased, a greater percentage of cows will react with behavioral responses becoming more pronounced. Numerous studies have documented avoidance behaviors at levels above the first reaction threshold. The median avoidance threshold for 50 or 60 Hz current flowing through a cow is about 8 mA (4 to 8 V, rms). Even when the threshold is exceeded not all cows would be expected to show a behavioral response but as the voltage increases, signs in a herd would be expected to be more widespread and uniform.

The scientific evidence strongly suggests there is no relationship between behavioral responses to stray voltage and physiological or hormonal responses. There is no apparent relationship among behavioral modifications, milk production, and animal health. The only studies that have documented adverse effects of voltage and current on cows had both sufficient current applied to cause aversion and forced exposures (animals could not eat or drink without being exposed to voltage/current). It is typical for voltage levels to vary considerably at different locations on a farm. Decreased water and(or) feed intake or undesired behaviors will result only if current levels are sufficient to produce aversion at locations that are critical to daily animal activity. These locations include feeders, waterers, and milking areas. Controlled research has shown that if an aversive voltage was administered to a water bowl once per second, water intake was reduced. However, when the same voltage was applied once every 10 min and once per day, no reduction in water intake was observed. If an aversive current occurs only a few times per day, it is not likely to have an adverse effect on cow behavior. The more often an aversive voltage occurs in areas critical to cows' normal feeding, drinking, or resting, the more likely it is to affect cows.

No one sign is pathognomonic; a variety of signs has been reported in cows exposed to different levels of voltage. Documented signs are behavioral changes and decreased drinks of water per day and length of time per drink (Merck, 2004). The amount of water consumed may not be affected even when behavioral modification occurs. Intermittent periods of poor performance, poor milk letdown, and incomplete or uneven milk-out, abnormal behavior during milking, increased milking time, refusal of feed or water, increased SCC in milk, and increased mastitis are signs often attributed by farmers to stray voltage; however, none of these signs were evident in numerous controlled studies. These signs are often caused by other factors such as abusive cow handling, faulty milking machine, poor milking techniques and hygiene, and nutritional deficiencies. Therefore, animal behavior or other symptoms cannot be used to diagnose stray voltage problems. The only way to determine if stray voltage is a potential cause of abnormal behaviors or poor performance is to perform electrical testing as discussed below. A thorough investigation of the entire production unit should be conducted to determine other sources of problems.

Electrical systems should comply with wiring codes and standards at all times to protect both animals and people. Whenever suggestive signs cannot be attributed to other causes, measurements should be taken to determine if a voltage potential exists, and the results recorded for future comparisons. A diagnostic confirmation of stray voltage must include a competent electrical measurement indicating at least 2 to 4 V (50 or 60 Hz, rms) between 2 points that a cow might contact, with some cows should exhibiting avoidance behaviors at this location (Lefcourt, 1991). Voltage levels may need to be monitored at different times of the day and on different days because the threshold level may be exceeded intermittently. All voltage readings should be made with a 500 to 1,000 Ω resistor across the 2 measuring leads to the cow contact points in addition to open circuit measurements. Readings without the use of a shunt resistor are meaningless. Although the resis-

Table 7-2. Recommended size[1] of free stalls as related to weights of female dairy cattle used in agricultural research and teaching

Target weight	Approximate age[2] (mo)	Free stall[3]	Tie stall[3]
118 kg (260 lb)	4	61 × 122 cm (24 × 48 in)[4]	NI[5]
182 kg (400 lb)	6	69 × 122 cm (27 × 48 in)	NI
236 kg (520 lb)	8	76 × 137 to 152 cm (30 × 54 to 60 in)	NI
327 kg (720 lb)	12	86 to 91 × 152 to 168 cm (34 to 36 × 60 to 66 in)	NI
377 kg (830 lb)	16	91 to 107 × 168 to 198 cm (36 to 42 × 66 to 78 in)	NI
454 kg (1,000 lb)	20	99 × 183 cm (39 × 72 in)	122 × 152 to 175 cm (48 × 60 to 69 in)
500 kg (1,100 lb)	24	107 × 198 to 213 cm (42 × 78 to 84 in)	122 × 160 to 175 cm (48 × 63 to 69 in)
545 kg (1,200 lb)	26	114 × 208 to 213 cm (45 × 82 to 84 in)	122 × 168 to 175 cm (48 × 66 to 69 in)
636 kg (1,400 lb)	48	122 × 213 to 218 cm (48 × 84 to 86 in)	137 × 183 cm (54 × 72 in)
727 kg (1,600 lb)	60	122 × 229 cm (48 × 90 in)	152 × 183 to 198 cm (60 × 72 to 78 in)

[1]Sizes are generally larger from midwestern sources than northeastern sources.

[2]Age of Holstein or Brown Swiss for target weights.

[3]Measurements are given as stall width times stall length. Length of stall is for the side-lunge free stall. For forward-lunge free stalls, add 30 to 45 cm (12 to 18 in) (MWPS, 1995). When brisket boards are in use, the stall bed from curb to brisket board should be 168 cm (66 in).

[4]Free stalls are not recommended for calves <4 mo (Graves and Heinrichs, 1984) or 5 mo of age (Woelfel and Gibson, 1978; MWPS, 1995).

[5]NI = not included in recommendations for dairy heifers (Woelfel and Gibson, 1978; Graves and Heinrichs, 1984; MWPS, 1985; Heinrichs and Hargrove, 1987).

tance of cow and human tissues is similar, the contact resistance is generally lower for cows than for humans, particularly if cows are in a wet environment. The resistance of a cow's body plus the contact resistance with the floor is commonly estimated as 500 Ω. This is a reasonable value for a cow standing on a wet floor. Cows standing on a dry surface will typically produce 1,000 Ω resistance or higher. Cows standing or lying on dry bedding will have a resistance many times higher than this. The resistance of a human can be as low as 1,000 Ω for wet hand-foot contact to >10,000 Ω for dry hand-foot contact. The contact voltage to produce sensation can therefore be higher for humans than for cows, depending on the conditions of the contact points. If more than 1 V (60 Hz, rms) is detected at the cow contact points, it is advisable to have a qualified electrician or the local power supplier evaluate the situation.

Bulls

The feeding (NRC, 1989) and watering (NRC, 2001) of growing and mature bulls should meet requirements of the National Research Council. Bulls should be housed in clean, well-lit, and ventilated buildings or outside in facilities that protect them from inclement conditions and allow them to remain clean and dry. Young bulls kept in small and uniform groups should be observed carefully as they mature to make certain that one or more individuals are not injured. A panel can be installed in the center of group-housing pens to allow subordinate bulls to escape aggressive behavior of dominant pen mates. Aggressive behavior increases with age, and group housing should be discontinued by around 3 yr of age. Smaller or subordinate bulls should be removed from the group, and a bull removed from a group for over a few hours should never be returned to the group. Visual and vocal social interactions with other bulls may be stressful. Space requirements for bulls are listed in Table 7-1.

The safety of humans and animals is the chief concern underlying bull management practices. By virtue of their size and disposition, bulls may be considered as one of the most dangerous domestic animals. Management procedures should be designed to protect human safety and to provide for bull welfare. Electroejaculation of bulls is sometimes necessary and should be performed by a qualified person using equipment that functions properly and is in good repair. A program of annual self-regulation should be followed for 1) semen identification and sire health auditing service and 2) minimum requirements for health of bulls producing semen for artificial insemination (Mitchell, 1992; Certified Semen Services, 2002).

EUTHANASIA

When necessary, euthanasia should be performed by trained personnel using acceptable methods established by the AVMA (2007a). The approved methods for cattle are further discussed in Chapter 2: Agricultural Animal Health Care.

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Chapter 8: Horses

Most horses are used for athletic competitions, companionship, or pleasure, but they also serve in a variety of agricultural and biomedical endeavors. Equine animals (horses, ponies, donkeys, and mules) are still commonly used as draft animals for plowing and transportation worldwide, especially by local communities (e.g., Amish) in the United States and among small-scale farmers in developing countries. Ranch horses are commonly used on cattle ranches and feedlots. Donkeys may be used to protect sheep and goats from predators while on pasture, and the biomedical industry uses equine animals, usually horses, for the production of antivenom serum, antibodies, and pharmaceutical products. For example, estrogens are extracted from pregnant mares' urine and used in the production of hormone replacement therapy for menopausal women.

Horses are commonly used in therapeutic riding programs for physically and mentally challenged people (Kaiser et al., 2006). In addition to research studies using equine animals to investigate questions pertaining specifically to this species, horses are used as models for human exercise physiology and aging (Malinowski et al., 2006; Gordon et al., 2007). The natural occurrence of metabolic disorders such as insulin resistance in horses mimic similar disorders in humans such that horses are used for research on the mechanisms and treatments of these disorders with human applications in mind (Hodavance et al., 2007). Whether horses are used for pleasure, work, teaching, research, or biomedical purposes, an appropriate and comprehensive level of animal care should be provided and implemented with all protocols.

FACILITIES AND ENVIRONMENT

Indoor Environment

Dimensions of indoor occupancy should be sufficient for a horse to make normal postural adjustments at will, unless the approved protocol requires otherwise. A reasonable area allowance in m^2 for a single horse is 2 to 2.5 times the height of the horse (at the withers) squared (Zeeb, 1981; Raabymagle and Ladewig, 2006), which permits essential movements, including lying down in sternal or lateral recumbency. Although horses can engage in slow-wave sleep while standing, rapid eye movement (**REM**) sleep occurs only when the horse is recumbent (Dallaire and Ruckebusch, 1974; Ruckebusch, 1975). Although the exact function and requirement needs of REM sleep may be unclear, the opportunity and space to experience REM sleep while in a recumbent position may be a consideration for suitable housing of horses.

Box stalls should be large enough to permit the horse to lie down, stand up, turn around, and roll (Table 8-1). A 3.7- × 3.7-m (12- × 12-ft) box stall should accommodate most light horse breeds. The recommended minimum area, including dimensions, for straight or tie stalls (including space for the manger) is shown in Table 8-1. General guidelines for metabolism stalls are given in Chapter 3: Husbandry, Housing, and Biosecurity.

Stall doors should be wide enough to permit the horse to safely enter and leave its stall comfortably. Stall doors should be either solid or made of material in which the horse cannot become entangled or injured. Stall doors may be sliding, hinged, or divided (Dutch). Divided doors allow the horse to have, in effect, a larger stall when it extends its head out, whereas closing of the top door will limit the visual field of the horse. Care must be taken when Dutch doors or stall guards are used so that the horse cannot reach light switches, electrical cords, or electrical outlets. Hinged or divided doors should be secured when open to prevent injuries or the blocking of adjacent alleys.

Suitable flooring materials for indoor stalls include rubber mats, artificial turf, packed clay, gravel, stone dust, asphalt, concrete, sand, and wood. Floor material should be selected for ease of cleaning and for sanitation, comfort, and safety of the horse. Slippery floors can lead to injuries and hard surfaces can cause lameness. Harder floorings require deeper bedding, especially for larger horses; the installation of rubber mats over the surface may be the best option. Concrete floors with a rough broom float surface that slope to a floor drain or exterior door are suggested for wash areas, alleys, and feed and equipment storage areas. Pervious concrete is an acceptable floor surface for wash areas as it will allow water to drain through the concrete and does not require an exposed drain. Pervious concrete does require specialized installation.

Table 8-1. Suggested dimensions of housing for horses and ponies used in agricultural research and teaching[1]

Area	m	ft
Indoor facilities		
Box stall: 1.8 m^2/100 kg (9 ft^2/100 lb) of body weight (BW)	3.7 × 3.7	12 × 12
Straight or tie stall, including manger: 0.82 m^2/100 kg (4 ft^2/100 lb) of BW	1.5 × 3.7[2]	5 × 12
Alleys, width		
Between rows of stalls	2.4–4.3	up to 14 ft
Behind rows of tie stalls	1.8	6
In front of rows of tie stalls	1.2	4
Outdoor facilities		
Run-in shed (per 1,000-lb horse; up to 2 horses)	3.3 × 3.3	11 × 11
Fencing height for		
Horses	1.4–1.8	4.5–6.0
Ponies	1.1–1.5	3.5–5.0
Outdoor pen (for single horse)	3.7 × 3.7	12 × 12
Pasture per horse	≥0.4 ha	≥1 acre

[1]Stall and pen sizes should accommodate normal postural adjustments of average-sized light breeds of horses.

[2]Lengths up to 3.7 m (12 ft) are used; length is measured from the manger front to the rear of the stall.

Stall design should allow for proper ventilation, which may assist in decreasing moisture or humidity levels and odors in the stall, and also provide better visual contact between horses and caretakers. An opening above the floor in walls and partitions sufficient in size to allow air movement will aid stall ventilation and can be closed with a removable filler strip. A variety of materials can be used between stalls to aid in ventilation such as steel rods, pipe, welded steel fencing, chain-linked fencing, hardwood slats, or comparable materials. Solid interior stall walls are suggested for housing stallions and for the walls of foaling stalls to prevent aggression by the postpartum mare toward horses in adjacent stalls (aggression that may be redirected toward her foal).

Ceilings, when present, should be made of a moisture-proof material, preferably one that is smooth with a minimum of exposed pipes and fixtures. Commonly, ceiling heights for stalls are 2.4 to 3.1 m (8 to 10 ft) to allow for adequate ventilation and safe confinement for the variety of different-sized horses. However, minimum ceiling height should be at least 0.3 m (1 ft) higher than the horse's ears when the head is held at its highest level and much higher in riding areas.

Windows or unglazed openings are recommended but not essential if adequate lighting and ventilation are supplied by other means. However, windows may provide visual contact between horses and may reduce some stereotypic behaviors associated with frustration of isolated horses such as weaving and head nodding (Cooper et al., 2000). A tip-out or removable window in each box stall aids lighting and natural (i.e., nonmechanical) ventilation in warm weather. The bottom of breakable stable windows should be at a height that is not vulnerable to kicking, and windows should be protected with metal bars or mesh to prevent breakage. Skylights or translucent panels in the roof are useful to let additional light into the barn area. Dutch doors in stalls may be used for windows and ventilation on exterior walls.

An alley should be provided between rows of stalls to allow room for horses to pass, handling feed and bedding, and manage manure; an alley located behind a single row of stalls or in front of a row of stalls allows for feeding horses and allows for people to pass safely. Alleys in horse barns should be wide enough for the horse to turn around, and if narrower, should have exits to larger areas at both ends. Alley doors to the outside may be overhead, swinging, or sliding and should be sized appropriately to the alleyway. A wider alley is suggested where Dutch doors permit horses to extend their heads into the alley and to avoid unnecessary contact with passing horses or people. The width of the alley should accommodate vehicles that deliver feed or remove waste and the movement of horses within the alley.

Horse facilities in tropical and subtropical climates have stall arrangements that are very open to the outside. Commonly used are shed row barns in which the stalls open to the outside under an overhanging roof. Added ventilation is encouraged by stall doors with openings to the floor and slatted or nonsolid stall walls. If barns without these features are used in these environments, these should be constructed to provide proper ventilation. Barns in tropical regions may have large stalls constructed with thick concrete block or well-insulated walls, very high ceilings, and extensive roof venting, unless complete climate control (air-conditioning) is planned.

Bedding. The type of bedding should be consistent with the comfort of the horse and proper sanitation. Acceptable bedding is any material that provides absorption and sound footing including wheat, oat, or rye straw, grass hay, dried pasture clippings, wood shavings or pellets, peat moss, sawdust, paper, shredded cardboard, and sand. Horses fed on the floor of the stall rather than from a feeder should not have sand bedding because they tend to ingest the sand and may suffer from intestinal impaction as a result. Bedding should be free of toxic chemicals or other substances that would injure horses or people. Black walnut shavings (Ralston and Rich, 1983), fresh cedar shavings, cocoa husks, and woods that have been pressure-treated have caused illness. Cocoa and cedar can also result in abnormal blood and urine profiles. Rubber mats alone may be used when the facility design or experimental or instructional protocol does not permit traditional bedding or for horses that are hyperallergic or suffering from respiratory diseases. Otherwise, absorbent bedding should be used over rubber mats.

Temperature and Ventilation. The horse can acclimate to subzero air temperatures, but benefits from the availability of simple structures such as a windbreak or a run-in stall to protect from wind and precipitation during winter months and from the sun during hot summer months. Newborn foals need more protection because of their relatively high lower critical temperature and their inability to regulate body temperature. Any enclosed building that houses horses should have a properly designed and maintained ventilation system. The purpose of ventilation during hot summer months is to aid in dissipating heat. Increasing the ventilation capacity during hot weather may be achieved by increasing the air velocity directly across the horse, usually by utilizing circulating fans and opening windows and doors. During winter months, proper ventilation helps with the control of moisture or condensation in enclosed buildings as well as decreasing the level of air contaminants such as dust, mold, pathogens, or gases (especially ammonia) that accumulate in enclosed buildings housing horses. Poor air quality inside stables may compromise the respiratory health of the horse, especially in the winter months. Supplemental heat may be considered with cold weather ventilation to improve the comfort of the horses and handlers, and insulation is recommended to prevent heat loss. Proper ventilation or the number of air changes per unit of time should be related to environmental temperature, humidity, atmospheric vapor pressure, total weight or stocking density of horses, and heat and water vapor production (from animals, equipment, and bedding) in the building.

Lighting. Lighting should permit adequate inspection of horses and be available during handling, feeding, or other activities involving horses. There is some evidence that total darkness in a horse barn should be avoided (Houpt and Houpt, 1988); it is recommended that windows or another light source be present at night to avoid injury. All lighting fixtures, electrical wiring, and switches should be recessed or otherwise protected against damage by or to the horses.

Noise. Horses are sometimes disturbed by sudden noises, and background white noise or music is often used to mask or habituate horses to unexpected sounds that might otherwise startle them.

Sanitation and Waste Disposal. Stalls should be cleaned as needed, usually daily, to minimize pests, keep horses clean and dry, and maintain the air suitably free of dust and odors, especially ammonia. Sloping floors in stalls and alleys are useful for drainage of urine and water. Gases may be emitted during storage and handling of manure and should be considered for human safety. A 450-kg (1,000-lb) horse produces about 24.5 kg (54 lb) of manure daily, plus spilled water, soiled bedding, and other waste. Although horse manure as deposited is composed of about 75 to 85% water, it is relatively dry to handle (MWPS, 2005). Horses should not have access to manure waste storage areas.

Outdoor Environment

Pastures, Paddocks, and Corrals. In general, horse pastures, paddocks, and corrals should provide a reasonably comfortable environment, including sunshade, windbreak, a firm surface upon which to rest, sufficient area for normal postural adjustments, and an enclosure that confines the horses safely and is free of trash, holes, and other dangerous objects but avoids unnecessary physical restraint. These outdoor accommodations also should provide for the biological needs of the animal (e.g., feed and water, exercise, reproduction if appropriate, and freedom to avoid contact with excreta).

The requirement of the horse for space in paddock and corral areas may vary considerably depending on environmental situations (e.g., soil type, climate, forage availability, and drainage), size and type of animals (ponies, light horses, or draft horses), and, in certain cases, temperament of the individuals in a group. The minimum area per horse in an outdoor pen should be suitable for normal postural changes, but a larger area per horse is suggested, especially for groups of horses. Continuous long-term maintenance of horses in the minimal area should be discouraged because it does not allow for sufficient exercise, especially for young horses. In wet or muddy conditions, dry areas should be available to allow horses to lie down. Tight spaces and sharp corners or projections should be avoided in the pens to reduce injury and the chance of dominant animals trapping subordinates. The pens should be cleaned as needed to ensure proper sanitation and pest control.

In temperate climates, horses may often be confined to paddocks or pastures without shelter other than that provided by terrain, trees, wind fences, or sunshades. However, shelters should be provided in very hot, very cold, or wet environments. The thermoneutral zone of horses has been estimated with the lower critical temperature at 5°C (41°F) and the upper critical temperature between 20 and 30°C (68 to 86°F) (Morgan, 1998). Depending on age, weight, feeding level, acclimatization status, and husbandry system, no additional shelter may be necessary. Still, in certain cases, bedding may be required to enable the horse to keep warm and dry. Sunshades or access to a ventilated stable should be provided in areas where summer temperatures reach 30°C (86°F) or higher if adequate natural shade is not available (Morgan, 1998).

In high traffic areas, there is a tendency for the formation of mud during wet seasons of the year. These areas can include gates, areas around waterers or feeders, and entrances to run-in sheds. To reduce the problems associated with mud, high traffic pads or alternatives are recommended.

Run-In Shed. The minimum sized shelter per horse is approximately the area of a box stall. As a general rule for the size of a run-in shed housing more than one horse, allow for 11.1 m^2 (120 ft^2) each for the first 2 average-sized horses and then 5.6 m^2 (60 ft^2) for each additional horse kept in the pasture or paddock. The size, design, and number of shelters should allow all animals in the paddock to share the shelter(s) at any given time. Eaves located on the back wall of the shed may be opened to allow for additional ventilation. Drainage systems should direct water away from areas of heavy use (e.g., near feeders, watering troughs, run-in sheds, and shades).

Fencing and Gates. Guides to fencing dimensions and materials are available from the MWPS (2005), and other sources. Fencing may be made of various materials, including wooden posts and rails, solid boards, wire (including high tensile wire), metal pipe, plastic, rubber, and V-mesh or chain-link fencing. It is not necessary to paint or seal fences, except when the protocol requires it. Barbed wire fencing should be avoided particularly where horses are housed in close confinement. Fences should be constructed to avoid features injurious to horses such as sharp, protruding objects (e.g., nails, wires, bolts, and latches), and, if possible, narrow tight corners in which a horse can be trapped by a herd mate and possibly injured.

Fence heights for horses are given in Table 8-1. The bottom of fences and gates should be high enough above the ground or extend to the ground to prevent the horse from catching a leg or hoof under the fence or gate, especially when rolling.

Electric fencing may be used for horses under certain conditions such as pasture rotation. Electric fences may not be adequate under some environmental conditions such as areas with heavy snow accumulation. Electric fence controllers should have been approved by Underwriters Laboratories or other accepted testing organizations. Highly visible, conductive plastic tape of 3/4" to 1 1/4" width is an effective fence material to cross fence pastures or paddocks. Other electric fence materials can also be used but they need to be highly visible in nature.

Gates may be constructed of several different materials, including wooden boards, pipe, sheet metal, and wire. The height of gates should be similar to that of adjoining fences to discourage animals from attempting to jump over at the lower point. The width of gates should span the opening completely and not leave a space where an animal may get caught between the fence and gate. The bottom of gates, like the bottom of fences, should either extend to the ground or be high enough above the ground to prevent injuries. Gates should be hung so they swing into the pasture or paddock.

FEED AND WATER

Horses have evolved over millions of years as grazing animals, spending their days traveling long distances in search of water and feed, primarily highly fibrous forages of widely varying types. The horse's digestive tract is well adapted to this lifestyle, with a stomach and small intestine capable of efficient enzymatic breakdown and absorption of the digestible components of feeds. The large intestine, composed of the cecum and large colon, functions as a fermentation chamber in which microbes reside. These microbes receive their nutrition from the less digestible components of the digesta and anaerobically produce end products that are beneficial to the horse. Nutritional and management practices that allow horses to eat throughout the day, have freedom of movement, and allow socialization with other horses will enhance the horse's well-being (Clarke et al., 1990; Davidson and Harris, 2007).

Horses kept on farms in pasture settings, surrounded by their herd mates, generally thrive in an environment not much different from their evolutionary environment. Provided that feed, water, and shelter are available, horses do an excellent job of utilizing accessible feeds in a natural environment to meet not only their nutritional needs, but also their exercise and social requirements.

Research and teaching facilities as well as modern, urban society usually do not keep horses in natural pastoral settings, but instead keep horses most of the time indoors in individual stalls or small outdoor paddocks. These horses have little opportunity to exercise freely and are often fed a diet that is too nutrient-dense, requiring dietary limitation in feed intake. Equine obesity, laminitis, colic, and associated maladies may result from inappropriate nutritional programs and management practices utilized in the care of horses.

Digestive Physiology

The digestive tract of the horse classifies the horse as a nonruminant herbivore. The horse eats only plant materials but does not possess a rumen, one of the distinguishing features of ruminants such as cattle, sheep, and goats. However, the horse's large intestine (cecum and colon) has a rumen-like function, because it hosts a large population of microbes (primarily bacteria) that can anaerobically digest the components of the horse's diet that are not previously digested by enzymes in the stomach or small intestine. Digestion of these indigestible (sometimes called insoluble) carbohydrates provides nutrition to the microbes resulting in end products called volatile fatty acids, which are absorbed into the circulatory system and utilized by the tissues of the body. In horses maintained on all-forage diets, volatile fatty acids derived from microbial fermentation can provide the majority of the horse's total energy requirement.

The microbes of the large intestine perform optimally in a stable internal environment. Intermittent meals or bolus feeding, when improperly managed, can disrupt the microbial population hindgut of the horse and may result in large fluctuations in nutrients and by-products in the circulation and to the tissues, setting up potentially detrimental physiological conditions such as laminitis or colic. Thus, the daily management of nutritional programs for confined horses is important to their health and welfare.

Horses housed inside or where they cannot graze should be fed and watered at least twice a day. More frequent feeding or ad libitum access to hay and water is preferred. For horses confined in areas where they cannot graze, roughage in the form of hay or other fibrous feedstuffs should be the main component of the diet as a dietary source of nutrients and bulk in the diet. Although a fiber requirement for the horse has not been determined, diets must provide adequate bulk for several reasons: 1) to maintain a more or less "full" digestive tract, 2) as a reservoir of water and to help buffer the chyme, 3) to maintain a constant environment for the microbes of the large intestine, 4) to reduce boredom in the stabled horse, lessening the incidence of stable vices such as cribbing, wood-chewing, tail-chewing, or ingestion of bedding, and 5) to approximate a more natural diet.

Feeding Recommendations

Horses should be fed so that they are neither obese nor too lean (Henneke et al., 1983). Body condition scores of 4 to 6 on a 9-point scale are considered average, although many horses exceed this and are still considered to be in good health. Horses that are not in appropriate body condition should be managed to allow body weight (BW) changes to occur slowly. Changes in energy intake should not exceed 10 to 15% per week in either direction. To increase BW, forage should be increased first before concentrates are added. To decrease BW, concentrate intake should be decreased before forage intake is reduced. A reduction in energy intake of the ration should be accomplished without decreasing total daily dry feed intake below 1.5% of BW.

To maintain normal body condition and health, horses should be fed to meet the current nutrient requirements (NRC, 2007) for their class using feeds that are high quality, palatable, and consistently available. Although nutrient requirements of individual horses may diverge from NRC recommendations, NRC requirements are an excellent starting place for meeting the nutrient needs of horses in different life stages.

Horses in different life stages and exercise regimens have different nutrient requirements. Total daily dry feed (hay and concentrate) consumption usually falls within a range of 1.5 to 3% of BW. The common types of hay for horses are legumes, grasses, cereal grains, or mixtures thereof. Hay is usually fed at the rate of 1% or more of BW for mature horses. However, no minimum amount of forage intake has been set for horses under various conditions with the existing data (NRC, 2007). Legume hays, usually alfalfa or clover, are generally higher in protein, energy, and calcium compared with grass hay. Horses can easily gain weight on free-choice quantities of legume hay, whereas grass hay or cereal grain hay (i.e., oat hay) can sometimes be fed ad libitum because of their lower nutrient content while adding fiber or bulk to the ration.

Concentrates are used to supply energy, protein, vitamins, and minerals to the ration. Concentrates can be fed at different rates, depending on the nutritional need, but care should be taken when total concentrate exceeds 1% of BW. Cereal grains such as oats, corn, barley, wheat, or milo are often supplemented as a source of calories in the diet and tend to be high in starch content. Elevated levels of starch in diets, however, have been implicated as causative for laminitis and other metabolic disorders in horses (Kronfeld et al., 2004). Supplemental fat, usually in the form of vegetable oil, is sometimes used instead of or with cereal grains to increase the caloric density of the diet. Generally, it is recommended that the oil content not exceed 10 to 15% of the total ration. Supplemental protein is often required for growing horses fed grass hay-based rations, and soybean meal is commonly added because of its palatability and high level of digestible protein. Vitamin and mineral supplements are frequently added to concentrate mixes to fortify the nutrient content of concentrates or the entire ration.

Most natural forages and cereal grains are deficient in salt. Because horses can also lose considerable amounts of salt through sweat, sodium chloride (NaCl, common salt) is often added to concentrates at rates of 0.5 to 1.0% or offered as a salt block or free-choice as plain, iodized, cobalt-iodized, or trace-mineralized salt.

Young horses, late-pregnant mares, lactating mares, and hard-working horses have the highest nutrient requirements. While growing, pregnant and lactating mares have greater protein, vitamin, and mineral requirements as well as energy requirements compared with adult horses in maintenance condition. The primary requirement of performance/athletic horses above maintenance is for increased energy. Often, somewhat higher needs for other nutrients are satisfied while the energy requirement is met. Geriatric horses may do better on rations with higher nutrient levels, similar to those for growing horses, perhaps because of diminished digestive or metabolic efficiencies. Details of nutrient requirements are presented in NRC (2007). In all cases, rations should be formulated with good-quality feeds free of contaminants, molds, and toxic weeds.

Rations should be of appropriate physical form. Hay should be relatively fine-stemmed, leafy, soft, and free of dust, mold, and foreign material. Concentrates should be dust free and not too finely ground. Complete pelleted diets are sometimes fed to horses, but at least some long-stem hay or pasture is recommended to increase bulk in the ration and to slow the rate of passage of feed through the digestive tract. Hard, crunchy pellets are consumed more slowly than soft, crumbly pellets (Freeman et al., 1990). However, horses with poor quality teeth and geriatric horses may benefit from softer pellets or the addition of water to pellets to form a mash consistency. Care should be taken to ensure that horses are not accidentally given feed formulated for cattle that is supplemented with ionophores; horses are highly susceptible to illness or death when fed ionophores (NRC, 2007).

Pastures for Horses

Nutrient needs of horses on pasture may be provided from forages available in the pasture or by a combination of pasture forage plus supplemental feeding of roughage or concentrates.

During certain periods of the year, growth of forages may be greatly reduced or the forage may become less palatable and digestible, necessitating supplemental feeding. Also, it is important to consider the effect of the environment on energy requirements, which increase significantly during periods of cold, wet weather (NRC, 2007). At other times, depending on stocking rate, little if any supplemental feeding may be required. If supplemental feeding is required in pasture situations, fence-line mangers, buckets, or boxes may be used to allow feeding from the fence line. Multiple sites (buckets or boxes) are preferable to a single site to decrease the risk of injury during aggressive competition for feed. Salt should be available to horses on pasture, especially if the sodium content in the grasses and legumes of the pasture is insufficient to meet the horse's requirement. When horses are feeding only on pasture, the trace minerals known to be deficient locally may be added to the salt source or fed as palatable supplements.

If horses are expected to meet their nutrient needs solely from pasture, care must be taken to ensure that the pasture can indeed support their requirements. Pasture stocking density varies from 0.4 to 4 ha (1 to 10 acres) or more per horse, depending on the type, concentration, and growth stage of the forage and the season (Hintz, 1983). Good pasture management is required to optimize utilization of improved pastures. Care should include regular fertilization and clipping (mowing) of excess growth to increase the nutrient value and palatability and the control of parasites through manure removal or pasture dragging to break up the manure piles. Pastures should be inspected routinely for growth of unusual or poisonous plants (Kingsbury, 1964; Oehme, 1986), especially when pastures are overgrazed.

Feed Containers

Feed containers may be constructed of metal, plastic, rubber, concrete, wood, or any other material that is safe, sturdy, and cleanable. Hay may be fed from mangers, bags, nets, and racks or directly on the floor. Horses appear to prefer eating from the ground (Sweeting et al., 1985), and, in a properly cleaned environment, relatively little danger exists of parasite transmission although significant forage may be wasted. Eating in the head-down position facilitates drainage of the respiratory tract and minimizes inhalation of dust from feed. However, ground feeding of hay (especially outdoors in group feeding situations) usually results in hay wastage, and concomitant ingestion of sand from sandy soils can lead to impaction colic. Hayracks or feeders may be beneficial in minimizing hay wastage and the ingestion of sand.

Hayracks should be free of sharp edges and corners. The distance between the ground and bottom of the rack should accommodate a comfortable posture of the horses during eating when outdoors. Grain may be fed in buckets in the lower part of many hayracks or from separate troughs or boxes. Feed containers should permit the horse to insert its muzzle easily to the bottom of the container. Examples of acceptable dimensions of hay mangers and boxes have been published (MWPS, 2005). It is important to monitor feed containers daily to ensure that these are clean, free of moldy or wet feed, and not broken or damaged.

Freestanding hayracks may also be used for groups of horses. These racks may be placed away from the fence or adjacent and perpendicular to the fence, allowing them to be filled from the other side of the fence. Drainage away from the feeder should be provided to minimize mud during rainy weather. Alternatively, feeders can be placed on aprons constructed of rubber, concrete, or other all-weather surfaces. Hay also can be placed in a large, stable container placed directly on the ground. The container should be cleaned out and spilled or soiled hay removed regularly.

Creep feeders may be used for foals. These feeders may consist of an enclosure located in the pasture (usually near the hay manger) with openings too small for adult horses to enter, but large enough for foals to enter to allow feeding of rations formulated specifically for growing foals without competition from the adult horses. Creep feeders, like other feeders, should be clean, free of sharp protrusions, and in good repair, and the feed should be kept fresh.

Feeding space for horses has not been well defined and may vary considerably depending on the size, number, and temperament of the individuals that must eat from the same feeder simultaneously. Sufficient bunk space or feeding points should be provided to preclude excessive competition for feed. An extra feeding point (one more than the number of horses) reduces aggression toward and stress upon the lower ranking of horses in the dominance hierarchy. This extra feeding point is particularly important if the feed ration is restricted. Hay racks that provide 1 m (3.3 ft) of eating space per animal and a continuous opportunity for consumption are usually placed down the center or long side of the pen or paddock (MWPS, 2005). The feeding of concentrate should be avoided in large groups, unless the horses are separated into individual feeding slips areas with head dividers or stalls to reduce competition by dominant horses (Holmes et al., 1987). There should be enough space between individual concentrate feeders for group-fed horses to feed but with minimal aggressive behaviors (Motch et al., 2007).

Water

Clean water should be continuously available or made available ad libitum at least twice daily. The requirement for water depends on several factors such as environmental temperature, animal function, and diet composition. In general, mature horses in a moderate environment (20°C) require water in the range of 5 to 7 L/100 kg (5 to 7 quarts per 220 lbs) of body weight per day (NRC, 2007). A horse fed to maintenance in a thermoneutral environment may need 21 to 29 L (4 to 8 gal) daily, but a horse that is working and sweating or a lactating mare may need 50 to 100 L (12 to 25 gal) daily, especially in hot environments. Signs of dehydration are sunken eyes, skin that tents (remains compressed when pinched), and increased capillary refill time at the gums. Also, lack of adequate water may be a cause of colic.

If a natural water source is used, care must be taken to ensure that flow rate is sufficient in dry weather, water is not frozen in cold weather, and supplementary water sources are provided if necessary. Environmental concerns, however, are such that use of natural water sources should be discouraged. Watering devices used in pastures or corrals should be durable and require little maintenance. The water source should be clean and safe; water quality standards and guidelines for horses are provided in the NRC (2007) publication.

Water Containers. Waterers may vary from simple buckets to troughs or automatic drinking devices. Waterers should be free of sharp edges. Automatic waterers must be functional, clean, and able to be operated by the horses. Waterers that operate by a pressure plate pressed by the horse require several days for most horses to learn to operate them. Foals and horses with very small muzzles may not be able to operate these devices. Also, the noise of some waterers refilling may frighten some horses initially. It is wise to provide a water bucket near the waterer until the horses are observed to operate the water device.

Automatic waterers should be inspected daily to be certain that they are operating properly and are free of foreign material. Water troughs should be cleaned as needed to prevent algae or dirt from accumulating. It is recommended that waterers be heated to prevent freezing in cold weather because provision of warm water increases intake in cold weather (Kristula and McDonnell, 1994). Proper installation of heating devices is necessary to prevent electrical shock. A float or stick may be placed in a trough to allow birds and other animals that fall into the trough to escape. Waterers should be positioned in a manner to prevent horses from injuring one another. Several widely spaced waterers or a large water trough may be necessary in enclosures housing a large group of horses.

HUSBANDRY

Social Environment

Horses are social animals that interact based on a dominance hierarchy within a herd structure. Horses develop strong attachments to herd mates; the strongest bond is between a mare and her foal. Horses can adapt to different environments, from free roaming on large areas of pasture to being confined in individual stalls. When separated from a group, horses may display restlessness, pacing, and vocalizations. Chronic social deprivation or isolation is a factor affecting the incidence of some locomotor stereotypies such as weaving, stall-walking, and fence-line pacing (McGreevy et al., 1995; Cooper et al., 2000; Bachmann et al., 2003). Careful selection of the horses' social environment must be considered so as not to interfere with the research and teaching objectives.

Geldings may be housed with mares or broodmares and their foals without causing physical or behavioral indicators of reduced welfare (van Dierendonck et al., 2004). It is not recommended that more than one stallion be kept with a group of mares because aggression and play may result in injuries; often stallions are housed individually. Stallions should be housed and managed to reduce the potential for aggression, although they can be effectively managed in groups under certain circumstances (Christensen et al., 2002).

Social hierarchies remain stable over time, with dominant mares maintaining their status even after reproductive senescence (Feh, 2005). Aggression is common when unfamiliar horses are mixed and dominance relationships are uncertain. Biting and kicking can inflict serious damage during these agonistic interactions; for this reason, horses that are shod should be introduced into new herds with extra caution. In established groups, aggression increases when resources such as feed and space are limited (Heitor et al., 2006). In many facilities, horses are turned out as a group in pastures or paddocks during the day, but are placed in individual stalls when they are fed. This approach accommodates individual feeding and minimizes aggression. Introduction of an unfamiliar horse to a group should take place in daylight, when the horses can see the fences and caretakers can observe the horses to detect injuries or deprivation of feed, water, or shelter of individual horses. Compatibility between neighboring individuals in stalls may depend on temperament in addition to social rank (Morris et al., 2002; Lloyd et al., 2007). Aggression between neighboring stabled horses is often expressed as threats, bar biting, or kicking of the stable walls. These behaviors can result in injury and damage to the stable and are performed more frequently by mares than by geldings (Drissler et al., 2006).

Horses exhibit a wide range of behavior and temperament based on their breeding, training, age, sex, and past experiences. Horses are best managed with predictable routines. Horses respond favorably to positive handling and can be acclimated to novel environments and procedures. A horse can be quite anxious when approached by an unfamiliar handler or while experiencing a novel environment or research procedure. Because horses have evolved as prey animals, their basic reaction to a threatening, painful, or stressful situation is to flee from the stressor. If a horse is confined or restrained during an unpleasant or novel situation, it is likely to fight using a variety of behaviors such as nipping, biting, kicking, rearing, or striking with a front foot. Visual contact with other horses is recommended to reduce the stress associated with isolation. Totally isolating, even for a few hours, a horse that previously lived in a group causes immune changes that may affect research results (Mal et al., 1991). There is little scientific information about auditory communication by horses and whether vocalizations affect the stress responses of neighboring horses. However, olfactory communication may be important for horses subject to novel environments or procedures.

Management

Observation and Daily Schedule. Horses should be observed carefully for health and well-being at least once daily. This observation can be done during feeding. Lack of appetite or other abnormal feeding behaviors are excellent indications of problems. Horses maintained in large pastures where daily feeding is not routine benefit from daily observation to ensure their health and well-being. It is particularly important to check and monitor water sources for adequacy.

Exercise. With proper husbandry, horses may be kept in an indoor stall for several months at a time if necessary, but those standing for prolonged periods in either box or tie stalls may develop edema of the lower limbs (stocking up) or abdomen, especially if pregnant. The frequency and duration of either controlled exercise or free time (turn out) has not been established by scientific studies for confined horses (McDonnell et al., 1998; Houpt and Houpt, 2000). Horses confined to box stalls should receive 30 min of free time (turn out) or 15 min of controlled exercise per day; horses in tie-stalls should be provided with more time for exercise. Behavioral problems such as stall walking, weaving, and cribbing are commonly thought to occur in confined horses. However, mares confined for up to 2 wk in tie-stalls for continuous urine collection were documented to exhibit fewer stereotypies than observed in the general population (McDonnell et al., 1998).

Grooming. Horses that are maintained in stalls are usually groomed daily. Horses maintained outdoors or in groups that have an opportunity to mutually groom each other and roll in clean dirt or grass do not necessarily require additional grooming. Horses that are maintained in dry lots that become muddy may require additional grooming to remove mud and fecal material.

Hoof Care. Routine hoof care is important to the health and well-being of the horse. Daily hoof care is recommended for horses maintained in stalls or tie stalls. Hooves should be inspected and cleaned using a hoof pick or hoof knife to remove fecal and bedding material to prevent the development of infections. Hoof growth should be monitored and hooves trimmed when the hoof wall becomes excessively long, cracked, or broken. In general, this will occur in about 6 to 12 wk, although the exact timing is highly variable. Trimming of hooves should be done by trained personnel, because improper trimming can result in lameness.

Teeth Floating. The upper and lower arcade of the horse's pre-molars and molars do not match. The upper arcade sets slightly outside the lower arcade. As a result, during the normal wear process, sharp points develop on the outside of the upper molars and the inside of the lowers. These points are extremely sharp and may result in irritation of the cheeks and tongue of the horse. The horse may turn the head sideways while eating in an attempt to relieve the pressure from the affected tissue or may slobber feed while eating. The teeth may be examined by running the index finger along the top of the upper gum line and then carefully lowering onto the outside of the upper molars. If sharp points exist, the teeth should be filed or "floated" with appropriate instruments (floats). The frequency of tooth floating is dependent on age, diet, housing, and environment. No standard recommendation can be made; however, horses that appear unthrifty, slobber feed, or exhibit other abnormal eating behavior should have their teeth examined and treated if needed. In general, very young and old horses require more attention to oral health programs and dental care.

Preventative Health Care. Certain equine diseases are endemic and of concern in protecting the health of horses. The major diseases that horses should be vaccinated against are Eastern equine encephalitis (EEE), Western equine encephalitis (WEE), and tetanus. In certain areas of the United States, Venezuelan equine encephalitis (VEE), West Nile virus, rabies, botulism, and influenza may be significant risks that should be considered in development of a vaccination program. Appropriate vaccination schedules should be developed in consultation with the attending or facility's veterinarian. Additionally, when indicated or through state or federal regulations, disease monitoring and surveillance programs should also be developed and implemented.

Parasite Control. Control of internal and external parasites is extremely important in most horses. Factors that affect internal parasite load include concentration of horses, age of horses, size and type of enclosures, environment, and sanitation and other management procedures. The major internal parasites that can severely affect horse health include, but are not limited to, large strongyles (*Strongulus vulgaris*), small strongyles (40 species), ascarids (*Parascaris equorum*), bots (*Gastrophilus intestinalis*), and pinworms (*Oxyuris equi*). Regardless of load factors, however, a program of screening, and treatment with an appropriate anthelminthic should be implemented. The class of drug used and timing of treatment varies with type of internal parasite targeted and the exposure load. Consultation with the attending or facility's veterinarian is recommended.

External parasites are generally less important than internal parasites but can affect the horse's health if present in sufficient numbers. Ticks, lice, and mites are the most common external parasites and can be easily detected and controlled with an appropriate drug, in consultation with a veterinarian.

Flying Insect Control. The 2 most common flying pests are flies and mosquitoes. The stable fly and the house fly are the most common species of flies. House flies are primarily a nuisance as these lack biting mouthparts, but they can be present in sufficient numbers to negatively affect the comfort of horses. Stable flies, deer flies, and mosquitoes do present a significant risk of disease transmission because they have biting mouthparts and feed on blood. They can serve as transmission vectors of blood born diseases such as equine infectious anemia (EIA).

Control of flying insects begins with sanitation. Manure, wasted feed, consistently wet areas, and standing water provide excellent breeding areas for flying insects and should be managed accordingly. Elimination of insect breeding areas to the extent possible should be of primary concern. If sanitation does not provide sufficient control, use of other methods may be required. Fly traps, fly baits, use of pyrethroids (synthetic or natural), use of lavacides on standing water, and release of parasitic wasps are all acceptable methods of controlling flying insects. Prolonged use of chemical treatments may result in resistant populations of flying insects. An integrated pest management approach to control is preferred.

Foaling Management. Mares can be managed extensively or intensively during the foaling process. Parturition in mares is normally uneventful. In multiparous mares, the process often occurs in less than 30 min. However, when problems occur, they require immediate attention and action. As a result of an artificially manipulated breeding season, many mares foal in January, February, and March when the weather in many parts of the United States is less than ideal. If extremely cold weather exists, foaling inside is preferable. Indoor foaling stalls should be larger than the normal box stall and easily accommodate the ambulatory movements and lateral recumbent positions of the mare during parturition, and subsequently provide ample space to avoid injuries for the mare and her foal. In more temperate weather, foaling outside is acceptable. An important consideration is that the enclosure used is free from objects that could injure the mare or foal if they lie down or fall. The walls of the stall or fence (in the case of an outdoor paddock) should be constructed such that the mare's legs cannot become entangled when she lies down to foal.

Most mares foal after dark. Mares should be grouped by expected foaling date and observed closely at the evening feeding. The presence of a waxy substance on the end of the teats may be indicative that the mare is within 24 to 36 h of foaling. Maiden mares, however, may not exhibit this classic sign. The onset of parturition is signified by strong abdominal contractions followed by presentation of the water bag. Once the water bag breaks, the foal's front hooves should be visible with the soles of the hooves pointed downward (toward the mare's legs). The foal's nose should be positioned on top of the front legs just above the fetlocks. Any presentation other than described here is an indication of a malpresentation and is cause for concern. If the foaling attendant(s) is(are) not experienced in handling emergency obstetric situations, a qualified veterinarian or his/her designee should be called immediately.

If the presentation of the foal is normal, the mare should be left alone until the foal has been delivered and the umbilical cord has been broken. The umbilical stump should be treated with a tincture of iodine to prevent introduction of pathogenic bacteria into the foal's body. The foal should be allowed to stand and nurse on its own without interference. This process allows the mare and foal to recognize each other and to bond. This process can take an hour or more. If the foal has not stood and nursed within 2 h, assistance may be required. At 8 to 12 h post-foaling, the foal can be tested for the presence of antibodies absorbed from colostrum. There appears to be good correlation between the concentration of antibodies from colostrum and the health of foals during the first 6 wk of life. If the mare does not produce adequate colostrum, frozen colostrum may be available from large breeding farms, but feeding colostrum to the foal more than 12 to 24 h after birth is ineffective. In cases of a failure of transfer of passive immunity from colostrum, transfusion of plasma from hyperimmunized donors may be advisable.

Mares should be observed for the passing of the placenta, which should occur within the first couple of hours post-foaling. Retention of the placenta by the mare more than 3 h post-foaling is considered a medical emergency. A qualified veterinarian should be called to assist in resolving the situation. Endometritis, septicemia, and laminitis are common secondary occurrences when a mare retains the placenta.

Breeding Procedures. Pasture breeding, natural cover, and artificial insemination are all appropriate methods of breeding mares. All can result in acceptable conception rates. Pasture breeding requires the least intensive management. The pasture needs to be of an appropriate size so that submissive mares can retreat from dominant mares or the stallion. Also, there should not be breeding horses in adjacent areas. Natural breeding and artificial insemination require additional management skills and should only be attempted by personnel who are appropriately trained and understand the behavioral characteristics of both stallions and mares during the breeding season. Although the breeding of mares is not a sterile procedure, proper hygiene should be observed during artificial insemination procedures. All equipment should be kept clean and in good repair, and facilities should be constructed such that risk of injury to horses and personnel are minimized.

Restraint. Proper restraint of horses is an important management skill that is critical to the health and well-being of both the handler and the horse. Restraint can be as simple as putting a horse in a pen to restrict its range of movement to as complex as the use of chemical restraint to perform a surgical procedure. As a general rule, the handler should use the minimal amount of restraint necessary to perform the procedure. Regardless of the restraint used, it should be correctly and appropriately applied. Below is a list of acceptable restraint methods and a description of the proper application of each.

Pens: Pens should be constructed of material that is of sufficient strength to contain the horse. Material should be smooth with no sharp points or edges. Pipe, smooth cable, PVC fencing, wooden planks, and woven wire are all appropriate materials.

Stalls: Stalls should be constructed of material that is of sufficient strength to contain the horse. The lower part (0.9 to 1.1 m; 3 to 4 ft) should be of solid construction such that the horse's legs cannot become entangled. Wood planking, metal sheeting, and concrete are all appropriate materials.

Halters: Halters may be constructed of rope, nylon webbing, synthetic materials, or leather. These should fit tightly enough that the crown piece will not slide down the neck but be loose enough that the horse can chew comfortably. It is not recommended that horses be turned loose in a pasture or stall with a halter on unless the halter is made such that it will break away should the horse become entangled. If a horse is to be tied with a lead rope attached to the halter, there are several factors that must be considered: 1) the horse should be tied at wither height or above; 2) a slip knot that can be untied easily should be used; 3) the horse should be tied to something that will not become detached or move; and 4) there should be no objects in the immediate area that could injure or entangle the horse.

Front Foot Hobbles: Front foot hobbles are a traditional form of restraint used to allow horses to graze on the open range without running off. If used, hobbles should be constructed of leather or soft cotton rope. These are applied to the front feet only and should only be used on horses that have been trained to them. Horses that have not been trained to hobbles may have a violent reaction to them when first applied. Front foot hobbles should not be applied in confined spaces where the horse may be injured by running or falling into a fence, wall, or other object.

Sideline or Breeding Hobbles: Sidelines or breeding hobbles are used to prevent a horse from kicking with the hind legs. As the name implies, they are used to protect a stallion when mounting a mare during breeding or during collection for artificial insemination. These are sometimes used to restrain the horse when trimming feet or when training a horse for riding. Hobbles should be constructed of leather or soft cotton rope to prevent abrasion injuries during application. Horses that have not been trained to sidelines or breeding hobbles may have a violent reaction to them when first applied. These should not be applied in confined spaces where the horse may be injured by running into or falling into a fence, wall, or other object.

Leg Straps: Leg straps are used to hold one front leg off the ground by flexing a front leg and placing the strap around the forearm and cannon bone. Leg straps are applied by trained individuals primarily to keep the horse from moving forward and encourage them to stand still. The strap should be made of leather or soft cotton rope to prevent abrasion injury. Horses that have not been trained to leg straps may have a violent reaction to them when first applied. These should not be applied in confined spaces where the horse may be injured by running into or falling into a fence, wall, or other object.

Twitches: Twitches are used to immobilize horses for procedures where movement of the horse prevents the accomplishment of the task. Twitches are generally applied to the upper lip of the horse and then tightened. This usually results in the horse standing immobile despite even moderately uncomfortable procedures such as rectal palpation or insertion of nasogastric tubes. Twitches come in many types from the so-called humane twitch constructed like a large pair of smooth pliers to wooden handles with rope or chain attached to the end. Regardless of the type, the upper lip is grasped and placed in the loop of the twitch, which is then tightened by clamping or twisting. When used correctly, twitches are a safe and effective method of restraint that often can be used in lieu of chemical restraint. When used incorrectly, twitches are dangerous to both the horse and the handler. Horses often have a violent reaction to twitches when they are improperly used.

Chemical Restraint: Surgical or other procedures that require chemical restraint should be performed only under the advice or supervision of a veterinarian. Improper application of chemical restraint can result in injury or death of the horse and presents a safety hazard to the handler.

STANDARD AGRICULTURAL PRACTICES

Identification

Permanent identification of individual horses may be done by hot or freeze branding, insertion of microchips, or lip tattoos. Proper restraint, physical and/or chemical, should be used to ensure proper application of the brand and to safeguard the handler and horse during the process. The resultant wounds should be monitored for infection (Lindegaard et al., 2009). For microchip insertion, tranquilization is usually not necessary but numbing the insertion site with lidocaine may be indicated. The insertion site midway between the poll and withers in the nuchal ligament should be clipped and surgically scrubbed before insertion to prevent infections. Lip tattoos are traditionally done on the inside surface of the upper lip and do not require chemical restraint.

Castration

Castration may be performed on horses at any age from a few weeks to many years of age. Surgical castration is performed with the horse standing or in recumbency. Anesthesia, provided by a licensed veterinarian, is essential at all ages. Horses should be carefully monitored post-surgery for infection or herniation of bowel through the castration site. Appropriate analgesia may be provided by a licensed veterinarian for use following castration surgery.

Exercise and Equipment

Harnesses, saddles, or other equipment necessary for research and teaching purposes should be properly fitted for each individual horse, such that the equipment does not cause uneven pressure or injury, or rub sores. Horses being exercised should be offered water at regular intervals, and the duration of actual work should take into account climatic condition, fitness of the horse, and physical demands.

Pain and Distress

Chronic signs of pain or distress in horses include lameness, weight loss, hair loss or open sores, loss of appetite, repeated flight attempts or aggression, and depression. Acutely painful or stressed horses may show elevated heart and respiratory rates, inappropriate sweating (not heat or exercise induced), repetitive rolling on the ground, groaning, teeth grinding, pinned ears, clenched jaw, restlessness, tucked-up posture, and other signs of abdominal pain (Kaiser et al., 2006; Mills et al., 2007). Common causes of pain and distress in horses include social isolation, lack of adequate feed or water, improperly fitting harness or equipment causing pressure or friction, improper handling or restraint, prolonged transportation (Stull et al., 2004), and repeated invasive research procedures such as venipuncture, intravenous catheterization, and muscle biopsies.

ENVIRONMENTAL ENRICHMENT

Refer to Chapter 4: Environmental Enrichment for information on enrichment of horse environments.

HANDLING AND TRANSPORT

Refer to Chapter 5: Animal Handling and Transport for information on handling and transportation of horses.

EUTHANASIA

Personnel who perform euthanasia of horses must be trained in the appropriate protocols, humane handling and restraint techniques, and knowledgeable about safety concerns associated with each euthanasia method. Euthanasia of horses can be performed using the intravenous administration of pentobarbital or a pentobarbital combination, gunshot, or captive bolt gun. Pentobarbital is a substance controlled by the US Food and Drug Administration; thus, a veterinarian must be registered through the US Drug Enforcement Agency for its use. Usually a catheter is placed in the jugular vein to facilitate the large volume of solution that must be used. Barbiturates administered too slowly or in insufficient amounts may cause sudden or violent falling and thrashing of the horse. Thus, the use of sedatives or tranquilizers (e.g., xylazine, detomidine, or acetylpromazine) before the intravenous administration of pentobarbital can provide a more controlled recumbency process, which also may be safer for the personnel handling the horse. However, the use of sedatives and tranquilizers before administration of pentobarbital may prolong the time to unconsciousness because of their effect (i.e., bradycardia, hypotension) on the circulatory system (AVMA, 2007).

In emergency situations, or if the use of drugs is contraindicated for any reason, a gun or a penetrating captive bolt gun may be used by trained personnel. For gunshot, a 0.22-caliber long rifle is recommended, but a 9-mm or 0.38-caliber handgun will be effective for most horses. The optimal site for penetration of the skull is one-half inch above the intersection of a diagonal line from the base of the ear to the inside corner of the opposite eye. Personnel must comply with laws and regulations governing the possession and discharge of firearms; local ordinances may prohibit the discharge of firearms in certain areas. A penetrating captive bolt gun fires a blank cartridge that propels a steel bolt into the brain, producing immediate brain destruction.

Proper selection of the cartridge strength should be appropriate for the size of the horse and varies between manufacturers. The site of entry for the projectile is the same as for gunshot. Because the captive bolt device must be held firmly against the area of penetration on the head, horses must be adequately restrained. The advantage of a captive bolt procedure is that is does not fire a free bullet, and therefore may be safer for personnel.

Confirmation of death is essential using any euthanasia method. The horse should be checked for at least 5 min to confirm death by monitoring its vital signs. Death is confirmed by the lack of breathing, heartbeat, and corneal reflex. Additional euthanasia procedures should be initiated if there is any evidence of responsive vital signs.

Carcass Disposal

When practical, choose a location for euthanasia procedures where the carcass can be removed easily by equipment. Animal carcasses should be disposed of promptly, usually by a commercial rendering company or other appropriate means (burial, land fill, incineration, or possibly composting or biodigestion) in accordance with all federal, state, and local regulations. Some local regulations may not allow burial, and rendering services may not accept carcasses containing pentobarbital or other medications. Limit the access of carcasses to scavenging animals, because residues of pentobarbital may remain in the carcass.

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Chapter 9: Poultry

The animal care guidelines in this chapter are for the 3 major domesticated poultry species in the United States: chickens (both egg-type and meat-type), turkeys, and ducks.

FACILITIES AND ENVIRONMENT

The physical environment afforded by a poultry research or teaching facility should not put birds at undue risk of injury or expose them to conditions that would be likely to cause unnecessary distress or disease (Davis and Dean, 1968; Berg and Halverson, 1985; Tauson, 1985; Bell and Weaver, 2002; Appleby et al., 2004). The facility should be maintained in such a way as to allow the birds to keep themselves clean and free from predators and parasites, prevent bird escape and entrapment, and avoid unnecessary accumulation of bird waste.

Environmental conditions are known to have major implications on the health, performance, and welfare of poultry (Dawkins et al., 2004; Estévez, 2007). Air quality and the thermal environment should be maintained by ventilation, cooling, and heating to provide birds with the right environmental conditions for their age and time of the year.

Welfare of the caretaker, in addition to bird well-being, deserves consideration in evaluation of housing systems (Whyte, 1993) and should receive attention during remodeling and development of future designs and concepts.

Bird exposure to high levels of ammonia causes irritation of the mucous membranes of the respiratory tract and eyes, increasing susceptibility to respiratory diseases (Kristensen and Wathes, 2000). Birds detect and avoid atmospheric ammonia at or below 25 ppm (Kristensen et al., 2000). According to the National Institute for Occupational Safety and Health (**NIOSH**), the recommended exposure limits for humans should be no greater than 25 ppm for an 8-h day; for short-term exposure of 15 min, the threshold is 35 ppm (Agency for Toxic Substances and Disease Registry, 2004). Ideally, ammonia exposure for birds should be less than 25 ppm and should not exceed 50 ppm (Miles et al., 2004).

Design of all housing systems should facilitate cleaning of the house and equipment as well as the inspection of birds. Cages with multiple decks should allow for cleaning of equipment and inspection of birds without handling them, yet the birds should be easily accessible. Adequate lighting should be available for examination of all birds, and a movable platform or other system should be provided for examination of higher level decks, if those cannot be readily seen by attendants standing on the floor. Feeding and watering equipment also should be accessible for easy maintenance.

Advantages and Disadvantages of Conventional and Alternative Housing Systems

Although there are a variety of systems that can be used for housing poultry, including conventional and furnished cages, aviaries, littered floor systems, and free range, no housing system is perfect, with each system having its own health and welfare advantages and disadvantages. For a colored schematic of the welfare risks of different housing systems for egg-laying strains of chickens, see Table 7.7 of the LayWel report (LayWel, 2006b).

Research into alternative housing systems has been extensive in recent years (Appleby et al., 2004; Vits et al., 2005; Guesdon et al., 2006; Nicol et al., 2006; Zimmerman et al., 2006) including furnished cages, aviaries, and free-range systems as alternatives to conventional cages for egg-laying strains of chickens. Conventional cages lack nests, perches, and dust baths to meet the behavioral needs of hens, but conventionally caged hens have less cannibalism and pecking because of smaller group sizes (Appleby and Hughes, 1991; Abrahamsson and Tauson, 1995) leading to a reduced trend in mortality compared with hens in non-cage systems (Flock et al., 2005; Laywell, 2006b; Tauson et al., 2006; Arbona et al., 2009; Black and Christensen, 2009; Fossum et al., 2009; Glata and Hinch, 2009). Because conventional cages lack perches and do not have access to litter, poor foot health and keel bone deviations and deformities are not as problematic in cages as they are in non-cage systems or furnished cages (Tauson et al., 2006); however, because of lack of exercise, conventionally caged hens are susceptible to osteoporosis (Whitehead and Fleming, 2000; Jendral et al., 2008). Moreover, free-range birds are able to express behaviors such as freedom of movement, running, short-distance flying, and the scratching of soil, and have the opportunity to be exposed to a variety of environmental stimuli (Appleby and Hughes, 1991). They are also leaner with more muscle mass and plumage than caged birds (Hughes and Dun, 1986). However, ranged birds are more susceptible to problems caused by inclement weather and have increased risks of bacterial disease, parasites, cannibalism (Fossum et al., 2009) due to larger group sizes (Appleby et al., 1992), predators (Darre, 2003), environmental contaminants such as dioxin (Schoeters and Hoogenboom, 2006; Kijlstra et al., 2007), and increased frequency of old bone fractures (Gregory et al., 1990). No housing or management system is likely to be ideal in all respects. Therefore, ethically acceptable levels of welfare can exist in a variety of housing systems (Duncan, 1978).

Alternative Housing

Furnished Cages for Egg-Laying Strains of Chickens. Furnished cages are available to house large (~60 hens), medium (15 to 30 hens), and small (up to 15 hens) group sizes. The European Commission (1999) offers standards for furnished cages that include perching space for all hens and a nest and dust bath area, with minimum available space per hen of 750 cm^2 per bird. Appleby (2004) suggests that group sizes of 8 hens or more in furnished cages should have 800 cm^2/hen and that smaller groups of 3 or less should have 900 cm^2/hen, plus an area with litter. In these systems, claw-shortening devices are helpful to maintain short claws, and perches can help to increase leg strength (Hughes and Appleby, 1989; Jendral et al., 2008). Problems observed in this type of housing include increased keel bone deformities associated with high perch use (Vits et al., 2005; Tauson et al., 2006) and should be monitored.

Aviaries or Multi-Tier Systems for Egg-Laying Strains of Chickens. Aviaries, designed to use vertical space, consist of a ground floor plus one or more tiers consisting of perforated or slatted floors or platforms with manure belts underneath (Appleby et al., 2004; LayWel, 2006a; RSPCA, 2008b). Providing a littered area allows for dust bathing and reduces the incidence of cannibalism and feather pecking. The scratch area also allows the hens to keep their claws trimmed. The litter should cover enough area to allow for proper mixing of manure and avoid excessive manure and moisture accumulation. The depth of the litter should be sufficient to prevent hens from coming in contact with the floor. Likewise, the depth of the litter should not be so deep that it encourages the laying of eggs on the floor. Opening and closing the littered areas for specified periods can be used as a management tool to prevent the laying of floor eggs. The European Commission (1999) recommends that the littered areas cover at least 30% of the useable floor area of the house (including the floor area of tiers). The recommended floor space per hen for aviaries (Table 9-9) excludes nest space. Only the floor area and the tiers can be counted as usable space when calculating stocking density for hens in aviaries.

Hens housed in aviaries have a high incidence of bone fractures during the laying cycle because of crash landings or failing to jump gaps effectively (Broom, 1990; Gregory et al., 1990; Nicol et al., 2006). Each tier should allow hens to safely access other vertical tiers, including the littered floor. For example, a ramp can be used to allow birds to move from the littered floor area to the first raised tier. If ramps are used, they should be designed to prevent droppings from falling on the birds below. Hens should have access to the entire littered floor area, including the area under the raised tiers. Raised tiers need a system for frequent removal of manure. To reduce the incidence of hen injury, including broken bones, the highest tier (measured from the littered floor to the underside of the manure belt of the highest tier) should not exceed 2 m (6.5 ft).

Vertical distance between tiers, which also includes the floor to the first tier, is recommended to be between 0.5 and 1.0 m (1.6 and 3.3 ft). Measurements may be taken from the top of the littered floor or slat area to the underside of the manure belt. When adjacent tiers are staggered to allow for diagonal access to tiers of different heights, the hen's angle of descent (measured horizontally from the top tier) should not exceed 45°. The horizontal distance between tiers should not be more than 0.8 m (2.6 ft). Where design discourages horizontal movement between different tiers, there should be a minimum distance between tiers of 2 m (6.6 ft). For flock sizes that exceed 3,000 hens in a room, no more than 2 raised tiers above the floor are recommended. Smaller flock sizes of 3,000 or less can have up to 3 raised tiers in a room (RSPCA, 2008b).

Birds that are to be housed in aviaries as adults should be reared as pullets in similar aviaries to facilitate adaptation to perches and nests. Typically, day-old chicks are housed in a central tier the first 10 d of age and then about half of the pullets can be distributed to the lower tier to provide more space as they age. In this manner, the pullets quickly find the feed and water and are provided proper brooding temperatures during the early stages of growth. By 15 to 21 d of age, pullets are given full access to the aviary. Ramps are provided to allow pullets easy access to all levels of the aviary. Perch space per pullet is recommended to be 8 cm (3.1 in)/pullet during the first 10 wk of age and 11 cm (4.3 in)/pullet after 10 wk of age. Welfare standards for pullet aviaries are still in the investigational stage.

Outdoor Access or Free Range

Poultry may also be raised with access to the outdoors. Poultry raised under an organic protocol require outdoor access (USDA Agricultural Marketing Service, 2001), which can be a range or a semi-enclosed yard often referred to as a veranda or winter garden. During inclement weather or for health-related reasons, birds should remain indoors or in shelters until such conditions are improved.

A range is an outside fenced area. Fence height and fencing material should be of appropriate mesh size to retain domesticated poultry and prevent predator entry. A permanent fence can be extended underground to a minimum depth of 0.25 m (0.82 ft) to prevent ground predator entry. The fence can be surrounded by an electric wire 25 to 45 cm (10 to 18 in) above the ground and 0.6 to 1.0 m (2 to 3 ft) away from the primary fence (Scanes et al., 2004). Overhead fine netting, as used for game birds, can be used to protect domestic poultry from wild avian predators and minimize disease transmission from wild species to domesticated poultry. Ranges should be free of debris such as large rocks and fallen trees, environmental contaminants, and be designed to prevent muddy areas, to avoid injuries and foot problems, and to promote overall bird health. Vegetation should be used for ranges or sections of the range where soil erosion is problematic. Range rotation is one tool for minimizing the threat of a disease outbreak and to provide opportunity for land to recover from bird activity. A covered veranda provides shade and is connected to the house and is made available to the hens during the daylight hours. The floor of the veranda can be solid and may be covered with litter. To minimize the probability of cannibalism, natural light or high-intensity artificial light can be used during early stages of rearing to facilitate the transition of birds from indoor to outdoor lighting conditions.

Free-ranged birds without access to a permanent building should have covered shelters that provide shade, protection from inclement weather, litter, food, and water. The sheltered area should provide space to allow all ranged birds to rest together without risk of heat stress. Mobile shelters should be moved on a regular basis or managed to minimize the probability of a disease outbreak or muddy conditions. Elevated perches designed for poultry can be provided on the range or inside the indoor shelter. See perch section under husbandry for more details.

All range, veranda, or any other type of outdoor access should be managed so that birds are protected from potential predators. Weather permitting, birds should be given access to the outside as soon as they have full feather coverage to encourage ranging behavior. Vegetation such as small bushes, crops such as corn, or cover panels (Cornetto and Estévez, 2001a; Leone and Estévez, 2008) that provide a sense of protection in the outdoor area can be used to encourage the use of the range (Hegelund et al., 2005).

When indoor birds are allowed free access to the outdoors, they should have appropriately sized openings (popholes) of sufficient number to facilitate bird exit from and entrance into the building; alternatively, the doors of the house can be opened to allow birds freedom of movement. The size of each pophole should allow for easy passage of a bird to and from the outside. The number of popholes provided should allow birds to comfortably access the outside or inside without significant congregation of birds on either side of the pophole. A roof can be placed over a pophole to provide protection and baffles installed to reduce entry of wind into the house. Slats can also be used to prevent the formation of muddy areas around the popholes (LayWel, 2006a).

For whole house configuration without individual pens, popholes should be evenly distributed down the entire length of the building to prevent birds from blocking the access in and out of the building. On windy days, it may be wise to open popholes only on the leeward side, so providing more than the minimum number of popholes is advisable.

Egg-Laying Strains of Chickens. The approximate age that egg-laying strains of chickens are allowed access to the range is about 12 wk of age. Before 12 wk of age, they are brooded in confinement. To allow for range rotation, provide each hen with 4 m^2 (43 ft^2) of outdoor access (European Union, 2001). Shade should be evenly distributed in the outdoor area and provided at a minimum of 8 m^2 (86 ft^2) per 1,000 hens (RSPCA, 2008b).

Meat-Type Chickens. Fast-growing strains of broilers should have access to a minimum of 1 m^2 (10.8 ft^2) of outdoor access, whereas slower growing strains (e.g., French Label Rouge) require 2 m^2 (21.6 ft^2) of outdoor access (Fanatico, 2006).

Turkeys. The age that turkeys are given access to outdoors may vary from 5 to 12 wk depending on weather conditions and predator risk, with 8 wk being the most common age. A flock can gradually be transitioned to range by moving one-third of the flock the first morning and then moving the remainder of the flock a day or two later (Scanes et al., 2004). The following formula can be used to calculate the minimum amount of shelter (m^2) recommended: area, $m^2 = [(n \times 0.3)W]/D$, where n is the number of birds in the flock, W is the expected average weight (in kg) at depopulation, and D is the maximum stocking density in kg/m^2 (RSPCA, 2007). Growing turkeys are allowed a minimum space allocation of 6 m^2 (65 ft^2)/bird of free range (Parkhurst and Mountney, 1988).

Ducks. Information for porches or winter gardens for ducks is not available. When growing ducks are first introduced to the range, they need to be shown the location of the feeders, drinkers, and shelters. The outdoor feeders and drinkers should be surrounded by slatted or solid flooring to prevent the ground in the immediate area from becoming muddy. Free-ranged growing ducks are allowed a minimum of 2.5 m^2 (27 ft^2)/bird when reared on well-maintained ranges with ground cover. If the vegetation is poor, then a minimum of 4 m^2 (43 ft^2)/growing duck should be provided. If ponds are available, they should be well maintained so as to avoid stagnant water containing decaying vegetation. Botulism in ducks can be a problem when pond water is not well aerated or not filtered to remove plant debris (RSPCA, 2006). Developing breeders may be raised outdoors on well-drained soil (preferably sand) with open shelter. A minimum of 1,290 cm^2 (200 in^2) of shelter area/bird is recommended for developing breeders.

FEED AND WATER

Feed

Circular or linear troughs can be used to supply feed. Feed troughs can be located either inside or outside the area where the birds are housed. If feed troughs are located outside the area where the birds are housed (as is the case for most adult cages), then only one side of the trough is available to the birds. Unless the feeder is mounted on a wall, feeders located in the area where the birds are housed generally provide bird access to both sides of the trough. Minimum feeder space recommendations for egg-laying strains of chickens, meat-type chickens, turkeys, and Pekin ducks are shown in Tables 9-1, 9-2, 9-3, and 9-4, respectively. Depending on species, specifications are for birds housed in multiple-bird pens and cages, individual cages, or aviaries. Feeder space allocation is presented in the tables as linear trough space per bird when both sides of the trough are available. If only one side of the trough is available, then the amount of feeder space per bird must be doubled.

Because meat-type chickens, ducks, and turkeys have been bred for rapid growth to market age, excessive body weight (**BW**) gain of broiler breeders, duck breeders, and male turkey breeder stocks is a problem unless energy intake is controlled beginning early in life. Because breeders are allocated limited feed to allow for a gradual increase in BW each week, birds are hungry as indicated by motivational test (Savory et al., 1993), stereotypic pecking on nonnutritive objects, and excessive drinking of water. Stress is also apparent in feed-restricted broiler breeders between 8 and 16 wk of age (Hocking et al., 1993). Feed restriction of breeders allows for controlled BW gain, reduces skeletal problems, increases activity, and improves livability, fertility, immune function, egg production, and disease resistance. Evidence to date indicates that the welfare of breeders is better if they are feed restricted (DEFRA, 2002).

Feed should be allocated and BW routinely monitored to maintain the recommended BW for the particular stock and age. Rations may be either a fixed amount of feed allotted daily or under various alternate-day feeding schemes. Alternate-day feed restriction as opposed to limited feed each day allows more-timid birds access to feed, resulting in better flock uniformity (Bell and Weaver, 2002). Inhibition of feeding by subordinate birds is likely if feeder space is limited (Cunningham and van Tienhoven, 1984). Therefore, procedures that require restricted feeding should have enough feeder space so that all birds can eat concurrently. It may also be helpful to use low-density diets and to provide birds with environmental enrichment such as devices that they can manipulate to obtain small amounts of food to fulfill their feeding behavior.

Table 9-1. Minimum feeder space (linear trough space/bird) for egg-laying strains of chickens in floor pens, aviaries, or cages[1,2]

	White Leghorns				Mini Leghorns				Medium-weight breeds			
	Female		Male		Female		Male		Female		Male	
Type of housing and age (wk)	(cm)	(in)	(cm)	(in)	(cm)	(in)	(cm)	(in)	(cm)	(in)	(cm)	(in)
Pen[3]												
0 to 6[3]	1.27	0.50	1.65	0.65	1.15	0.45	1.50	0.59	1.40	0.55	1.82	0.72
6 to 18	2.54	1.00	3.30	1.30	1.91	0.75	2.48	0.98	2.92	1.15	3.80	1.50
>18[4]	5.08	2.00	6.61	2.60	3.81	1.50	4.96	1.95	5.84	2.30	7.60	3.00
Cage and aviary												
0 to 3[3]	0.51	0.20	0.64	0.25	0.46	0.18	0.57	0.23	0.56	0.22	0.70	0.28
3 to 6	1.00	0.40	1.27	0.50	0.92	0.36	1.15	0.45	1.12	0.44	1.40	0.55
6 to 12	1.53	0.60	2.03	0.80	1.15	0.45	1.53	0.60	1.76	0.69	2.34	0.92
12 to 18	2.54	1.00	3.30	1.30	1.91	0.75	2.48	0.98	2.92	1.15	3.80	1.50
18 to 22	3.81	1.50	4.95	1.95	2.86	1.13	3.72	1.47	4.38	1.73	5.70	2.25
>22	5.08	2.00	6.61	2.60	3.81	1.50	4.96	1.95	5.84	2.30	7.60	3.00

[1]Feed should be allocated and body weight routinely monitored to maintain the recommended body weight for the particular stock and age. Specifications for feeder space for single bird cages are the same as multiple bird cages.

[2]Linear trough space is when both sides of the trough are available. If only one side of the trough is available, double the amount of feeder space/bird. Perimeter space for round feeders is obtained by multiplying linear trough space by 0.8.

[3]During the first week, supplementary feed should be placed on some type of temporary feeders (such as egg flats) on the floor.

[4]Feeder space for White Leghorn and medium-weight breeders is the same as commercial layers except for pens in which 5.35 cm (2.1 in) and 6.16 cm (2.42 in), respectively, is provided to mature breeders after 18 wk of age. Male and female breeders are housed together for natural mating.

Table 9-2. Minimum feeder space for meat-type chickens[1]

Bird type and body weight, kg (lb)	Approximate age, d	Linear trough space/bird[2] (cm)	(in)
Commercial broilers on 100% litter or multiple bird cages			
<1.53 (<3.3)	0 to 28	1.9	0.75
1.5 to 3.3 (3.3 to 7.2)	29 to 65	2.5	1.00
>3.3 (>7.2)	>66	3.2	1.25
Broiler breeder females or mixed ratio of 1 male to 10 females on 100% litter			
<0.3[3] (<0.7)	0 to 21	3.8	1.5
0.3 to 0.6 (0.7 to 1.3)	22 to 42	5.1	2.0
0.6 to 0.9 (1.3 to 2.0)	43 to 63	6.4	2.5
0.9 to 1.2 (2.0 to 2.6)	64 to 84	7.6	3.0
1.2 to 1.5 (2.6 to 3.3)	85 to 105	8.9	3.5
1.5 to 1.8 (3.3 to 4.0)	106 to 126	10.2	4.0
1.8 to 2.1 (4.0 to 4.6)	127 to 140	11.4	4.5
>2.1 (>4.6)	>141	12.7	5.0
Broiler breeder males only on 100% litter			
<0.3[3] (<0.7)	0 to 14	3.8	1.5
0.3 to 0.6 (0.7 to 1.3)	15 to 28	5.1	2.0
0.6 to 0.9 (1.3 to 2.0)	29 to 43	6.4	2.5
0.9 to 1.2 (2.0 to 2.6)	44 to 61	7.6	3.0
1.2 to 1.5 (2.6 to 3.3)	62 to 77	8.9	3.5
1.5 to 1.8 (3.3 to 4.0)	78 to 92	10.2	4.0
1.8 to 2.1 (4.0 to 4.6)	93 to 104	11.4	4.5
2.1 to 2.4 (4.6 to 5.3)	105 to 120	12.7	5.0
2.4 to 2.7 (5.3 to 6.0)	121 to 138	14.0	5.5
2.7 to 3.0 (6.0 to 7.2)	139 to 149	15.3	6.0
3.0 to 3.3 (6.1 to 7.2)	150 to 161	16.5	6.5
>3.3 (>7.2)	>162	17.9	7.0

[1]Feed should be allocated and body weight routinely monitored to maintain the recommended body weight for a particular stock and age.
[2]Linear trough space is when both sides of the trough are available. If only one side of the trough is available, double the amount of feeder space/bird. Perimeter space for round feeders is obtained by multiplying linear trough space by 0.8.
[3]Provide 1 accessory feeder tray/75 chicks the first week of age.

Although adult broiler breeders are housed together for mating, they are fed separately to control BW gains. If both sexes have access to the same feeder, the more aggressive males will consume more than their share of feed. The female feeder is fitted with a 4.3-cm (1.7 in) grill sufficiently wide to allow feeding, whereas the male trough is fitted with a 5.1-cm (2.0 in) grill. In this manner, the installation of narrow grills over the female feeder may prevent males with larger heads from consuming the hen's feed. However, some genetic lines of male breeders have smaller heads allowing them access to the female feeder, which not only deprives the hens of proper nutrient intake, but may lead to excessive BW gains for those males eating the hen's feed. University research uses a multitude of genetic lines in their studies; therefore, a one-size restriction grill does not exist to meet the head size of all breeds of meat-type chickens. To rectify this situation, small plastic pegs that are 6.3 cm (2.5 in) in length (Noz-Bonz) are inserted through the nares of genetic lines of male broiler breeders known to have small heads at 20 to 21 wk of age to minimize male access to female feeders (Wilson, 1995a,b). The behavior of males with Noz-Bonz inserted did not appear to be affected, with resumption of foraging activities immediately post-insertion (Millman et al., 2000). Use of breeds or genetic lines that do not require Noz-Bonz is highly encouraged.

Ducks experience difficulty consuming mash because the mash, as it becomes moist, may cake on their mouth parts. Therefore, it is recommended that all feeds for ducks be provided in pelleted form. Pellets no larger than 0.40 cm (5/32 in) in diameter and approximately 0.80 cm (5/16 in) in length should be fed to ducklings less than 2 wk of age. Pellets 0.48 cm (3/16 in) in diameter are suitable for ducks over 2 wk of age.

Water

Recommendations for watering space vary widely, depending on species, type of bird (Siegel, 1974), bird density, and whether water intake is restricted. Minimum watering space recommendations for egg-laying

Table 9-3. Minimum feeder space for turkeys[1]

Bird type and age (wk)	Linear trough space/bird[2] (cm)	(in)
Commercial turkeys		
0 to 12[3]	1.9	0.75
12 to 22	3.8	1.50
Turkey breeder females[4]		
6 to 16 (physical feed restriction)	7.6	3.00
6 to 16 (full fed or ad libitum consumption of a low protein or energy diet)	3.8	1.50
16 to 29 (physical feed restriction)	12.7	5.00
16 to 29 (full fed or ad libitum consumption of a low protein or energy diet)	6.4	2.50
>29 (full fed)	7.6	3.00
Turkey breeder males (feed restricted)[4]		
>16 (physical feed restriction)	35.6	14.00
>16 (ad libitum consumption of low protein or energy diets)	10.0	4.00

[1]Feed should be allocated and body weight routinely monitored to maintain the recommended body weight for a particular stock and age.

[2]Linear trough space is when both sides of the trough are available. If only one side of the trough is available, double the amount of feeder space/bird. Perimeter space for round feeders is obtained by multiplying linear trough space by 0.8.

[3]During the first week, supplementary feed should be placed on some type of temporary feeders (such as egg flats) on the floor so as to double feeder space.

[4]Feeder space during earlier ages is the same as commercial or market turkeys.

strains of chickens, meat-type chickens, turkeys, and Pekin ducks are shown in Tables 9-5, 9-6, 9-7, and 9-8, respectively. Depending on type of poultry, specifications are for multiple-bird pens and cages, individual cages, or aviaries. These recommendations assume moderate ambient temperatures.

Newly hatched birds may have difficulty initially obtaining water unless they can find the waterers easily. Similar difficulties may occur when older birds are moved to a new environment, especially if the type of watering device differs from that used previously by the birds. Watering cups that require birds to press a lever or other releasing mechanism involve operant conditioning. Because individuals may fail to operate the releasing mechanism by spontaneous trial and error, shaping of the behavior may be required. Thus, it may be necessary to press the individual bird's beak or bill to the trigger to facilitate finding the water source. Watering cups may need to be filled manually for several days (or weeks in some cases) until the birds have learned the process. Water pressure must be regulated carefully with some automatic devices and watering cups. In such cases, pressure regulators and pressure meters should be located close to the levels at which water is being delivered. Manufacturer recommendations should be used initially and adjusted if necessary to obtain optimal results. Automatic watering devices require frequent inspection to avoid malfunctions that can result in flooding or stoppage. Waterers should be examined at least once per day to ensure they are in good working condition.

The height of drinkers should be adjusted to meet bird size. Birds accessing nipple drinkers should raise their heads up while standing to activate the trigger pins (Bell and Weaver, 2002). As a general guide, the bottom of the water trough should be approximately even with the back of the bird (Parkhurst and Mountney, 1988).

Poultry ordinarily should have continuous access to clean drinking water. However, with some restricted

Table 9-4. Minimum feeder space for Pekin ducks[1,2]

Bird type and age (wk)	Linear trough space/bird[3] (cm)	(in)
Growing ducks		
1[4]	0.9	0.35
2	1.0	0.40
3	1.3	0.50
4	1.5	0.60
5	1.7	0.65
6	1.8	0.70
7	1.9	0.75
Developing breeders (feed restricted)[5]		
7 to 28	10.2	4.0
Breeders		
>28	2.0	0.8

[1]Feed should be allocated and body weight routinely monitored to maintain the recommended body weight for a particular strain and age.

[2]Feeder space allocations may be slightly excessive for smaller breeds of ducks.

[3]Linear trough space is when both sides of the trough are available. If only one side of the trough is available, double the amount of feeder space/bird. Perimeter space for round feeders is obtained by multiplying linear trough space by 0.8.

[4]During the first week, supplementary feed should be placed on some type of temporary feeders (such as egg flats) on the floor.

[5]Feeder space during earlier ages is the same as for growing ducks.

Table 9-5. Minimum drinker space for egg-laying strains of chickens in floor pens, aviaries, or cages[1]

Bird type and age (wk)	Linear trough space/bird[2]				Cups or nipples	
	Females		Males		Females	Males
	(cm)	(in)	(cm)	(in)	(maximum no. birds/device)	
White Leghorns						
0 to 6[3]	0.75	0.30	1.00	0.40	20	15
6 to 18	1.00	0.40	1.25	0.50	15	11
>18	1.25	0.50	1.65	0.65	12	9
Mini Leghorns						
0 to 6[3]	0.68	0.27	0.90	0.36	22	17
6 to 18	0.75	0.30	0.94	0.38	19	14
>18	0.94	0.38	1.24	0.49	15	11
Medium-weight breeds						
0 to 6[3]	0.83	0.33	1.10	0.44	18	14
6 to 18	1.15	0.46	1.44	0.58	14	9
>18	1.44	0.58	1.90	0.75	10	8

[1]Egg laying strains of chickens should have continuous access to clean drinking water. Drinker space for layer breeder parent stock is the same as the commercial table egg-producing hen. Specifications for drinker space for single bird cages are the same as for multiple bird cages.

[2]Linear trough space is when both sides of the trough are available. If only one side of the trough is available, double the amount of drinker space/bird. Perimeter space for round drinkers is obtained by multiplying linear trough space by 0.8.

[3]Provide one 3.78-L [1-gal] or four 0.95-L [1-qt] chick drinkers/100 chicks during the first week of age.

Table 9-6. Minimum drinker space for meat-type chickens[1]

Bird type and age (wk)	Linear trough space/bird[2]		Cups	Nipples
	(cm)	(in)	(maximum no. birds/device)	
Commercial broilers				
0 to 4[3]	0.5	0.2	28	10
4 to 8	1.3	0.5	28	10
Broiler breeders				
0 to 8[3]	1.3	0.5	28	10
9 to 16	1.5	0.6	28	10
16 to 23	2.5	1.0	28	10
>23	5.0	2.0	28	10

[1]With the exception of feed restriction used with broiler breeders, meat-type chickens ordinarily should have continuous access to clean drinking water.

[2]Linear trough space is when both sides of the trough are available. If only one side of the trough is available, double the amount of drinker space/bird. Perimeter space for round drinkers is obtained by multiplying linear trough space by 0.8. A 40 in circumference hanging drinker would provide 0.4 in/broiler.

[3]Provide 2 satellite supplemental drinkers/100 chicks or one 3.78 L [1 gal] or four 0.95 L [1 qt] chick drinkers/100 chicks during the first wk of age.

feeding programs, overconsumption of water may occur, leading to overly wet droppings that can hamper health and performance of poultry due to poor litter quality. This situation can be controlled by restricting excessive water intake, usually by limiting water availability to certain times of the day, in accordance with accepted management programs that consider the amount of time that feed is available and also environmental temperature conditions. There is little effect on welfare indicators of breeders with limited access to water compared with breeders consuming water ad libitum (Hocking et al., 1993). Water should be provided each day and also made available during the time that feed is being consumed. Adequate drinker space is needed to prevent undue competition at the drinkers when the water is turned back on. Water may also be shut off temporarily in preparation for the administration of vaccines or medications in the water.

Most conventional poultry drinkers may be used for ducks, except for cup drinkers that are smaller in diameter than the width of the duck's bill. Nipple drinkers support slightly poorer duck performance during hot weather than do trough waterers. Ducks can grow, feather, and reproduce normally without access to water for swimming or wading, but weight gain may be improved slightly during summer months if such water is provided (Dean, 1967). If ducks are provided water for swimming or some other wet environment, they should also have access to a clean and dry place; otherwise, they are unable to preen their feathers and down properly, and the protection normally provided by this waterproof, insulated layer may be lost.

HUSBANDRY

Social Environment

All poultry species are highly social and should be maintained in groups when possible. However, certain social environments can be stressful to poultry and should be avoided. For example, repeated movement of individuals from one socially organized flock to another may induce stress in those individuals that are moved (Gross and Siegel, 1985). Human interactions with chickens can also contribute, either favorably or unfavorably, to the social environment of the animal (Gross and Siegel, 1982; Jones, 1994). A calm, friendly interaction between known animal caretakers and the birds will result in reduced stress and better performance compared with abrupt, careless interactions. Human–poultry interactions are discussed in more detail in the chapter on environmental enrichment.

Chickens, turkeys, and ducks are likely to panic when sudden changes occur in their environment (e.g., a wild bird flying overhead or loud noises to which the birds are not habituated). When birds are kept in group housing, this panic reaction may result in birds trampling each other and piling up against barriers or in corners with resulting injury and mortality. Husbandry

Table 9-7. Minimum drinker space for turkeys[1]

Bird type and age (wk)	Linear trough space[2] (cm)	Linear trough space[2] (in)	Cups (maximum no. birds/device)	Nipples (maximum no. birds/device)
Commercial females				
0 to 16.5[3]	1.27	0.50	28	10
Commercial males				
0 to 8[3]	1.27	0.50	30	20
8 to 16	1.91	0.75	25	10
16 to 20	2.54	1.00	20	10
Breeder females[4]				
8 to >54	1.91	0.75		
>30 restricted	2.54	1.00		
Breeder males[4]				
8 to >54	1.91	0.75		
>25 restricted	2.54	1.00		

[1]With the exception of feed restriction used with turkey breeders, turkeys ordinarily should have continuous access to clean drinking water.

[2]Linear trough space is when both sides of the trough are available. If only one side of the trough is available, double the amount of drinker space/bird. Perimeter space for round drinkers is obtained by multiplying linear trough space by 0.8.

[3]Provide satellite drinkers during the first week of age.

[4]Drinker space during earlier ages is the same as market or commercial turkeys.

methods should be used to prevent death loss caused by smothering. Such sudden changes should be prevented to the extent possible. Alternatively, young birds, which are less reactive to such stimuli, can be habituated to conditions that are likely to be encountered and could cause panic responses later in life.

Chickens. Excessive fighting and mounting (Millman et al., 2000) may occur in groups of mature males residing in floor pens. If such abuse is likely to be encountered, as when aggressive stocks are used, late adolescent or mature males should be placed in environments where those behaviors are not possible or are less injurious; for example, in individual cages, in multiple-bird cages with moderate density (Craig and Polley, 1977), or in mixed-sex flocks with appropriate sex ratios. The proportion of mature males in sexually mature flocks should be low enough to prevent injury to females from excessive mounting. Male to female ratios for breeding purposes can be variable in regard to different breeds and strains of chickens. The optimal ratio in most breeder flocks is 1 male to 12 to 15 females for egg-type strains and 1 male to 9 to 11 females for meat-type chickens. Some environmental enrichment techniques can be used to control aggression and over-mating in poultry (Estévez, 1999; Cornetto et al., 2002).

Recent research has shown that social dynamics in layers and chickens raised for meat are complex and increments in group size or density do not necessarily result in a linear increase in aggression or reduced welfare and performance (Estévez et al., 1997; 2003; 2007). Intermediate group sizes of around 30 birds were found to be more problematic than smaller (15) or larger (60 to 120) groups of layers in floor pens (Keeling et al., 2003). Chickens kept for meat production can be safely maintained in large groups of several hundreds or thousands of birds with no increased aggression or behavioral problems, as long as sufficient feeding and drinking space is provided to prevent competition for resources (Estévez et al., 1997). The welfare of broiler chickens tends to be affected more by environmental conditions (Dawkins et al., 2004) than by group size or density effects, as long as density is maintained within a reasonable range (Estévez, 2007).

Turkeys. Tom turkeys are prone to excessive aggression as they become older. Early beak trimming reduces the likelihood of injuries from fighting among toms. Breeder toms are housed separately from breeder hens using artificial insemination to produce fertile hatching eggs.

Ducks. Ducks, being very sociable animals, do not perform well in isolation. Therefore, it is imperative that individually caged ducks have some means of social interaction such as a wire partition between adjacent cages so that they can see and touch each other. For sexually mature breeder ducks, injury to females resulting from excessive mounting by drakes may be exacerbated in the presence of other stressful conditions such as lameness associated with foot pad trauma caused by improper flooring (discussed later in this chapter). For Pekin breeders, the ratio of males to females should not exceed 1:5 and may require periodic adjustment throughout the breeding cycle because of higher mortality rates for females than for males.

Table 9-8. Minimum drinker space for Pekin ducks[1]

Bird type and age (wk)	Linear trough space[2] (cm)	Linear trough space[2] (in)	Cups[3] (maximum no. birds/device)	Nipples (maximum no. birds/device)
Growing				
0 to 7[4]	1.91	0.75	10	15
Breeders[5]				
7 to >52	2.54	1.00	12	18

[1]With the exception of feed restriction used with duck breeders, ducks ordinarily should have continuous access to clean drinking water.

[2]Linear trough space is when both sides of the trough are available. If only one side of the trough is available, double the amount of drinker space/bird. Perimeter space for round drinkers is obtained by multiplying linear trough space by 0.8.

[3]Swish-type cups are 7.6 cm (3 in) in diameter and 2.54 cm (1 in) deep.

[4]Provide satellite drinkers during the first week of age.

[5]Drinker space during earlier ages is the same as for growing ducks.

Table 9-9. Minimum floor area per bird for egg-laying strains of chickens in floor pens, cages, or aviaries[1]

Type of housing and age (wk)	White Leghorns				Mini Leghorns				Medium-weight breeds			
	Female		Male		Female		Male		Female		Male	
	(cm^2)	(in^2)	(cm^2)	(in^2)	(cm^2)	(in^2)	(cm^2)	(in^2)	(cm^2)	(in^2)	(cm^2)	(in^2)
Pen[2]												
0 to 6	464	72	606	94	418	65	545	85	510	79	667	103
6 to 18	929	144	1,206	187	697	108	905	140	1,068	166	1,387	215
>18 Litter[3]	1,625	252	2,116	328	1,219	189	1,587	246	1,869	290	2,433	377
>18 S&L, W&L[3]	1,393	216	1,812	281	1,045	162	1,359	211	1,602	248	2,084	323
>18 All-S, All W	1,161	180	1,509	234	871	135	1,132	176	1,335	207	1,735	269
Cage[4]												
0 to 3	97	15	129	20	87	14	116	18	107	17	142	22
3 to 6	155	24	200	31	140	22	180	28	171	26	220	34
6 to 12	232	36	303	47	174	27	227	35	267	41	348	54
12 to 18	310	48	400	62	233	36	300	47	357	55	460	71
18 to 22	387	60	503	78	290	45	377	59	445	69	578	90
>22	464	72	606	94	348	54	455	71	534	83	697	108
Aviary[5]												
>22									1,155	173		

[1]A chicken should have sufficient freedom of movement to be able to turn around, get up, lie down and groom itself.
[2]Kinds of flooring: S&L, W&L = >50% slats (S) or wire (W) and <50% litter (L); All-S, All-W = all slats or all wire.
[3]Floor area for breeders is the same as commercial layers up to 18 wk of age. After 18 wk of age, provide 1,858 cm^2 (288 in^2) and 2,137 cm^2 (331 in^2) for litter pens and 1,625 cm^2 (252 in^2) and 1,869 cm^2 (290 in^2), respectively, for S&L or W&L to White Leghorn and medium weight breeders, respectively.
[4]A bird within a cage should be able to stand comfortably without hitting its head on the top of the cage. The cage door should be wide enough to allow for the easy removal of the bird.
[5]Space allocation when based on floor area only is 855 cm^2 (132 in^2).

Floor Area and Space Utilization

Chickens, turkeys, broilers, and ducks should have sufficient freedom of movement to be able to turn around, get up, lie down, and groom themselves (Brambell, 1965). Use of floor area by birds within groups follows a diurnal pattern and is influenced by the dimensions and design of the facilities. Birds may huddle together for shared warmth or spread out for heat dissipation. They generally use less area during resting and grooming than during more active periods and will often seek the protection offered by the walls of the enclosure (Newberry and Hall, 1990; Cornetto and Estévez, 2001b). Recommendations for minimum floor area for multiple-bird pens and cages as well as individually housed birds are presented for layer-type chickens, broiler-type chickens, turkeys, and ducks in Tables 9-9, 9-10, 9-11, and 9-12, respectively.

Floor space allowances for layer-type chickens in conventional cages are based on extensive research. In a survey of experiments involving density effects (mostly White Leghorn hens), Adams and Craig (1985) made multiple comparisons within specific categories for several production traits and for livability. Their survey indicated that livability and hen-housed egg production were reduced significantly when areas of 387 cm^2 (60 in^2) and 310 cm^2 (48 in^2) were compared with 516 cm^2 (80 in^2), amounting to reductions of 2.8 and 5.3% in livability and 7.8 and 15.8 eggs per hen housed, respectively.

Decreases in livability and other measures of well-being were also associated with high density. Craig et al. (1986a,b) found that livability and egg mass were significantly lower with 310 cm^2 (48 in^2) than with 464 cm^2 (72 in^2); Okpokho et al. (1987) and Craig and Milliken (1989) found livability was lower at 348 cm^2 (54 in^2) than at 464 cm^2 (72 in^2) and 580 cm^2 (90 in^2); and Craig and Milliken (1989) found lower hen-day rate of lay and egg mass per hen at the highest density. In the same studies, however, no differences in survival and egg production measures were detected between the 2 lower densities. From data on plasma corticosterone concentrations, Mashaly et al. (1984) concluded that more than 387 cm^2 (60 in^2) of space per hen should be provided; Craig et al. (1986a,b) found that plasma corticosterone concentrations were greater at 310 cm^2 (48 in^2) than at 464 cm^2 (72 in^2). Similarly, feather condition was worse (Craig et al., 1986a,b) and fearfulness was greater when estimated at 40 wk of age or older (Okpokho et al., 1987; Craig and Milliken, 1989). Using data on egg production, mortality, and serum corticosterone concentrations, Roush et al. (1989) concluded that 3 hens, rather than 4, should be kept in cages of 1,549 cm^2 (240 in^2) area; that is, within the goals and

Table 9-10. Minimum floor area for meat-type chickens in pens or cages[1]

Bird type, flooring, and body weight, kg (lb)	Approximate age (d)	Floor area/bird (cm^2)	Floor area/bird (in^2)
Commercial broilers on 100% litter or multiple bird cages[2]			
<0.3 (<0.7)	0 to 13	248	38
0.3 to 0.6 (0.7 to 1.3)	14 to 18	342	53
0.6 to 0.9 (1.3 to 2.0)	19 to 24	432	67
0.9 to 1.2 (2.0 to 2.6)	25 to 27	516	80
1.2 to 1.5 (2.6 to 3.3)	28 to 31	606	94
1.5 to 1.8 (3.3 to 4.0)	32 to 35	703	109
1.8 to 2.1 (4.0 to 4.6)	36 to 39	780	121
2.1 to 2.4 (4.6 to 5.3)	40 to 43	871	135
2.4 to 2.7 (5.3 to 6.0)	44 to 48	948	147
2.7 to 3.3 (6.0 to 7.2)	49 to 57	1,019	158
>3.3 (>7.2)	>58	1,097	170
Broiler breeder females or mixed ratio of 1 male to 10 females on 100% litter			
<0.3 (<0.7)	0 to 21	320	50
0.3 to 0.6 (0.7 to 1.3)	22 to 42	690	107
0.6 to 0.9 (1.3 to 2.0)	43 to 63	870	135
0.9 to 1.2 (2.0 to 2.6)	64 to 84	1,058	164
1.2 to 1.5 (2.6 to 3.3)	85 to 105	1,238	192
1.5 to 1.8 (3.3 to 4.0)	106 to 126	1,426	221
1.8 to 2.1 (4.0 to 4.6)	127 to 140	1,612	250
2.1 to 2.4 (4.6 to 5.3)	141 to 150	1,740	270
2.4 to 2.7[3] (5.3 to 5.6)	151 to 160	1,860	288
Individually caged adult broiler breeder female[2]			
>2.4 (>5.3)	>151	1,161	180
Broiler breeder males only on 100% litter in multiple bird pens			
<0.3 (<0.7)	0 to 14	320	50
0.3 to 0.6 (0.7 to 1.3)	15 to 28	690	107
0.6 to 0.9 (1.3 to 2.0)	29 to 43	870	135
0.9 to 1.2 (2.0 to 2.6)	44 to 61	1,058	164
1.2 to 1.5 (2.6 to 3.3)	62 to 77	1,238	192
1.5 to 1.8 (3.3 to 4.0)	78 to 92	1,426	221
1.8 to 2.1 (4.0 to 4.6)	93 to 104	1,612	250
2.1 to 2.4 (4.6 to 5.3)	105 to 120	1,740	270
2.4 to 2.7 (5.3 to 6.0)	121 to 138	1,860	288
2.7 to 3.0 (6.0 to 7.2)	139 to 149	1,974	306
3.0 to 3.3 (6.1 to 7.2)	150 to 161	2,090	324
>3.3 (>7.2)	>162	2,195	340
Individually caged adult broiler breeder male[2]			
>3.3 (>7.2)	>162	1,393	216

[1]A chicken should have sufficient freedom of movement to be able to turn around, get up, lie down, and groom itself.

[2]All birds in cages should be able to stand comfortably without hitting their heads on the top of the cages. The cage door should be wide enough to allow for the easy removal of the bird.

[3]Provide this amount of floor area/bird during the egg-laying phase when birds are housed on two-thirds slats and one-third litter or in multiple bird mating cages. Provide 2,787 cm^2 (432 in^2)/ bird on 100% litter during egg laying.

constraints employed, hens should have 516 cm^2 (80 in^2) rather than 387 cm^2 (60 in^2) area. Using operant determination for laying hens' preference for cage size, Faure (1986) indicated that a stocking density of 400 cm^2 (62 in^2) was sufficient most of the time, although hens would work to obtain more space (up to 6,000 cm^2 or 930 in^2) up to 25% of the day.

Modification of commercial cages from those currently in wide usage for chickens may improve the health and welfare of birds (Tauson, 1995). Thus, cage height should allow birds to stand comfortably without hitting their heads on the top of the cages. Studies have indicated at least 40 cm (15.7 in) over 65% of the cage area and not less than 35 cm (13.8 in) at any point is desirable (Harner and Wilson, 1985; Nicol, 1987). Taller cages may be necessary for larger breeds. Cage floors with a slope of no more than 9° in shallow, reversed cages may result in better foot health (Tauson, 1981).

Table 9-11. Minimum floor area for turkeys in pens or cages[1]

	Floor area/bird		
Bird type, flooring, and body weight, kg (lb)	(cm^2)	(in^2)	(ft^2)
Commercial turkeys on 100% litter or multiple/individual bird cages[2,3]			
<0.3 (<0.7)	257	40	0.3
0.3 to 2.0 (0.7 to 4.4)	580	90	0.6
2.0 to 3.0 (4.4 to 6.6)	807	125	0.9
3.0 to 6.0 (6.6 to 13.2)	1,419	220	1.5
6.0 to 8.0 (13.2 to 17.6)	1,871	290	2.0
8.0 to 12.0 (17.6 to 26.4)	2,741	425	3.0
12.0 to 16.0 (26.4 to 35.2)	3,548	550	3.8
16.0 to 20.0 (35.2 to 44.1)	3,866	600	4.2
Turkey breeder females on 100% litter in multiple bird pens			
<8.0 (<17.6)	2,786	432	3.0
8.0 to 12.0 (17.6 to 26.4)	3,715	576	4.0
>12.0[4] (>26.4)	4,644	720	5.0
Turkey breeder males on 100% litter in multiple bird pens			
<12.0 (<26.4)	3,715	576	4.0
12.0 to 17.0 (26.4 to 37.4)	4,644	720	5.0
>17.0 (>37.4)	5,573	864	6.0
Individually caged turkey breeder females with a solid littered floor[3]			
<12 (<26.4)	2,696	418	2.9
>12 (>26.4)	4,644	720	5.0
Individually caged turkey breeder males with a solid littered floor[3]			
<20 (<44.0)	4,644	720	5.0
>20 (>44.0)	8,359	1,296	9.0

[1]A turkey should have sufficient freedom of movement to be able to turn around, get up, lie down, and groom itself.
[2]Thin-stranded wire flooring not recommended after 3 kg of BW. Other cage flooring types such as hog wire (welded wire) or PVC piping may be appropriate for short-term housing of older and heavier birds.
[3]An individual bird within a cage should be able to stand comfortably without hitting its head on the top of the cage. The cage door should be wide enough to allow for the easy removal of the bird.
[4]Does not include space for nests or broody pens.

However, such low slopes may not be desirable in deeper cages, because difficulties are encountered in getting eggs to roll out efficiently (Elson and Overfield, 1976). Horizontal bars across the front of the cage appear to allow egg-laying strains of chickens to feed easily and with reduced probability of entrapment (Tauson, 1985). White Leghorn hens housed in cages with horizontal cage fronts had better feather scores than hens in cages with vertical bars fronts (Anderson and Adams, 1991). The cage door should be wide enough to allow easy removal of the bird.

Caged hens may cease egg production temporarily or birds may undergo a molt if removed from the cages to which they have become accustomed; for example, for cage cleaning. Therefore, hens and roosters may be kept in their cages for 18 mo or longer, as long as air cleanliness is maintained and excreta are disposed of regularly from under the cages. However, the incidence of osteoporosis and weak bones may be higher in hens caged for prolonged periods compared with hens housed in systems where greater freedom of movement is possible (Knowles and Broom, 1990).

The welfare of meat chickens is not compromised at densities of 15 to 17 birds/m^2 (1.4 to 1.6 birds/ft^2) as long as adequate environmental conditions are maintained (Dawkins et al., 2004; Estévez, 2007). However, welfare status for a given density will depend in part on the final BW at which the birds are grown and managed (Estévez, 2007). For example, heavy male broilers raised to 49 d of age at a stocking density of 30 kg of BW/m^2 (~1,053 cm^2/bird or 9.5 birds/m^2) had the lowest incidence of foot-pad lesions, the lowest incidence of scratches on the back and thigh, and had the best market BW compared with higher stocking densities of 35, 40, and 45 kg of BW/m^2 (Dozier et al., 2005). With 35 d-old male broilers grown to a lower BW of 1.8 kg, feed consumption, feed conversion, BW gain, and foot pad lesions were adversely affected with increasing stocking densities (25, 30, 35, and 40 kg of BW/m^2, Dozier et al., 2006). These results on lighter weight broilers suggested that the best bird performance and welfare was achieved at 25 kg of BW/m^2 (~761 cm^2/bird or 13 birds/m^2).

In terms of space use, there is no scientific evidence to suggest that social restriction on use of space occurs in large groups of broilers (Estévez et al., 1997), even in mature broiler breeders (Leone and Estévez, 2008). Although less active than layer strains, meat chickens

Table 9-12. Minimum floor area for Pekin ducks raised in total confinement[1]

	Litter floor[2]		Wire floor	
Bird type and age (wk)	(cm^2)	(in^2)	(cm^2)	(in^2)
Growing ducks in multiple bird pens				
1	232	36	232	36
2	464	72	439	68
3	839	130	651	101
4	1,116	173	974	151
5	1,393	216	1,187	184
6	1,671	259	1,413	219
7	1,858	288	1,625	252
Developing breeders in multiple bird pens[3]				
7 to 28	2,322	360		
Breeders in multiple bird pens				
>28	3,251	504		
Individually caged breeder female or male[4]				
>28	3,715	576		

[1]A duck should have sufficient freedom of movement to be able to turn around, get up, lie down, and groom itself. Space allocations may be slightly excessive for smaller breeds of ducks. The inside and outside areas for ducks in semi-confinement are totaled and equal the space allocations for confined ducks.

[2]Space for drinkers is included. Drinkers are located on a wire-covered section with a cement drain underneath.

[3]Developing breeders may be raised outdoors on well-drained soil (preferably sand) with open shelter. A minimum of 1,290 cm^2 (200 in^2) of shelter area /bird is recommended.

[4]An individual bird within a cage should be able to stand comfortably without hitting its head on the top of the cage. The cage door should be wide enough to allow for the easy removal of the bird. Does not include space for feeder, drinkers, or a hen's nest.

will use more space when available to them (Leone and Estévez, 2007). Studies have also shown that provision of partitions such as cover panels help to maintain a more-even bird distribution in the facility (Cornetto and Estévez, 2001b) and can help to control behavioral problems (Cornetto et al., 2002). Use of space can be improved by providing rectangular rather than square pens for the same available area (E. H. Leone and I. Estévez; personal communication). Although broiler chickens can be maintained in cages, it is best for their health and welfare to use floor pens provided with some type of litter such as wood shavings.

Because of a relative absence of research on well-being indicators for turkeys and ducks, recommendations are based on professional judgment and experience. Generally, area allowances are assumed to be adequate when productivity of the individual birds is optimal and conditions that are likely to produce injury and disease are minimal.

Singly caged birds are frequently used in agricultural research and teaching to establish or demonstrate fundamental principles and techniques. Because within-cage competition for feed and water is absent, feeding and watering spaces are not critical; however, individually caged birds must have ready access to sources of feed and water except during feed-restriction periods for meat-type breeder birds.

Flooring

Poultry may be kept on either solid floors with litter or in cages or pens with raised wire floors of appropriate gauge and mesh dimension. When poultry reside on solid floors, which are more adequate for heavy strains of poultry, litter provides a cushion during motor activity and resting and absorbs water from droppings. The ideal litter can absorb large quantities of water and also release it quickly to promote rapid drying. A dry, dusty litter or a litter that is too wet will have a negative effect on the health, welfare, and performance of poultry. Litter, when sampled away from the drinkers, needs to be moist but not so moist that it forms into a ball when handled. Litter should not emit excessive dust when disturbed. The poultry house should be ventilated to maintain litter in a slightly moist condition. Avoiding excess moisture in the litter improves bird health by reducing dirty foot pads, hock lesions, leg defects, and fecal corticosterone (Dawkins et al., 2004). Some examples of acceptable materials used for litter, depending on local availability, include rice hulls, straw, wood sawdust or shavings, and cane bagasse. Because litter materials differ in their ability to absorb and release water, husbandry practices should be varied to maintain proper litter conditions. Litter being stored for future use should be kept dry to retard mold growth.

When poultry are kept in cages or on raised floors, accumulated droppings should not be permitted to reach the birds. Droppings should be removed at intervals frequent enough to keep ammonia and odors to a minimum.

Ducks. Particular attention should be paid to the type of floor provided in pens or cages for the common duck because the epidermis of the relatively smooth skin on the feet and legs of this species is less cornified than that of domesticated land fowl (Koch, 1973) and, therefore, is more susceptible to injury. Properly designed, nonirritating floor surfaces minimize or prevent injury to the foot pad and hock and minimize subsequent joint infection. Dry litter floors are least irritating to the feet and hock joints of ducks and should be used whenever possible, particularly if ducks are going to be kept for extended periods. Litter floors that are not kept dry present a serious threat to the health of the flock.

Wire floors and cage bottoms of proper design may be used without serious adverse effects if the ducks are not kept on wire for more than 3 mo. Younger ducks and smaller egg-type breeds (e.g., Khaki Campbell) are less susceptible to irritation from wire than are older and larger meat-type breeds (e.g., Pekin). Properly constructed wire floors and cage bottoms should provide a smooth, rigid surface that is free of sags and abrasive spots. The 2.5-cm (1-in) mesh, 12-gauge welded wire is usually satisfactory for ducks of all ages over 3 wk. Mesh size should be reduced to 1.9 cm (0.75 in) for ducklings less than 3 wk of age. Vinyl-coated wire is preferable, but stainless steel or smooth, galvanized wire floors are satisfactory. Slats are not recommended for ducks because leg abnormalities have developed in ducks kept in research pens with slatted floors. Raised plastic flooring is commonly used in commercial duck production and is superior to wire in terms of reducing foot and hock damage.

Irritation to the feet and legs of ducks is reduced greatly if hard flooring such as wire occupies only a portion of the total floor area of a pen. In large floor pens, one-third wire and two-thirds litter is a satisfactory combination, provided that drinking devices are located on the wire-covered section of the pen, which greatly reduces the transport of water from the drinking area to the litter.

Maintenance of litter in a satisfactorily dry condition is considerably more difficult in housing for ducks than for chickens and turkeys. Ducklings drink approximately 20% more water than they need for normal growth (Veltmann and Sharlin, 1981), and, as a result, the moisture content of their droppings is relatively high—approximately 90% (Dean, 1984). To offset this extra water input in duck houses, extra litter and removal of excess water vapor by the ventilation system are essential. Supplemental heat may be necessary to aid in moisture control.

Perches

Egg-laying strains of chickens housed in cage-free systems are highly motivated to use perches at night (Olsson and Keeling, 2002). An entire flock (100%) will utilize perches at night if sufficient roosting space is provided (Appleby et al., 1993; Olsson and Keeling, 2000). Perches allow hens to roost comfortably with a minimum of disturbance and provide the opportunity for hens to seek refuge from aggressive birds so as to avoid cannibalistic pecking (Wechsler and Huber-Eicher, 1998). Perches also minimize bird flightiness (Brake, 1987). Early exposure to perches during rearing encourages adult perching behavior (Faure and Jones, 1982) leading to a lower incidence of floor eggs (Appleby et al., 1983; Brake, 1987). Adult Spanish breeds of chickens housed on a slatted/litter combination floor with perches compared with no perches were less stressed (Campo et al., 2005). However, if perches are not designed properly, they can lead to keel bone deformities (Tauson et al., 2006).

Perches should be designed to allow hens to wrap their toes around the perch and to balance themselves evenly on the perch in a relaxed posture for an extended period of time. The perch should be elevated high enough from the surface floor to allow hens to grasp the perch without trapping their claws between the perch and the floor and to discourage the harboring of mites. The center of the upper surface of the perch should be flat to allow for weight distribution so as to minimize keel deformities and foot problems. Perch edges should be smooth and round. The perch should be made of non-slip material. Ideally, perches should be positioned over slats or wire to prevent manure accumulation under the perches. Perch placement should minimize fecal contamination of birds, drinkers, and feeders below.

Egg-Laying Strains. All hens should be able to roost at the same time; therefore, provide a minimum of 15 cm (6 in) of usable linear perch space per egg-laying strain of chicken. Perforated floors that have perches incorporated into the floor structure and the rail in front of nest boxes can be counted as perch space. A minimum of 20% of the perch space should be elevated above the adjacent floor. Perches also need to be away from the wall at a sufficient distance to allow birds to use the perch. The height of the perch should not exceed 1 m (3.3 ft) above the floor so as to minimize skeletal fractures during bird flight from a perch. Provide enough space to allow a bird to jump down from its perch at an angle no steeper than 45°. Perches should be at least 30 cm (12 in) apart (horizontally) to minimize cannibalistic pecking between birds on parallel roosts.

Meat-Type Chickens. Only about 20% of broilers in a flock will use perches at a single time. Depending on bird size, each broiler requires a perch space of 15 to 20 cm. If colony size is 100 birds and bird size indicates 20 cm of perch space/bird, then provide 400 cm of perch space/100 birds for 20% usage. The width of the perch can range from 4 to 6 cm (1.6 to 2.4 in) with perch heights of 10 to 30 cm (4 to 12 in) depending on bird size (RSPCA, 2008a). Broiler breeder hens prefer a roost with a width of 5 cm (2 in) over narrower roosts of 3.8 cm (1.5 in) and 2.5 cm (1.0 in) (Muiruri et al., 1990). For adult broiler breeders, provide 28 cm (11 in) of elevated roost per bird.

Turkeys. If perches are to be used for turkeys, provide a minimum of 30 cm (12 in) to 40 cm (16 in) of elevated roost per bird. Perch height is dependent on bird size relative to breed, sex, and age of marketing with ranges from 20 to 150 cm (8 to 59 in). Turkeys appear to do well on wooden perches with rounded edges with dimensions of 5 cm (2 in) in height and 7.5 cm (3 in) in width (RSPCA, 2007).

Nests

Hens place a high value on accessing nests, and their motivation for use increases greatly as the time of oviposition approaches (Cooper and Albentosa, 2003). Hens without prior exposure to nests also show strong motivation to use nests for egg laying (Cooper and Appleby, 1995; 1997). Nests facilitate egg collection and minimize the risk of cloacal cannibalism. Because eggs laid in nests are cleaner and more sanitary, every effort should be made to avoid floor eggs. Use of electrical hot wire near walls outside of the nests may discourage the laying of floor eggs, as may a bright light that eliminates shadows when directed toward the corner.

Pullets intended for systems with nests should be reared with access to raised areas and perches from an early age to become adept at moving up and down in space. Pullets allowed to access perches during rearing are less likely to lay eggs on the floor during the laying period (Appleby et al., 1983; Brake, 1987). Birds should be transferred to the layer house before sexual maturity to allow for sufficient time for exploration of the house and to find the nests before onset of lay.

Nests should be dark inside. Lights in nest boxes should be avoided because of increased risk of cannibalism. Nests should be constructed and maintained to protect hens from external parasites and disease organisms. Nests should be closed to bird access at night and re-opened before lay early in the morning. Nests should be regularly inspected and cleaned as necessary to ensure that there is no manure accumulation.

Nests should be provided with a suitable floor substrate (e.g., turf pads or wood shavings) that encourages nesting behavior. Nests with wire floors or plastic-coated wire floors alone should be avoided. The provision of loose litter material in nests can be useful for training hens to use nests.

For individual nest boxes with a single opening, provide a minimum of 1 nest box per 5 birds. Nest size for hens of egg-laying strains, which includes table-egg producers and layer breeders, can be 30 cm wide by 30 cm deep by 36 cm high (12 × 12 × 14 in). Nests for broiler breeders are slightly larger than those for egg-laying strains of chickens with recommendations of 36 cm wide by 30 cm deep by 36 cm high (14 × 12 × 14 in). Turkey breeders require a nest size of 51 cm wide by 61 cm deep by 61 cm high (20 × 24 × 24 in), whereas duck breeders are provided a nest size of 36 cm wide by 45 cm deep and 30 cm high (14 × 18 × 12 in). For colony nests, provide a minimum of 0.8 m^2 (9 ft^2) of nest space per 100 chickens (egg-laying strains). Use of colony nests with duck breeders is not recommended because of increased incidence of floor eggs, egg breakage, and egg eating compared with individual nests. Hotter climates may require more nest space.

Brooding Temperatures and Ventilation

Because thermoregulatory mechanisms are poorly developed in young chicks, poults, and ducklings, higher environmental temperatures are required during the brooding period. Requirements of young birds may be met by a variety of brooding environments (e.g., floor pen housing with hovers or radiant heaters distributed in localized areas, battery brooders, and cage or pen units in heated rooms).

Ventilation is ordinarily gradually increased over the first few weeks of the brooding period. Whether ventilation is by a mechanical system or involves natural airflow, drafts should be avoided, and streams of air that impinge upon portions of pens or groups of cages should be minimized. In relatively open brooding facilities, as in houses having windows for ventilation and with chicks kept in floor pens, draft shields may prove beneficial up to 10 d after hatching.

Young birds may huddle together or cluster when sleeping but are likely to disperse when awake. Within limits, birds can maintain appropriate body temperatures by moving away from or toward sources of heat when that is possible and by seeking or avoiding contact with other individuals. Extreme huddling of young birds directly under the source of heat, especially during waking hours, usually indicates a need for more supplemental heat; dispersal associated with panting indicates that the environment is too warm.

With brooding systems that allow birds to move toward or away from heat sources, the temperature surrounding the brooding area should be at least 20 to 25°C (68 to 77°F) during the first few weeks but not be so high as to cause the young birds to pant or show other signs of hyperthermy. When the entire room is heated and chicks are not free to move to cooler areas, the minimum temperatures that are recommended below may be too high. Thus, during the first week after hatching, a lower temperature (e.g., a few degrees below 32°C) may reduce the lethargy and nonresponsiveness that is otherwise likely to be seen.

Areas with minimum temperatures that are adequate for comfort and prevent chilling should be available to young birds. The following minimum temperatures and weekly decreases are suggested until supplementary heat is no longer needed:

- for chicks, a 32 to 35°C ambient temperature (90 to 95°F) initially, decreasing by 2.5°C (4.5°F) weekly to 20°C (68°F); however, for some well-feathered strains, supplemental heat may be discontinued at 3 wk if room temperature is 22 to 24°C (72 to 75°F);
- for poults, 35 to 38°C (95 to 100°F), decreasing by 3°C (5°F) weekly to 24°C (75°F);
- for ducklings, 26.5 to 29.5°C (80 to 85°F), decreasing by 3.3°C (6°F) weekly to 13°C (54°F). After the brooding period, ducklings are comfortable at environmental temperatures of 18 to 20°C (64 to 68°F).

Ducks. The recommended ventilation rates for chickens and turkeys have also given good results with ducks (Davis and Dean, 1968). Generally, however, lower relative humidity is desirable in duck houses to help offset the higher water content of duck droppings. Proper screening underneath watering equipment in houses with litter floors and the addition of generous amounts of litter are necessary features of the moisture control program. When outside temperature allows, supplemental heat may be used to help to control moisture build-up in duck houses.

Semen Collection and Artificial Insemination

Semen collection and artificial insemination may be used in poultry depending on the species and type of research being conducted. Several good references are available for information and training procedures (Bakst and Wishart, 1995; Bakst and Cecil, 1997). Methods for semen collection and artificial insemination in poultry were developed in the 1930s and put into practice by the turkey industry such that artificial insemination is commonly used in commercial turkey breeding.

Under conditions of artificial insemination, the breeder males and females are usually housed separately. Careful and calm handling of the birds is needed to prevent injury and facilitates the success of the collections. Collection of semen from poultry involves restraining the male by the legs during the process. After stimulating the male by manual massage of the back area toward the tail, the semen is removed by squeezing the upper part of the cloaca (called a “cloacal stroke”) and collected into a clean container. The number of cloacal strokes used should be limited to 4 strokes to avoid damage to the cloacal tissues. The semen may be inseminated without dilution or diluted with an extender. Males may be used for semen collection several times a week on alternate days although more than 3 collections per week may result in reduced semen volume and sperm concentration. The males must be acclimated to the handling and the semen collection process. Males may need to go through the procedure 3 to 4 times before they have a good response, but this can vary largely from male to male.

During the insemination process, the hen is gently restrained by the legs or held between the legs of the inseminator. Manual pressure is applied to evert the cloaca and expose the opening to the vagina. Semen is placed into the vaginal opening with an insemination straw, a small syringe (without a needle), or a pipette tip (when accuracy of volume inseminated is of critical importance). Depth of insemination will vary with species. As insemination occurs, the pressure on the cloaca is gradually released. After insemination, the hen should be gently released. If done correctly, the process takes only a few seconds to complete and should cause no pain or discomfort to the hen. Hens should also be acclimated to handling and the insemination process. If females are stressed or nervous, they may expel all or a portion of the semen immediately after the insemination.

A typical insemination schedule that will give the highest level of fertility involves 3 inseminations within the first 10 d at the onset of reproduction, followed by insemination on a weekly basis. In turkey hens, more-frequent inseminations may be necessary to maintain fertility as they become older. Actual insemination schedules will vary depending on the research objectives.

STANDARD AGRICULTURAL PRACTICES

For handling birds and for all practices under this heading, experienced and skilled persons should carry out or train and supervise those who carry out these procedures.

Beak Trimming

Trimming of the tip of the beak is done to minimize injury and death due to aggressive and cannibalistic behavior. Outbreaks of cannibalism among egg-laying strains of chickens, turkeys, and ducks can occur with any housing system, resulting in a serious welfare problem. If the trimmed beak grows back, a second trim may be needed.

An alternative to beak trimming is use of low light intensity in housing systems where light control is feasible. Genetic stock that shows little tendency towards cannibalistic behavior and feather pecking should be used when possible (Hester and Shea-Moore, 2003). Use of enrichments to control cannibalism and feather pecking are discussed in Chapter 4: Environmental Enrichment.

Egg-Strain Chickens. Production, behavior, and physiological measurements of stress and pain as indicated by neural transmission in the trimmed beak are used as criteria to determine well-being in beak-trimmed birds. In addition, the welfare of those hens that are pecked by beak-intact hens has been evaluated. Disadvantages of beak trimming include short-term stress (Davis et al., 2004) as well as short-term, and perhaps long-term, pain following the trimming of the beak (Kuenzel, 2007). Because feeding behavior must adapt to a new beak shape, a bird’s efficiency in eating is impaired following a trim. Welfare advantages include decreased mortality; reduced feather pulling, pecking, and cannibalism; better feather condition; less chronic stress; and less fearfulness and nervousness. Welfare advantages are more applicable to the interactive flock, whereas welfare disadvantages are applicable to individual birds whose beaks are trimmed (Hester and Shea-Moore, 2003). Genetic lines differ in their aggressiveness and beak-trimming requirements (Craig, 1992). Genetic selection is effective in reducing or eliminating most feather-pecking and beak-inflicted injuries (Craig and Muir, 1993, 1996; Muir, 1996), and heritability estimates for survival suggest that the prospects for improving livability through genetic selection are good (Ellen et al., 2008). Therefore, when feasible, stocks should be used that require either minimal or no beak trimming. Nevertheless, beak trimming is justified in stocks that otherwise are likely to suffer extensive feather-pecking and cannibalistic losses. Management guides, available from most breeders, indicate methods for beak trimming to reduce these vices. Beak trimming should be carried out when birds are 10 d of age or younger (Hester and Shea-Moore, 2003; Glatz, 2005; Kuenzel, 2007).The amount of beak removed should be 50% or less to avoid neuroma formation and to allow the keratinized tissue to regenerate (Kuenzel, 2007). The length of the upper beak distal from the nostrils that remains following trimming should be 2 to 3 mm (0.08 to 0.12 in). The lower beak should be slightly longer than the upper beak. If a second trim is needed due to regrowth of the beak, it is recommended that it be done before the pullets are 8 wk of age to avoid a decrease in egg production (Andrade and Carson, 1975).

Broiler-Type Chickens. Beak trimming is generally not required in young broilers raised for meat production. For broiler breeders, early beak trim before 10 d of age is generally sufficient to control feather-pecking and cannibalism in breeder stocks.

Turkeys. Beak trimming of turkeys is a standard management practice. Strains of turkeys (Noble et al., 1994) and sexes (Denbow et al., 1984; Cunningham et al., 1992) differ in their requirement for and their response to beak trimming. In strains of turkeys that exhibit a high incidence of beak-inflicted injuries, arc-type beak trimming at hatching is effective in reducing such injuries (Noble et al., 1994). Severe arc-type beak trimming (1.0 mm anterior to the nostrils) increased mortality relative to hot-blade trimming of the upper beak at 11 d of age (Renner et al., 1989). There was no evidence that arc-type beak trimming 1.5 mm from the nostrils at hatching or hot-blade trimming of the upper beak at 11 d of age increased mortality relative to leaving beaks intact (Renner et al., 1989; Noble et al., 1994). Beak trimming (infrared, hot-blade, arc-trim) completed shortly after hatch did not modify performance or behavior in commercial market toms compared with nontrimmed controls and also reduced pecking damage when beak regrowth did not occur (Kassube et al., 2006; Noll and Xin, 2006). Arc-type beak trimming 1.5 mm anterior to the nostrils or hot-blade trimming of the upper beak at 11 d of age is recommended to prevent cannibalism in strains of turkeys that exhibit a high incidence of beak-inflicted injuries.

Ducks. Feather pecking is a behavior that sometimes occurs in ducks and may be controlled either by partial removal of the nail of the upper bill or inhibition of the growth of the nail by heat treatment (Dean, 1982; Gustafson et al., 2007). If not controlled, feather pecking injures the feather follicles of the tail, wings, and back, and the protective feather and down covering breaks down. Tip searing using cautery only (compared with hot-blade trimming with cautery) may be a preferred method of bill trimming in Pekin ducks because of better weight gains following a trim and fewer changes in the morphology of the bill (Gustafson et al., 2007).

For all species of poultry it is critical that the equipment used to trim beaks is maintained in good working condition. Personnel involved in beak trimming should receive species-specific training on proper procedures to use during beak trimming.

Toe Trimming

Because of the size and weight of the birds involved and the sharpness of their toenails, broiler breeder males and market turkeys generally have certain toes trimmed to prevent them from inflicting serious injuries to the hens during natural matings or to their penmates. Toe trimming should be done at 1 d of age using an electrical device that removes and cauterizes the third phalanx of the toes involved. Microwave energy application to the tip of the toe is also used to restrict toenail growth and is conducted using specialized equipment at the hatchery. In chickens, the microwave method did not result in increased stress or fearfulness (Wang et al., 2008). Provision of abrasive strips or hard surfaces in the facility may help to control excessive claw growth and reduce the need for declawing. Trimming toes for the purpose of identification is unjustified and should not be performed.

Egg-Laying Strains of Chickens. Leghorn hatchlings whose claws were trimmed through use of microwave energy experienced increased mortality and reduced feed consumption and BW during the pullet grow-out period. Removal of the claws resulted in a reduced foot spread allowing the toe of some pullets to slip into the wired mesh of the cage floor. The pressure on the web between the toes led to a splitting of the foot epidermis in 24 of the 1,200 pullets whose claws were trimmed (Honaker and Ruszler, 2004). Compton et al. (1981a,b) reported similar results when using a hot blade to reduce claw length and suggested that chick movement about the wired cage was difficult until the toe grew long enough to allow the foot to spread across the wired cage floor. These results suggest that trimming the claws of egg-laying strains of chickens is not recommended.

Broiler Breeder Males. When meat-type males of certain genetic lines are to be used in natural matings, the practice of trimming certain toes (inside toe and dewclaw nail) at 1 d of age can be considered; toe trimming of breeding males may prevent injury to the female during natural mating. However, there is also evidence that toe trimming may impair the mating ability of males (Ouart, 1986). The removal of one nail does not appear to cause chronic pain (Gentle and Hunter, 1988). For those genetic lines with long spurs, the spur bud on the back of the cockerel's leg may be removed at 1 d of age using a heated wire. Use of genetic lines with short, blunt spurs is preferable over spur removal. Most commercially available broiler breeder lines do not need to have their spurs removed.

Turkeys. Toe trimming is a widespread management practice in turkey production. The number of toes trimmed per foot varies from 1 to 3 plus the dewclaw.

Carcass grade of turkeys may or may not be improved by toe trimming (Owings et al., 1972; Proudfoot et al., 1979; Moran, 1985), although rate of early mortality may be increased (Owings et al., 1972; Newberry, 1992). Toe trimming may be justified when excessive injuries are likely to occur, but alternative methods should be considered to prevent bird injury.

Snood Removal

Turkeys have a frontal process called a snood, which is an ornamental appendage for the adult male. The snood can be grasped by other turkeys during fighting and can be torn or damaged. Breaks in the snood skin can be a health concern (e.g., erysipelas) among older turkeys (mature or breeders) or those housed on pasture or on ranges. Data collected from industry showed that snood removal in tom poults reduced the odds of mortality (Carver et al., 2002). To avoid injury and possible infection, the snood can be removed from the newly hatched male poult by clipping or pinching the snood from its base on the head. If removed, the process should occur as soon as possible after hatching (most likely at the hatchery) and no later than 3 wk of age (Berg and Halverson, 1985; Clayton et al., 1985; Parkhurst and Mountney, 1988). Snood removal after 3 wk of age is possible by clipping (Scanes et al., 2004) but not recommended without veterinary advice (Clayton et al., 1985) as the snood will continue to increase in size and vascularization especially in the males (toms).

Partial Comb and Wattle Removal

Removal of part of the comb (dubbing) and wattles of chickens may be needed if birds are kept in cages. Combs and wattles can get caught in wire openings or feeders after significant comb and wattle growth has occurred (Card and Nesheim, 1972; Fairfull et al., 1985). Comb and wattle removal is more commonly performed on cockerels because these structures are larger in males. Dubbing or removal of part of the wattles should only be used as a last resort when equipment or housing conditions cannot be modified to prevent torn or damaged combs or wattles.

To perform successful comb and wattle removal with minimal bleeding and excellent long-term results, surgical scissors, scalpel blade, or electrocautery/radiosurgery electrode (Bennett, 1993; 1994) should be used to remove part of the comb and wattle during the first few days after hatching. To reduce risk of infection between birds, the scissor blades can be disinfected.

Pinioning

Surgical pinioning, which involves amputation of the wing tip from which primary feathers grow, or tendonotomy is used mainly in exhibit birds to render them permanently incapable of flight. Pinioning is not recommended as a means of reducing bird flightiness in chickens, broilers, and ducks used for research and teaching. If flightiness is problematic, the primary feathers of one wing may be clipped.

Induced Molting

In birds, plumage is normally replaced before sexual maturity through a natural molt. Molting also occurs naturally after sexual maturity and is associated with a pause in egg production, which can be lengthy and take place out of synchrony with others in the flock. Inducing synchronized molting is used to rejuvenate laying flocks to extend the productive life of hens for 2 or 3 cycles of production. Molting has become a common procedure for commercial table-egg layers and sometimes for broiler breeders and turkey breeders. In recycled egg-laying strains of chickens, molting decreases the demand for chicks by 47% and thereby reduces the need to process, render, or bury the same percentage of spent hens. Rejuvenation of flocks also prevents the annual euthanasia of one hundred million additional male chicks. Additional advantages of molting include feather rejuvenation, thus improving thermoregulation. After a molt, livability and egg quality are improved during the second cycle of egg production compared with a nonmolt control group (Bell, 2003).

Egg-Strain Chickens. Several procedures used to induce a molt have included short-term (Ruszler, 1998) and long-term feed withdrawal; manipulation of dietary energy, protein levels, and dietary ingredients such as calcium, iodine, sodium, or zinc; and addition of feed additives that influence the neuroendocrine system such as iodinated casein (Kuenzel et al., 2005; Bass et al., 2007). These procedures have been used coupled with a reduction in the daily photoperiod. These methods cause a cessation of egg production along with decreased BW and feather loss. To allow for a return to egg laying, feather regrowth and BW gain are accomplished by feeding a diet designed to meet the nutritional requirements for a nonovulating, feather-growing hen (Bell, 2003).

Until 2000, the most common procedure used to induce a molt was to withdraw feed for 4 to 14 d without water restriction (Yousaf and Chaudhry, 2008). Feed withdrawal for inducement of ovarian arrest is stressful (Alodan and Mashaly, 1999; Kogut et al., 1999; Davis et al., 2000; Kuenzel, 2003) leading to increased mortality during the first 2 wk of the molt (Bell, 2003). Hens are more fearful during a fasted molt compared with before and after a molt (Anderson et al., 2007). Temporary frustration (Duncan and Wood-Gush, 1971) as indicated by a moderate increase in aggression on the first day of feed removal has been noted in molted hens compared with nonmolted full-fed controls (Webster, 2000). Aggression dissipated by the end of the first day, and molting hens showed elevated activity on the second day of fasting as indicated by increased nonnutritive pecking, standing, and head movement. Resting behavior increased by d 3 of fasting, and although nonnutritive pecking decreased from d 2, this pecking, interpreted as a redirection of foraging activity, remained higher than in control hens (Webster, 2000). Resting behavior persisted for the remaining part of the fast (Webster, 2000; Anderson et al., 2004). Similar changes in behavior of hens subjected to a fasting molting regimen have been reported by Simonsen (1979) and Aggrey et al. (1990) with the notation of an additional behavioral repertoire of increased preening on d 8 to 10 post-feed removal, most likely coinciding with the dropping of feathers.

Hens subjected to a fasting molt compared with nonmolted controls demonstrated decreased skeletal integrity (Mazzuco and Hester, 2005a), immunity (Holt, 1992a), helper T cells (CD4+ T cells, Holt, 1992b) and heterophil phagocytic activity (Kogut et al., 1999). In addition, hens subjected to a fasting molt showed an increase in *Salmonella enteriditis* (**SE**) fecal shedding (Holt and Porter 1992a,b; 1993; Holt, 1993; Holt et al., 1994; 1995), the prevalence of SE in organs (Holt et al., 1995), inflammation of the intestines (Holt and Porter, 1992a; Porter and Holt, 1993; Macri et al., 1997), the recurrence of a previous SE infection (Holt and Porter, 1993), and susceptibility to SE infection (Holt, 1993) compared with nonmolting controls. *Salmonella enteriditis* was readily transmitted horizontally among molting birds under simulated field conditions (Holt and Porter, 1992b; Holt, 1995; Holt et al., 1998), whereas in actual field settings, increased environmental *Salmonella* was observed in molted versus nonmolted hens (USDA, 2000; Murase et al., 2001).

As an alternative to fasting, hens subjected to non-feed-removal molting regimens show post-molt performance (egg production, egg weight, feed efficiency, and egg shell quality) not unlike the hens of the fasting molting regimen. Examples of successful non-feed-removal molting methods include the ad libitum feeding of diets high in corn gluten, wheat middlings, corn, or a combination of 71% wheat middlings and 23% corn (Biggs et al., 2003; 2004). *Salmonella* shedding, intestinal inflammation, and internal organ contamination of SE-challenged hens were reduced (Holt et al., 1994; Seo et al., 2001) and bone mineral density improved (Mazzuco and Hester, 2005b; Mazzuco et al., 2005) through the use of non-feed-withdrawal molting programs (wheat middlings or wheat middling/corn combinations) compared with hens of a fasted molt. Environmental presence of *Salmonella* increases during the molt in rooms containing fasting hens, but not in rooms of hens molted through wheat middlings (Murase et al., 2006). *Salmonella* fecal populations did not increase during a non-feed-removal molting program compared with the pre-molt and post-molt periods, with *Salmonella* prevalence being the lowest during the molting period (Li et al., 2007). Biggs et al. (2004) reported no differences in social behavior between fasted hens and hens subjected to a non-feed-removal molting program. These results on increased resistance to *Salmonella* and improved skeletal integrity suggest that non-feed-withdrawal methods of molting should be used rather than the more conventional feed-withdrawal molting regimens. During the non-fast molt, hens should be monitored for health, mortality, and body weight. Water withdrawal or restriction, which can lead to increase mortality especially during hot weather, is not recommended.

Broiler Breeders, Turkey Breeders, and Duck Breeders. Induced molt is occasionally done on parent breeding stock using feed withdrawal methods (Leeson and Summers, 1997). Molting methods for breeder ducks are similar to those used for broiler breeders. Nonfasting methods of inducing a molt have not been reported in breeder stock.

ENVIRONMENTAL ENRICHMENT

Refer to Chapter 4: Environmental Enrichment for information on enrichment of poultry environments.

HANDLING AND TRANSPORT

Refer to Chapter 5: Animal Handling and Transport for information on handling and transportation of poultry.

SPECIAL CONSIDERATIONS

Genetically Modified Birds

To date, there are no special animal care requirements for transgenic or cloned poultry. Transgenic birds are cared for in the same manner as conventionally domesticated birds unless the genetic manipulation affects basic bird needs. Future transgenic animals may have special requirements (e.g., birds with specific gene insertions) and they should be cared for based on their genotype and phenotype rather than based on the technology that was used to create them.

Surgeries

All intrathoracic and intraabdominal invasive surgeries require anesthesia. Caponization, or removal of the testes, is an invasive surgical procedure that requires anesthesia. See the sections in Chapter 2: Agricultural Animal Health Care that deal with surgery of experimental animals.

Other Bird Species

Gaunt and Oring (1999) and the Canadian Council on Animal Care (1984, 2008) offer recommendations on the care and use of wild birds, pigeons, doves, nondomesticated waterfowl, budgerigars, and quail. Parkhurst and Mountney (1988) provide animal care recommendations for geese, Coturnix quail, Bobwhite quail, chukar partridge, pheasants, guinea fowl, peafowl, pigeons, and swan. The Standing Committee of the European Convention for the Protection of Animals Kept for Farming Purposes (1997) provides recommendations and minimum standards for the welfare of ostrich and emu. Recommendations from New Zealand (Animal Welfare Advisory Committee, 1998) provide animal care guidelines for ratites. These references are given not as an endorsement but as referral material only.

EUTHANASIA

Appropriate methods of euthanasia and slaughter for poultry are covered in Chapter 2: Agricultural Animal Health Care and by the American Veterinary Medical Association (**AVMA**) *Guidelines on Euthanasia* (AVMA, 2007). For the purpose of euthanasia, the AVMA accepts administration of barbiturates, inhalant anesthetics, carbon dioxide, carbon monoxide, gunshot (free-range birds only), and stunning followed by exsanguination, and conditionally accepts nitrogen and argon gases, cervical dislocation, decapitation, and maceration. Methods of euthanasia should ensure death and be selected to take into account any special requirements of experimental protocols so that useful data are not lost.

Anesthetic agents are generally acceptable, and most avian species can be quickly and humanely killed with an overdose of a barbiturate administered intravenously.

When relatively large numbers are involved, exposure to gas euthanasia agents such as carbon dioxide in enclosed containers may be used. Atmospheres containing a significant amount of carbon dioxide, with or without the presence of oxygen, cause birds to head shake and breathe deeply, but scientific evidence indicates that these behaviors are not associated with distress. These behavioral changes are not caused by irritation of mucosal epithelia in the nares or throat because they occur at carbon dioxide levels considerably below the threshold of trigeminal nerve nociception; that is, 40 to 50% carbon dioxide based on lab study of nerve fiber activity in chickens (McKeegan, 2004). Furthermore, although poultry can detect atmospheres containing significant concentrations of carbon dioxide and may show responses indicative of some degree of aversion, several studies have demonstrated that most chickens and turkeys will voluntarily enter carbon dioxide concentrations as high as 60 to 80% (Raj, 1996; Gerritzen et al., 2000; Webster and Fletcher, 2004; McKeegan et al., 2005; Sandilands et al., 2008). Because poultry can be rendered unconscious with 30% carbon dioxide in air, or less if enough time is allowed, (Webster and Fletcher, 2001; Gerritzen et al., 2004, 2006), and concentrations of carbon dioxide above 50% quickly kill adult birds (Raj and Gregory, 1990, 1994), it is not necessary to measure the carbon dioxide concentration closely when performing euthanasia. However, it is important that the process be observed and carbon dioxide added, if necessary, to ensure that death is attained without undue delay. Although euthanasia of poultry in high concentrations of carbon dioxide (60–80%) is relatively rapid, it also tends to promote vigorous convulsive wing flapping after loss of posture. Although the birds are not conscious when this occurs (Raj et al., 1990), the sight can be disagreeable to human observers. Slower induction of unconsciousness using lower concentrations of carbon dioxide appears to sedate birds and greatly reduces convulsions after loss of posture (Webster and Fletcher, 2001). Newly hatched chicks and poults have a greater tolerance to carbon dioxide so concentrations of 60 to 70% should be used to kill these birds (AVMA, 2007).

Anoxia using argon or nitrogen, or mixtures of these gases with carbon dioxide, has been found to be effective and to produce minimal distress, but residual oxygen should be kept below 2% (Raj, 1993; Raj and Gregory, 1994; Raj and Whittington, 1995; McKeegan et al., 2006). Anoxia causes strong convulsive wing flapping after loss of posture. When employing anoxia, the final gas concentration should be achieved quickly to avoid development of ataxia in conscious birds (Woolley and Gentle, 1988; McKeegan et al., 2006).

It is acceptable for an individual who has been properly trained to use cervical dislocation without stunning or anesthesia when small numbers of birds that are small in size require euthanasia. When enough experienced personnel are available for a given period of time, large numbers of birds can be euthanized via cervical dislocation, as long as operator fatigue is avoided. Cervical dislocation is not recommended with larger poultry such as turkeys and adult ducks or when one individual is required to kill a large number of birds. Following cervical dislocation, the necks of small birds should be checked for dislocation of vertebrae to ensure that the procedure was done correctly. Use of a captive bolt device for euthanizing large birds such as adult ducks and turkeys can be used by a skilled operator provided bolt diameter, mass and velocity, and angle of bolt impact are appropriate (Raj and O'Callaghan, 2001). Restraint of the head without compromising the handler is a major concern with use of captive bolt, so safety and restraint issues need to be considered. Both cervical dislocation and captive bolt killing are followed by severe convulsive wing flapping. A Burdizzo, a flat-edged clamp used for crushing tissue, may be used by trained individuals for the euthanasia of large poultry, particularly turkeys older than 10 wk of age. Birds must be rendered insensible (e.g., stunning or anesthesia) before crushing the cervical vertebral column with a Burdizzo.

Embryonated eggs may be destroyed by chilling or freezing at a temperature of 4°C for 4 h (European Commission, 1997). Decapitation or anesthetic overdose are suitable methods for embryos that have been exposed for experimental purposes. Maceration in a purpose-designed macerator, a mechanical apparatus with rotating blades, is also considered a humane method for killing embryos and surplus neonatal chicks. Chicks are rapidly fragmented by maceration, which results in immediate death (Bandow, 1987; American Association of Avian Pathologists, 2005).

Slaughter

Slaughter of animals entering the human food chain must comply with regulations as outlined in the *Federal Humane Slaughter Act* (Code of Federal Regulations, 1987). The processing area for poultry slaughter should be designed and managed to minimize bird discomfort and distress (Nijdam et al., 2005). The manager or person in charge of the processing area should be competently trained in animal slaughter and is responsible for training all staff to carry out their duties responsibly and humanely.

The holding area for birds to be processed should be adequately ventilated and protected from temperature extremes and adverse weather such as wind, rain, sleet, snow, and hail. Upon arrival, birds should be inspected to ensure that none are injured or suffering from heat or cold stress. Injured birds with signs of severe stress should be humanely killed or slaughtered immediately. If numbers are in excess, the farm manager should be contacted immediately. Birds should be processed as soon as possible once they arrive at the slaughter facility. All birds should be slaughtered within 12 h of feed and water withdrawal. Feed withdrawal minimizes microbial contamination of the carcass by preventing breakage of the gastrointestinal tract (e.g., the crop) during processing. All transport crates and trucks should be inspected to make sure that all of the birds have been removed for processing.

Birds should be handled carefully when removed from crates or, in the case of large turkeys, from livestock trailers. In plants with automated lines, birds should be shackled with a line running at a speed that permits the proper positioning of the birds to prevent injuries such as broken bones or bruising and to minimize discomfort (Gentle and Tilston, 2000) and stress (Kannan et al., 1997; Debut et al., 2005; Bedanova et al., 2007). Shackles should be of proper size to prevent bird escape and discomfort. Both legs should be hung on the shackles. To keep birds in the proper position for stunning, the height of the line should be adequate. Measures should be taken to minimize wing flapping such as use of funnels, breast bars, curtains, low light intensity or blue lights, reduction in noise, running a hand down birds after shackling, and avoiding bends in the line between the shackling area and the stunner. In nonautomated systems, cones (funnels) should be of appropriate size. Birds should not be suspended upside down in cones or shackles for more than 90 s before they are stunned.

Poultry killed using exsanguination should first be stunned using electrical or gas methods. Stunned birds may recover consciousness quickly; therefore, exsanguinations should be accomplished immediately after stunning to avoid recovery from consciousness. Exsanguination itself results in a rapid loss of consciousness if both carotid arteries are completely severed (Gregory and Wotton, 1986, 1988). Considerations involved in electrical stunning are discussed by Gregory and Wilkins (1989), Bilgili (1992), and Raj and Tserveni-Gousi (2000). Electrocution is acceptable if the current travels through the brain and through the heart. Occasionally some birds may not develop ventricular fibrillation after electrocution, so any birds showing signs of recovery should be immediately killed by other means such as by cervical dislocation, decapitation, or gas.

Electrical stunners adjusted for sufficient current (Bilgili, 1999) should render birds immediately insensible before neck cutting, and they should remain insensible during exsanguination. Acceptable stunners include a hand-operated stunner, stunning knife, a dry stunner incorporated into a metal bar or grid that is electrically live, or an electrical water bath. Hand-held electrical stunners may be used for shackled birds or for those birds that are restrained in a cone. The electrodes are applied to either side of the head between the ear and eye. The stunner should be applied to shackled birds until wing flapping stops or until the legs become rigid and extended when using the cone. With respect to use of a water bath for stunning, the water level in the bath should be set so that the heads of all birds make effective contact with the water. Use of an ammeter is recommended to monitor current flow through the water bath while it is loaded with birds. The water bath should be deep enough to prevent water overflow and the electrodes should extend the length of the water bath. Birds exiting the water bath should be regularly checked to ensure that stunning is effective. Characteristics of adequate stunning include rigidly extended legs, rapid and constant body tremors, wings held close to the body, open eyes, and an arched neck with the head directed vertically. If cardiac arrest is induced during stunning, birds become limp with no breathing or reflex of the nictitating membrane. Pupils are dilated and the birds do not respond to a comb pinch. Stunning equipment should be maintained properly (e.g., maintenance of water bath conditions, ground bars, connectors) to ensure an adequate stun.

Gassing birds before exsanguination may be a humane method of rendering birds insensible, but further research is needed to determine if it is a superior method. If birds are gassed before or immediately after removal from transport crates or vehicles, they avoid the stress of shackling (Gentle and Tilston, 2000) and the potential of pre-stun electrical shock. Gas types and concentrations appropriate for stunning poultry are discussed in the previous section on euthanasia.

Post-stun exsanguination should be initiated by making a ventral cut in the neck, wherein at least both carotid arteries or the carotid artery and the jugular vein on one side are severed. Properly stunned birds will not show voluntary behavior such as eye blinking, coordinated head or limb movements, or attempt to escape the shackle or cone during exsanguination. Some involuntary convulsive movement, such as a wing flap, is not unusual as the blood supply to the brain becomes depleted.

In some cases there may be a need for kosher or halal slaughter of birds, which does not allow stunning. For this purpose a very sharp knife with a straight surface that is at least twice the length of the head should be used to cut the arteries, veins, trachea, and esophagus. A poultry scalpel can also be used effectively. An aggressive single stroke cut is most effective. Birds must be permitted to bleed out before further work is conducted. This process should only be performed on birds that are adequately restrained such as by the use of a cone. Birds must be rendered insensitive (i.e., no eyeblink reflex when poked) in less than 30 s.

Following exsanguination, birds must not be breathing when they enter the scalder (USDA, 2008). Birds must be monitored to make sure they are dead before entering the scalding tank. If any bird shows signs of consciousness, they must be removed from the processing line and promptly stunned.

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Chapter 10: Sheep and Goats

Domestic sheep (*Ovis aries*) and goats (*Capra hircus*) are small ruminants, and, as such, their general care and management are often similar. However, because they are a different genus and species, their behaviors, foraging practices, diet selections, uses, and several physiological characteristics can be different. Thus, facility design and husbandry must be consistent with the behaviors, nutrient requirements, use, and physiology of each species. For optimal results, the people who care for these animals should be well trained, have appropriate education, certifications, and(or) relevant experience, understand the species requirements, and have good observational and communications skills.

In many countries, and states and provinces within countries, various laws and regulations define and govern animal husbandry practices. Local Institutional Animal Care and Use Committees (**IACUC**) and people using sheep and goats in research and teaching should be familiar with laws and regulations that govern animal husbandry practices, and they should be certain that animal care and use protocols are in compliance.

FACILITIES AND ENVIRONMENT

Sheep and goats used in research and teaching may be produced and managed under a variety of environmental conditions, including completely or partially enclosed buildings, drylots, pastures, and remote rangelands. Regardless of the production environment, the management system should be appropriate for the research or teaching objectives and must ensure that the animals are cared for properly.

Because of their adaptability and the insulating value of wool and hair, artificial shelter for sheep and goats may not be necessary. Site-specific needs for artificial shelter should take into account the geography, local environment and climate, and anticipated extremes of temperature. For shelter from wind, cold, or sun, sheep and goats typically seek shelter near terrain and structures, such as trees, shrubs, swales, boulders, ridges, and artificial windbreaks. Wind-chill effects can be predicted for small ruminants (Ames and Insley, 1975). Shelter for goats to provide warmth, shade, and protection from wind and precipitation is important.

When barns or sheds are provided, adequate ventilation and clean, dry surroundings are necessary to improve air quality, reduce the incidence of disease, and increase animal comfort. Poor ventilation has reduced the performance of dairy sheep, and recommendations for adequate ventilation have been published (Sevi et al., 2002, 2003a,b, 2006; Albenzio et al., 2005). Guidelines for facilities layout and housing can be found in *Management and Diseases of Dairy Goats* (Guss, 1977), *Goat Production* (Gall, 1981), *Goat Farming* (Mowlen, 1992), *Goat Husbandry* (Mackenzie, 1993), *Sheep Housing and Equipment Handbook* (MWPS, 1994), *Sheep Production Handbook* (ASIA, 2002), *Small Ruminant Production Medicine and Management: Sheep and Goats* (Faerber, 2004), and *Hoop Barns for Horses, Sheep, Ratites, and Multiple Utilization* (Harmon et al., 2004); Caroprese (2008) has discussed sheep housing and welfare.

In range, pasture, or outdoor drylot conditions, harvested feed resources, desirable forage, and prevailing weather conditions are key determinants of area requirements. The space required per animal depends on the intent of the research and teaching, type and slope of floor or ground surface, weather conditions and exposure, and group size. Floor or ground area requirements vary considerably among locations, depending on conditions, husbandry, and management. Estimated minimum area recommendations for confined sheep are listed in Table 10-1 (MWPS, 1994), the *Sheep Housing and Equipment Handbook* (MWPS, 1994), and in Sevi et al. (1999).

Acceptable floor surfaces include well-drained compacted soil, nonskid concrete, concrete-slatted floors, composition mats, wood, and expanded-metal or woven-metal flooring or other materials that allow for proper footing and comfort for small ruminants. When goats have access to outside lots or pastures, an adequate sheltered area is 0.5 m^2 (5.4 ft^2) per goat (Kilgour and Dalton, 1984). Stall feeding of dairy goats requires 1.5 m^2 (16 ft^2)/goat (Kilgour and Dalton, 1984). Sheep and goats are relatively intolerant of mud, so access to well-drained, dry shelter is desirable. Crushed stone or stone dust is a suitable surface for heavily trafficked areas. Dust control in pens may reduce respiratory and other health problems and improve fleece quality. The surface

Table 10-1. Recommendations for minimum floor and feeder space for confined sheep used in research and teaching[1,2]

Facility	Floor type	Rams (65–90 kg, 180–300 lb)		Dry ewes (65–90 kg, 150–200 lb)		Ewes and lambs (additional creep area required)		Lamb creep area (2–14 kg, 5–30 lb)		Feeder lambs (14–50 kg, 30–110 lb)	
		m^2	ft^2	m^2	ft^2	m^2	ft^2	m^2	ft^2	m^2	ft^2
Building floor area	Solid	1.86–2.79	20–30	1.12–1.49	12–16	1.39–1.86	15–20[3]	0.14-0.19	1.5–2.0	0.74–0.93	8–10
	Slotted	1.30–1.86	14–20	0.74–0.93	8–10	0.93–1.12	10–12[3]	0.14-0.19	1.5–2.0	0.37–0.46	4–5
Lot area	Dirt	2.32–3.72	25–40	2.32–3.72	25–40	2.79–4.65	30–50	—	—	1.86–2.79	20–30
	Paved	1.49	16	1.49	16	1.86	20	—	—	0.93	10
Feeder space		cm	in	cm	in	cm	in	cm	in	cm	in
Limit-fed		30.48	12	40.64–50.80	16–20	40.64–50.80	16–20	22.86–30.48	9–12	22.86–30.48	9–12
Self-fed		15.24	6	10.16–15.24	4–6	15.24–20.30	6–8	2.54–5.08	1–2	2.54–5.08	1–2

[1]Adapted from MWPS (1994).
[2]Space requirements should be increased for fully fleeced or horned sheep and during hot weather.
[3]Increase space if lambing rate is >170%.

of floors, pens, pastures, and other enclosures can affect hoof wear and health. Thus, an effective hoof care program is an important component of sheep and goat management and welfare, although this is occasionally overlooked when sheep and goats are kept indoors for prolonged periods.

Provision of additional feed and protection from wind and precipitation should be provided if the animals may experience extremes in temperature. Relationships between environmental conditions and nutrition have been described (NRC, 1981). Within intensive production facilities, ventilation and structural design should prevent moisture condensation during cold weather, provide cooling during hot weather, and ensure that air quality standards are met.

Newborn lambs and kids and recently shorn sheep and goats are susceptible to hypothermia, hyperthermia, and sunburn (see Shearing section). Frequency of neonatal observations should be increased, and appropriate shelter should be provided if natural conditions do not offer sufficient protection.

The water requirements of sheep and goats increase during hot and humid weather, and it is essential that animals have access to an adequate supply of potable water. Consideration for freezing of the water supply should be addressed in cold environments. Even though an adequate supply of liquid water is preferred, sheep will consume enough soft snow, as opposed to hard crusty snow, to meet their water requirements (Degen and Young, 1981). Established equations can be used to estimate water requirements under a variety of conditions (NRC, 2007). Additional information is available in the Feed and Water section of this chapter.

Small ruminants may need special attention when respiratory rates increase in response to increased air temperatures. During hot weather, handling or driving of sheep or goats should be restricted to the cooler times of day. Cold and cold stress should also be considered when using sheep and goats for research and teaching (for discussions of environmental, heat, and cold stress, see Ames et al., 1971; Morrison, 1983; Webster, 1983; Young, 1983).

Fencing

Fences allow managers to keep their animals together and isolated from unwanted animals. Proper fences and the appropriate use of fences can improve nutrition, health, and biosecurity, ensure the integrity of experimental designs and protocols, and protect the physical security of animals used in research and teaching. Because there are numerous research and teaching objectives, and many sizes, ages, and behaviors of sheep and goats, the appropriate fence design varies with experimental or teaching objectives (Miller, 1984). However, there are a few general recommendations for fencing:

1) Understand the behavior of sheep and goats and how they respond to, or cope with, fences. The agility, natural curiosity, and inquisitive nature of goats can make some difficult to contain. Because of their behaviors, goats and the occasional sheep will defeat traditional gate or pen latching mechanisms. Thus, safeguards or redundant measures for securing entrance and exit points should be considered. Sheep and goats may become entrapped in poorly constructed or inappropriate electric fencing, and one must consider this in the design and upkeep of any fencing with an electrical component. Sheep and goats frequently attempt to harvest forage that is beyond the perimeter of the fence. Sheep and

especially horned goats can get their heads and legs trapped in an inappropriate fence. During the breeding season, rams and buck goats often attempt to escape from their enclosure to reach ewes and does. Rams in adjacent enclosures will attempt to fight, which often destroys the fence between them and allows the rams to escape.

2) Design, construct, and maintain fences so that they do not endanger the animals being enclosed.
3) Determine the objectives for research or teaching activity and the features of the fence. Is the fence designed to keep animals enclosed? Keep animals enclosed and isolated from unwanted animals such as domestic, feral, or wild predators or other wildlife? Keep animals quarantined? Keep animals enclosed, but allow wild ungulates to safely enter and leave the enclosure? Provide a permanent enclosure? Provide a temporary enclosure?
4) Choose fencing designs and materials that offer the greatest and most affordable opportunity to accomplish the objectives for the fence.
5) Fence design should be consistent with institutional, local, state, and federal requirements, some of which may be legal requirements. Those requirements often vary among states, and they are likely to evolve and may become more stringent (Centner, 2000). Livestock laws, including fencing, for each state can be found at the following Web site: http://asci.uvm.edu/equine/law/fence/fnc_menu.htm
6) Ensure that a fence is constructed according to the appropriate design, make sure the fence is maintained properly, remains effective, and does not endanger the animals being enclosed.
7) Fencing is not always required (e.g., for sheep research on open rangelands), and federal rules in some locations prevent the construction of fences. Under these conditions, trained herders should stay with the sheep to protect the sheep and direct their grazing patterns. Sheep herding dogs and guardian animals such as special breeds of dogs (e.g., Akbash, Komondor, and Great Pyrenees) and llamas may be used for the care and protection of sheep on open rangeland or wherever there is a need for guardian animals (Cavalcanti and Knowlton, 1998; Andelt and Hopper, 2000; Meadows and Knowlton, 2000).

Lighting

Sheep or goats confined in a barn should experience diurnal cycles of light and dark, unless research protocols require alternative lighting regimens. Photoperiod and light intensity should be adequate for inspection, maintenance of activity patterns, and physiological control of reproductive functions in breeding animals (Ortavant, 1977). Illumination of 220 lx is recommended (MWPS, 1994). A window area of 0.5 m^2 (5.4 ft^2) per goat can provide adequate light and ventilation (Colby, 1972). Although natural daylight ordinarily is sufficient in most situations, supplemental light of 170 lx is recommended for ease of observation during lambing or kidding. In outdoor pens, lighting may deter predators, but it may interrupt reproductive cycles or alter feeding behaviors. Either natural or artificial light may be used to control reproductive cycles of sheep and goats.

Unless the experimental protocol has special light or photoperiod requirements, illumination in all animal rooms should minimize the physiological effects of variation in light intensity and duration. The diurnal cycle of light and darkness may also affect the performance of sheep and goats; therefore, maintaining a defined photoperiod is recommended. However, specified altered diurnal lighting may at times be implemented, for example, for certain reproduction research or for accelerated management systems that include autumn lambing and kidding because sheep and goats are sensitive to, and can be manipulated with, changing cycles.

FEED AND WATER

Feed

Sheep and goats should be fed according to established nutrient requirements to provide for proper growth of young animals and long-term maintenance of body weight (**BW**), body condition, which can be assessed as body condition score (**BCS**; Thompson and Meyer, 1994), and reproduction of adults (NRC, 2007). Body weight and condition of sheep and goats may vary considerably during different parts of the grazing and reproductive cycles (Engle, 1994; Taylor et al., 2009). Feeding programs should make it possible for animals to regain BW after the normal periods of BW loss. However, excessive feeding beyond what is needed to achieve defined production goals can result in nutrient wasting and metabolic disorders. Nutrient (i.e., protein, energy, fatty acid, mineral, vitamin, and water) requirements for sheep and goats and factors (e.g., feedstuffs, environmental, physiological, behavioral, and diseases) affecting nutrient availability and intake are addressed in *Nutrient Requirements of Small Ruminants: Sheep, goats, cervids, and New World camelids* (NRC, 2007). Furthermore, comprehensive descriptions and solutions for assessing and managing feed and metabolic-related diseases in sheep are discussed in the *Sheep Production Handbook* (ASIA, 2002).

A variety of feedstuffs may be fed to sheep and goats, but changes in relative amounts of forage and concentrates in diets should be made gradually. Animals should be managed during transition periods or sufficient potentially fermentable fiber should be fed to avoid the development of digestive disorders such as acidosis. Male sheep and goats consuming diets with moderate to large amounts of concentrate are prone to urinary calculi. Occurrences of this condition can be prevented or minimized by maintaining a dietary Ca:P ratio of at least 2:1, including urine-acidifying agents such as ammonium chloride in the diet, and increasing dietary salt content to promote water intake. When feeding nontraditional feedstuffs, their composition should be evaluated and potential nutrient toxicities or deficiencies should be corrected.

Feeding equipment should be constructed and located to be available for ready access, provide sufficient feeder space, prevent injury to animals, and minimize contamination of feed with excreta. Providing sufficient feeder space (see Table 10-1) is important for sheep and goats when feeding limited amounts of feedstuffs that are ingested quickly (e.g., supplements and concentrates) so that all animals have access to feed. If feeder space is limited so that all animals cannot eat at the same time, sufficient potentially fermentable neutral detergent fiber should be included in concentrate diets to provide substrate for rumen fermentation and to prevent metabolic disturbances (Thonney and Hogue, 2007).

Sheep and goats in some production settings undergo periods of nutrient deficiencies that result in considerable BW loss. Hence, research to address such scenarios may necessitate simulation of such conditions. Researchers should be aware that, even though restricted nutritional planes can decrease BW and BCS, adaptive decreases in the maintenance energy requirement (ME_m) can minimize the negative effects of such changes. In research dealing with limited nutritional planes, individual BW and BCS of sheep and goats should be monitored frequently so that excessive decreases are avoided. Thus, if a study has a target BCS for a group of 2 on a scale of 1 to 5, some animals will have lower BCS, perhaps ≤ 1.5, which is undesirable particularly if the research requires maintaining such a BCS for an extended period. Furthermore, animals on limited planes of nutrition with low BCS can be more susceptible to health concerns under adverse environmental conditions and, thus, less competitive for limited feeder and shelter space, compared with animals in better condition. Animals reaching very low BCS (<1.5 on a 5-point scale) should be placed on a higher plane of nutrition to regain BW and increase their BCS.

Sheep and goats can consume a variety of plants (i.e., grass, grass-like, forbs, and shrubs) when grazing on pasture or range. Goats in particular will selectively browse small woody plants and brush. Thus, pasture and range forages for sheep and goats can vary from season to season and among geographic locations. Nutritional management of pastured animals is mainly controlled by movement of sheep and goats to pastures of varying forage density and by supplying appropriate minerals and water as necessary. Sheep and goats differ somewhat in susceptibility to adverse effects or tolerance of some plant secondary metabolites, and physiological conditions in animals can change over time and confer some degree of adaptation to some plant secondary metabolites. When risks of plant secondary metabolite exposure are expected from pasture or a fed diet, animal conditions should be closely monitored.

In research and teaching settings, sheep and goats are sometimes used as biological control agents for managing invasive plant species. In such cases, animals may graze plant communities with limited plant diversity, be required to remove the majority of standing biomass, or graze plants that are potentially toxic or have large amounts of antiproductive secondary metabolites. Because sheep and goats differ in their susceptibility to plant secondary metabolites, grazing animals should be monitored regularly once grazing commences to ensure adequate forage availability and to identify potential or manifested nutrient deficiencies and plant-related toxicities. Any animals showing signs of nutrient deficiencies or toxicosis should be removed and treated accordingly.

Water

Water requirements of sheep and goats are based on, but not limited to, physiological state, dry matter intake, climatic conditions, and environment. A comprehensive discussion of water requirements is beyond the scope of this chapter, but NRC (2007) contains thorough descriptions of water use, sources, quality, and requirements for sheep and goats. Careful consideration of water source, location, and quality will enable caretakers to effectively assess and meet the water needs of sheep and goats in research and teaching settings.

Sheep and goats satisfy their water requirements from free-standing sources (i.e., drinking water), food (i.e., preformed water such as found in lush forages), and metabolic processes (i.e., metabolic water; NRC, 2007). In some research and teaching settings, sheep and goats consume water from sources such as ponds, streams, and springs. Even though it is common and preferred (NRC, 2007) for liquid water to be continually available to sheep and goats, this is not practiced in some production and research settings. For example, in extensive production systems (e.g., range or pasture), sheep and goats may derive their water requirement from fresh forages, as preformed water, or snow. Except under extremely hot temperatures, sheep that consume sufficient fresh forage to meet nutrient requirements also obtain enough moisture from the forage to meet their water requirements (Lynch et al., 1972). When cold drinking water is consumed in large volumes, the temperature of the rumen may decrease, which reduces the activity of rumen microorganisms (NRC, 2007). However, when water is available in the form of snow, sheep will consume it in small amounts along with the forage. Therefore, the cooling effect on rumen temperature may be less because of the temperature buffering capacity of water already present in the reticulum-rumen (NRC, 2007). Another example of when water is not continually available to research animals might be a head-box respiration calorimetry system in which water is offered at discrete times, perhaps twice daily, to avoid accumulation of excessive moisture in the calorimeter. Regardless of the specific setting, water availability should be appropriate for the desired level of productivity of the particular animal of interest and should be adequate to avoid dehydration, unless dehydration is a component of an approved research protocol.

Depending on source, drinking water can contain a variety of contaminants such as excessive sulfates and salts that are harmful or impair sheep and goat productivity. The NRC for dairy cattle (NRC, 2001) and beef cattle (NRC, 2000) are excellent sources of information on water contaminants that reduce livestock production. Historical records of water quality should be investigated or appropriate analyses should be conducted on drinking water sources. Water contaminants, not necessarily harmful to sheep, may interfere with results of experiments, such as in mineral balance studies.

Manufactured watering receptacles should be inspected, cleaned, and, if needed, repaired regularly to ensure that adequate supplies of good-quality liquid water are available. Watering receptacles should be designed and positioned to minimize feed and fecal contamination, be free of electrical and mechanical hazards that are harmful to animals and personnel, be protected from freezing, and accommodate the needs and behavior of sheep and goats. Improperly installed or defective electrically heated livestock waterers may allow stray voltage to flow through the water and metal in the waterer and deter animals from consuming adequate amounts of water. Several publications describe how to test for and prevent or eliminate stray voltage and the effects of stray voltage on livestock (for reviews, see USDA, 1991; Fick and Surbrook, 2007). Receptacles should be located in areas that facilitate research and(or) teaching goals and do not compromise the surrounding environment. In some locations, watering receptacles must contain ladders to allow birds and small mammals to escape. This adds to the maintenance of the watering receptacles, but it protects birds and small mammals, reduces contamination from birds and small mammals, and complies with federal or state regulations in some regions.

HUSBANDRY

People involved in using sheep and goats for research and teaching should be trained and skilled in performing a variety of routine management procedures. Injections (i.e., intramuscular, intravenous, subcutaneous, and intraperitoneal), ear-tagging, ear-notching, ear-tattooing, tail-web tattooing, deworming (i.e., drenching), shearing, and hoof care, including hoof trimming and detection, treatment, eradication, and prevention of contagious foot rot and other causes of lameness, are among the routine husbandry procedures that may be performed on sheep and goats at any age. Correction of entropion should be performed as soon as possible after birth. Immunization should be provided against pertinent diseases (e.g., clostridial diseases, caseous lymphadenitis, rabies, and "abortion diseases," particularly *Campylobacter jejuni* or *Campylobacter fetus*). Colostrum, preferably that obtained when a lamb or kid suckles its dam, should, unless it conflicts with an approved experimental protocol, be provided as a source of antibodies soon after birth to avoid disease during the neonatal period. To eliminate a possible route of transfer of disease into research and teaching settings, the practice of using raw colostrum from outside sources to supplement or replace colostrum from a lamb's or kid's dam should be avoided. The transfer of Johne's disease or paratuberculosis (*Mycobacterium paratuberculosis*) in cow colostrum is an important concern. In addition, viral diseases, such as the lentivirus diseases (e.g., caprine arthritis encephalitis and ovine progressive pneumonia), can be transferred through raw ewe and doe colostrum and milk (Herrmann-Hoesing et al., 2007). Pasteurization may reduce the likelihood of transferring pathogenic bacteria and viruses, but it may denature antibodies (for a brief review, see Loste et al., 2008). Detailed information on management procedures of sheep and lambs is described in the *Sheep Production Handbook* (ASIA, 2002), the *Sheep Care Guide* (Shulaw, 2005), *Goat Medicine* (Smith and Sherman, 2009), *Small Ruminant Production Medicine and Management: Sheep and Goats* (Faerber, 2004), and many other publications. For goats, husbandry and management information can be found in several references, including *Management and Diseases of Dairy Goats* (Guss, 1977), *Goat Production* (Gall, 1981), *Goat Husbandry* (Mackenzie, 1993), *Goat Farming* (Mowlen, 1992), *Small Ruminant Production Medicine and Management: Sheep and Goats* (Faerber, 2004), and *Meat Goat Production Handbook* (2007). In addition, a web-based training and certification program for meat goat producers is available (http://www2.luresext.edu/goats/training/qa.html).

Social Environment

Sheep and goats are social herbivores that typically live in flocks or herds of familiar animals and engage in frequent social interactions, especially during the active period of the day (Kilgour and de Langen, 1970). These interactions include establishment or maintenance of a social dominance hierarchy, grooming, competition for space or other resources, or play in young animals. At night, sheep and goats typically bed in close proximity to others in the flock or herd.

Housing sheep and goats in groups of familiar animals is desirable whenever this practice does not conflict with research and teaching objectives. When practical, a minimum group size of 3 is desirable. This provides for continuous social grouping even if one animal is removed. Social isolation is a source of distress for sheep and goats, and this stress may interfere with many physiological and behavioral variables. Isolation and restraint distress have been effective research tools for studying the effects of distress on physiology, behavior, and well-being (Matteri et al., 1984; Apple et al., 1995; Kannan et al., 2002). Animals that are isolated from the flock or herd or that have recently been separated from close social companions (e.g., at weaning) should be monitored frequently to reduce the possibility of injury or distress after separation.

New animals may be introduced into sheep and goat flocks and herds with relatively little social strife. However, unacquainted rams or buck goats may fight and severely injure each other. Occasionally, injuries can be fatal, especially when older, less agile rams are mixed with younger, stronger rams. Care should be taken to prevent excessive fighting among males when they are newly mixed. One method to reduce injury among newly grouped males is to severely restrict the space allocation for each animal for a few days to limit the distance available when rams run toward each other to butt heads. After rams appear to have established a social hierarchy, the space allocation per animal can be increased to provide sufficient space. Goats have a strong social hierarchy, and the addition of several goats to an established group is generally less stressful and more successful than the addition of an individual. Although horned and polled animals may be penned together, care should be taken to protect the polled animals when new animals are introduced to a flock or herd. Sufficient space and multiple feeders should be provided to prevent individuals from dominating feed and water supplies.

In intensive production conditions, dividing larger flocks or herds into smaller groups, modifying facility design, increasing the frequency of observation, and using claiming pens (otherwise known as jugs, lambing pens, kidding pens, or bonding pens) may enhance the survival rate of neonatal lambs or kids (Dwyer, 2008). Ewes and does should not lamb or kid in claiming pens because the pens are typically too small to allow the animals to move about freely during labor and parturition, become wet and very difficult to keep clean, and become sources of disease. Restricting the periparturient female's movements may increase the chances that a ewe or doe will step or lie on her offspring. Ewes and does should lamb or kid in a relatively large and open area that can be observed easily and, if necessary, then moved with their offspring into claiming pens to ensure bonding.

Parasite Control

Internal and external parasite control is essential, especially when sheep and goats are on pasture. Internal parasite control programs should be devised for each particular location with the recognition that programs that work for sheep may not be effective for goats at the same location, and vice versa. One should also recognize that most available anthelminthics are no longer adequately effective against *Hemonchus contortus*, which is the internal parasite of primary concern for sheep and goats. Because of this, new internal parasite control programs have been devised that emphasize the strategic, rather than general, use of anthelmintics, combined with new diagnostic procedures (e.g., FAMACHA eye color chart system), alternative treatments and preventatives, and managing to maximize resilience and resistance and minimize the development of infestations. Descriptions of internal parasite control programs can found at the Southern Consortium for Small Ruminant Parasite Control Web site (http://www.scsrpc.org/). *Small Ruminant Production Medicine and Management: Sheep and Goats* (Faerber, 2004) contains descriptions and images of how to administer dewormers (i.e., drench) to sheep and goats.

In intensive feedlot or laboratory environments, where pasture is not a potential route for parasite life-cycle maintenance, parasites such as *H. contortus* may not be a concern. However, in these same environments, parasites that are not primarily pasture driven (e.g., coccidia, giardia, and cryptosporidia) may be a greater problem and require added preventative and treatment considerations. Coccidia should be a concern when sheep and goats, especially younger animals, are managed under any confined conditions, which may include pastures of various sizes (Whittier et al., 2003).

External parasites are usually arthropods. They typically feed on the skin, wool, hair, and blood of sheep and goats and cause discomfort. External parasites may also be disease vectors and they can compromise the health and productivity of sheep and goats (Kaufman et al., 2006). Effective external parasite control programs should be developed and implemented to guard the health of sheep and goats. Kaufman et al. (2006) described various external parasites and typical control strategies.

Shearing

Because wool breeds of sheep do not shed their wool naturally and fiber is harvested from some breeds of goats, shearing may be necessary for the physical well-being of the animals, depending on specific environmental conditions and breed type, and to accomplish research and teaching objectives. Cashmere-producing goats are often sheared as well. Shearing lambs and kids during hot weather may improve feed intake and growth rates. Shearing ewes before lambing can increase lamb birth weights (Kenyon et al., 2006a,b), and it is often easier for newborn lambs to find a teat and suckle when ewes are shorn. In addition, shorn ewes usually transport less moisture into barns or claiming pens, are usually cleaner, and occupy less space. Crutching, the practice of shearing the wool from around the dock and udder, is an acceptable alternative when ewes are not completely shorn. However, shearing ewes before lambing is a more desirable management practice.

Hair-breed sheep and short-haired goats do not require shearing. Wool-breed × hair-breed crossbred sheep may require occasional or partial shearing, or they may shed. In any case, the decision of whether to shear wool-breed × hair-breed crossbred sheep should be based on the characteristics of the sheep and on the goal of ensuring the health and well-being of the animals.

The shearing facility should be clean and dry. Information on design is in the *Sheep Production Handbook* (ASIA, 2002) and Barber and Freeman (2007). To minimize the spread of infectious disease (e.g., caseous lymphadenitis, which is caused by infection with *Corynebacterium pseudotuberculosis*) between flocks, shearing equipment should be disinfected between flocks. When infectious disease conditions are present or suspected, equipment should be disinfected between animals. A good shearer is a skilled professional. A proper shearing technique restrains and positions the sheep correctly to ensure control and comfort of the animal (ASIA, 2002). Late-pregnant ewes (i.e., beginning of last third of pregnancy) may be shorn if handled properly. To facilitate the comfort of the animal during shearing, animals may be held off feed and water for 6 to 12 h before they are shorn. Sheep and goats should be dry when they are shorn. After shearing, sheep and goats should have protection from severe cold, windy, or wet conditions. Raised or stubble combs, which leave some wool on the sheep, may be used if sheep are likely to be exposed to inclement winter weather conditions. Another practice when sheep are shorn in cold climates is to increase the energy density of the diet for a period before and after shearing. In hot, sunny weather, shade may be necessary to prevent sunburn in recently shorn white-skinned sheep. Wind breaks, which may also provide shade, are beneficial under many environmental conditions.

STANDARD AGRICULTURAL PRACTICES

Other husbandry and health practices used in sheep and goat research and teaching that require special technical training and advanced skills include artificial insemination, semen collection, ultrasound examinations for pregnancy detection or predicting carcass traits, embryo flushing and transfer, and venipuncture. The *Sheep Production Handbook* (ASIA, 2002), *Small Ruminant Production Medicine and Management: Sheep and Goats* (Faerber, 2004), and several other references cited in this chapter contain descriptions of and images depicting many of these management practices. However, articles in peer-reviewed scientific journals are often the preferred sources for descriptions of specialized technical procedures. The publication *Producing Customer Products from Sheep: The Sheep Safety and Quality Assurance Program* contains information that may enhance training programs for the people who manage and care for sheep and goats for research and teaching (Roeber et al., undated).

Tail-Docking

Tail-docking of lambs is performed to reduce the possibility of soiling the long tail with urine and feces and the subsequent development of fly strike, a potentially fatal condition. With hair-breeds of sheep, tail-docking may not be necessary. Goat kids have an erect tail that is not docked. Tail-docking of wool-breed lambs is recommended unless the life span is limited to a season when fly infestations are unlikely and when the feed used does not result in a heavily contaminated fleece. There are several acceptable methods for tail-docking. These include rubber rings, hot-iron cautery, surgical removal, surgical removal after application of an emasculator, and various combinations of the basic procedures (Battaglia and Mayrose, 1981; Smith et al., 1983; Ross, 1989; ASIA, 2002; Kent et al., 2004). Tails should be docked when lambs are as young as possible, preferably before 2 wk of age. Very short tail docking should not be permitted because it increases the incidence of rectal, and perhaps vaginal, prolapses (Thomas et al., 2003). Based on recent research, tails should be docked at the distal end of the caudal folds, where the caudal folds on the underside of the tail attach to the tail (see photograph in ASIA, 2002); this practice reduces the incidence of rectal prolapse to negligible rates (Thomas et al., 2003).

Castration

Rams and bucks are castrated to prevent indiscriminate breeding and fighting, thus exercising genetic control, regulating the time of year of lambing, controlling the minimum age of first parturition and lactation, and reducing injuries. There are 3 commonly accepted methods for castrating rams and bucks: application of rubber rings, crushing the spermatic cord with an emasculator (i.e., the Burdizzo method), and surgical removal of the testicles; various combinations of the three are also common. For each method, the lamb's or kid's scrotum should be palpated to make sure that it contains 2 testicles and that there is no evidence of an inguinal hernia. The castration procedure should remove both testicles unless an approved experimental method precludes bilateral castration. Detailed descriptions of castration procedures are available in various publications (e.g., ASIA, 2002; Greiner and Wahlberg, 2003; Faerber, 2004). A common recommendation is to castrate lambs and kids when they are between 24 h and 7 d of age, although recommendations vary (Shutt et al., 1988; Lester et al., 1991; Wood and Moloney, 1992). Nevertheless, castrating lambs and kids as early in life as possible, considering weather, nutritional stress, environment, and the presence of complicating disease processes, seems prudent. Lambs are typically castrated and docked at one time to reduce the number of times they are handled. Ideally, ewes and does should be vaccinated prepartum against clostridial diseases so that their lambs and kids receive passive immunization via colostrum (de la Rosa et al., 1997). This will reduce the incidence of tetanus after docking or castration. If ewes and does are not vaccinated prepartum, tetanus antitoxin may be administered at castration and docking when there is risk of tetanus.

Acute Discomfort and Pain After Tail Docking and Castration

Tail docking and castration can cause acute alterations in the behavior of lambs, and the alterations in behavior are consistent with evidence of acute discomfort and pain (for examples, see Wood et al., 1991; Sutherland et al., 1999; Price and Nolan, 2001; Kent et al., 2000, 2004). The use of rubber rings without the use of analgesics, local anesthetics, or denervation (i.e., using a Burdizzo-type instrument to crush the tissue proximal to the rubber ring) increases the signs of acute discomfort and pain. Analgesics, local anesthetics, and denervation can reduce or eliminate the signs of discomfort and pain associated with using rubber rings for tail docking and castration (Wood et al., 1991; Sutherland et al., 1999; Price and Nolan, 2001; Kent et al., 2000, 2004). The Australian Veterinary Association recommends that tail docking and castration of sheep older than 3 mo should be treated as a major surgical procedure, and appropriate analgesia or anesthesia should be used (http://avacms.eseries.hengesystems.com.au/AM/Template.cfm?Section = Policies; accessed Nov. 13, 2008).

The people working with sheep and goats in research and teaching and the local IACUC should determine whether the methods used for tail docking and castration cause signs of acute or chronic discomfort and pain. Observational studies can be conducted locally, and a considerable body of scientific literature is available to make an informed decision, although not all methods for tail docking and castration have been studied (Wood et al., 1991; Sutherland et al., 1999; Price and Nolan, 2001; Kent et al., 2000, 2004). If the methods used cause signs of discomfort and pain, the IACUC should then work with the people who are using sheep and goats for research and teaching to develop and implement efficacious procedures for reducing or eliminating discomfort and pain after tail docking and castration.

Disbudding and Dehorning

Disbudding of goats should be performed at less than 1 mo of age for ease of the procedure and effectiveness of removing all of the horn bud. Cautery with heat should be used when possible and be considered the method of first choice, although surgery, freezing, and an acidic paste are other options. If disbudding or dehorning of young goats causes signs of significant discomfort, stress, and(or) pain, the local IACUC should work with the people using the goats for research and teaching to develop and implement efficacious procedures for reducing or eliminating discomfort, stress, and(or) pain. Horns of adult goats should be removed under general anesthesia or sedation and local anesthesia due to the anatomy and tissues involved and the significant development of horny tissue in older goats, especially bucks.

Dehorning is not a recommended management practice for sheep. Even though procedures for dehorning ram lambs have been reported, horn growth was not completely eliminated, even after a second procedure approximately 1 mo after the first; dehorned sites were prone to fly strike; and dehorning did not duplicate the phenotype of genetically polled rams (Dun, 1963). However, the horns of a mature ram may curl and become long enough to grow into the ram's head. To prevent this, a ram's horns should be trimmed or tipped but the living tissue inside the horns should not be cut. A fine-toothed saw blade may be used to trim and shape the horns so that they are not a danger to the ram, other sheep, and humans.

Mulesing

Because of their wrinkled skin and heavy fleece, Merino sheep seem to be more susceptible to fly strike, which causes severe discomfort, pain, and often death, than are other breeds. A surgical procedure called mulesing was developed to remove wrinkled, wool-bearing skin and reduce fly strike (for a description of the mulesing procedure, see Primary Industries Standing Committee, 2006; Paull et al., 2007). Mulesing has been a common practice in a few countries, but not the United States or other countries where Merino sheep are a minor breed. Even though mulesing seems to reduce the incidence of fly strike, it has been severely criticized because of the apparent discomfort and pain associated with the procedure. Thus, Australia and New Zealand, where mulesing has been used routinely, are phasing out the practice. The Australian wool industry announced in 2004 that the practice of mulesing will end by 2010. Until then, the *Model Code of Practice for the Welfare of Animals, The Sheep* (Primary Industries Standing Committee, 2006) describes the mulesing procedures that must be followed. A recent study indicates that a combination of a local anesthetic and a long-acting nonsteroidal antiinflammatory drug can reduce the discomfort and pain associated with mulesing (Paull et al., 2007). Nevertheless, mulesing is no longer an acceptable procedure, and an IACUC should be reluctant to approve the use of mulesing in research and teaching.

ENVIRONMENTAL ENRICHMENT

Refer to Chapter 4: Environmental Enrichment for information on enrichment of sheep and goat environments.

HANDLING AND TRANSPORT

The *Sheep Production Handbook* (ASIA, 2002) and *Sheep Care Guide* (Shulaw, 2005) contain detailed information about handling facilities and transportation. Information in Chapter 5: Animal Handling and Transport should also be considered.

SPECIAL CONSIDERATIONS

Dairy Sheep and Goats

Sheep and goats have been used as dairy animals for centuries, and dairy sheep and goats have been used for research and teaching in many countries for decades. However, dairy sheep and goat research and teaching are relatively new in North America. Publications such as *Principles of Sheep Dairying in North America* (Berger et al., 2004), *Management and Diseases of Dairy Goats* (Guss, 1977), and *Sheep Production Handbook* (ASIA, 2002) describe the management and care of dairy sheep and goats. Information in Chapter 7: Dairy Cattle of this guide is also applicable to sheep and goats, although the details of sheep, goat, and cattle dairying are species-specific and management plans should be developed with that in mind.

Even though the basic requirements and management of dairy sheep and goats are similar to those for meat animals, machine or hand milking to harvest milk for further processing introduces several conditions that are unique to dairy animals. Those include the design, sanitation, and maintenance of milking parlors and milk handling and storage equipment; frequent animal movement and handling; continuous udder care; increased risk of mastitis; artificial rearing of offspring (for methods, see Umberger, 1997; Berger et al., 2004) to prevent them from competing for milk that can be harvested for processing; manipulating nutrition to increase and sustain milk yield; and nutrient intervention to exert some degree of influence on milk quality. Before research and teaching programs with dairy sheep and goats are initiated, each element of dairy production should be evaluated so that the health and well-being of the sheep and goats are ensured.

Zoonotic Diseases

Zoonotic diseases, the risk of acquiring zoonotic diseases, how to reduce the likelihood of acquiring a zoonotic disease, and the signs, symptoms, and treatment of common zoonotic diseases should be explained to people who work with sheep and goats in research and teaching. See Chapter 2: Agricultural Animal Health Care for more information.

Predator Control

In certain geographic locations and during certain seasons, protection from predators (e.g., dogs, coyotes, bears, wolves, mountain lions, and some species of birds) is an important part of providing adequate care for sheep and goats. Nonlethal means of predator control (e.g., guard animals, lights, noise, and fencing) are preferable but may be inadequate. Special fencing such as electrified netting may be used to exclude some predators from livestock pastures (ASIA, 2002). Lethal means of control are appropriate when necessary to reduce injury and loss of sheep and goats. Federal, state, and local laws and ordinances must be followed. Animal and Plant Health Inspection Service, Wildlife Services, USDA, which provides expertise for resolving wildlife conflicts and protecting agricultural resources, is an important source of information and may be contacted to assist with developing effective and legal predator control programs.

Intensive Laboratory Environments

Certain laboratory settings do not allow for or utilize any range or pasture. These environments may include traditional outdoor feedlot operations, indoor/outdoor operations, or entirely indoor housing with natural or manufactured surfaces and several bedding possibilities (e.g., straw, wood shavings, recycled paper products, sand, dirt, or compost).

Some research and teaching objectives require sheep and goats to be housed under intensive laboratory conditions. Sheep and goats that are used for intensive procedures requiring prolonged restraint, frequent sampling, complete collection of feces and urine, or other procedures may experience less stress if they are pretrained and adapted to their intensively managed environments (Bowers et al., 1993; Hsieh et al., 1996). Sheep and goats may be kept in pens, metabolism stalls, stanchions, respiration chambers, or environmental chambers to facilitate these procedures. Sheep and goats are social animals and prefer companionship when they are housed. In general, sheep and goats should not be housed alone in intensive environments, and they should be able to maintain visual contact with other animals (Matteri et al., 1984; Apple et al., 1995; Kannan et al., 2002). Only under scientifically justified and approved protocols that dictate isolation (e.g., metabolic, respiratory, or environmental chambers) should this type of housing be considered for sheep and goats.

A common and beneficial practice is to shear sheep and fiber-producing goats before they are moved to intensive laboratory conditions; this improves animal and facility hygiene, often prevents reductions in feed consumption, and reduces the size of the animals, effectively providing more usable space per animal. If sheep and goats are managed under intensive laboratory conditions for extended periods, a hoof-care program should be developed and followed.

Sheep and goats housed in intensive laboratory environments should be kept clean and dry, and excreta should be removed on an appropriate schedule to achieve clean animals. Pens and stalls should be washed thoroughly at the beginning of every experimental period and as needed thereafter. Collection vessels for feces and urine depend on the design and construction of the units. Cleanliness should be maintained, and fly infestations should be avoided. Pens, stalls, and stanchions should be large enough to allow sheep and goats to stand up and lie down without difficulty and to maintain normal standing and lying postures.

The activity of sheep and goats maintained in intensive laboratory environments is restricted, and animals in these environments should be observed at least daily. The period of time that sheep and goats may be maintained in these environments before removal to a larger space for additional exercise should be based on professional judgment and experience. The IACUC should carefully evaluate studies that require sheep and goats to be housed in intensive laboratory environments; particular attention should be given to the duration that activity is restricted. Opportunities for regular exercise should be provided if exercise does not affect the experimental protocol. For sheep and goats housed in intensive environments, one should pay particular attention to appetite, fecal and urinary output, and soundness of feet and legs. The floor surface of pens in intensive laboratory environments is likely to be less abrasive than the ground surface of outdoor enclosures, and the reduced activity of sheep and goats in intensive laboratory environments may limit hoof wear. Thus, the frequency of hoof trimming may be greater when sheep and goats are housed in intensive laboratory environments.

Another aspect of intensive laboratory environments that should be addressed is unwanted animals and vermin, such as birds, rodents, insects, and feral cats. Whether it is in a complete indoor laboratory environment, a feedlot, or confined barn-type housing, vermin can be sources of disease for sheep and goats. Depending on the type of operation, studies, and production environment, local management or the IACUC should review the need for adequate pest-control measures. Birds nest and roost in barns and can spread diseases to sheep and goats. Adequate bird control measures may include netting or flaps at openings into buildings and an overall elimination of perching areas where possible. For rodents, which may vector a number of specific diseases, establishing a monitoring and(or) trapping program should be considered. Rodent attractants (e.g., exposed feed storage, feed waste, garbage, and excess fecal material) should be kept to a minimum or eliminated where possible. For insects where fly strike can be a concern or mosquitoes that can transmit viral agents such as West Nile virus, an active removal and destruction program should be considered. (Fly strike or myiasis refers to infestation with fly maggots. More specifically, fly strike is a condition in which parasitic, dipterous fly larvae feed on the necrotic or living tissue of the host.) As always, the local management or governing IACUC is responsible for reviewing each program and determining whether such measures are necessary or appropriate for the animals under their care.

Transgenics and Cloning

Transgenics as a technology was initially pioneered with mice (Gordon et al., 1980), with the production of the first transgenic sheep, pigs (Hammer et al., 1985), and goats (Ebert et al., 1991) following soon thereafter. Since then, the field has expanded considerably, and transgenic animals have become commonplace in many programs and facilities. The applications for transgenic animals are vast with utility not only in the investigation of gene function but also for development of animal models, increased disease resistance, altered or enhanced production traits, and production of proteins (e.g., recombinant biopharmaceuticals) in several biological fluids such as milk, blood, urine, and semen (Nieman and Kues, 2003).

Transgenics and cloning bring additional and unique aspects of care, health, and welfare for sheep and goats. Specifically, a thorough understanding of normal endogenous gene function and homeostasis is required to increase the likelihood of detecting abnormal gene function, often manifested as abnormal sheep and goat physiology from exogenously introduced transgenes or constructs, which may occur in some animals. Additionally, carrying a transgene in a homozygous state may elicit abnormalities or lethal conditions not seen in the hemizygous state.

Another concern relates to whether the protein being produced as a result of a transgene is already found endogenously in sheep or goats or whether the protein is novel to the transgenic animal. Understanding the function of the protein is important for anticipating the potential for adverse effects on the animal. In some cases, the diet must be modified or fortified to provide increased concentrations of specific nutrients or classes of nutrients.

With the development of cloning technology, nuclear transfer has become the preferred method for propagating transgenic sheep (Campbell et al., 1996; Wilmut et al., 1997) and goats (Baguisi et al., 1999; Keefer et al., 2001), and cloning has improved the overall efficiency of the process. However, cloning by nuclear transfer has created additional health concerns in a small percentage of animals. For example, fetal survival may be decreased, with an increased in utero loss rate through resorption or an increased rate of abortions if fetal loss is during late pregnancy. Protocols should address the possibility of increased fetal loss and describe the appropriate care for the animals and situations.

The potential for abnormal physiology, without or with clinical signs, in transgenic and cloned animals may continue after birth and into the neonatal and early prepubertal periods (Hill et al., 1999; Wells, 2005; Farin et al., 2006; Loi et al., 2006; Fletcher et al., 2007). In some large-animal species, renal, cardiac, respiratory, hepatic, hematopoietic, and immune system abnormalities have been documented. However, if the small percentage of animals with these physiological abnormalities can be clinically supported over time as the animals grow, many of the abnormalities resolve, and the animals can lead normal and healthy lives (Chavatte-Palmer et al., 2002). Protocols should recognize these potential abnormalities and contain clear plans for addressing them should they occur.

Research results, risk assessment, and regulatory guidance for meat, milk, reproductive efficiencies, and other variables indicate that most cloned animals are normal and healthy (Enright et al., 2002; Walsh et al., 2003; Tayfur Tecirlioglu et al., 2006; FDA, 2008, 2009a,b). Subsequent generations of animals produced from first-generation clones have been studied, and they do not seem likely to have the health-related issues observed in a small percentage of original clones. Indeed, passage through the germ line may reverse abnormal patterns that are detected at the DNA level in first-generation clones (Wells, 2005). Nevertheless, appropriate monitoring of subsequent generations would address the possibility that abnormal patterns may not be corrected in subsequent offspring.

Production of transgenic sheep and goats using microinjection or nuclear transfer are no longer scientific research endeavors and are now established production systems. However, this field of research and development is still relatively young, and the full nature and extent of the potential effects of cloning by nuclear transfer on animal health and welfare have not yet been revealed. Operations or institutions that house and care for transgenic sheep or goats should be prepared for and capable of handling the issues that are associated with these animals and the increased oversight required from a regulatory perspective.

Thus, the local management or governing IACUC must be responsible for reviewing each program and determining whether animal care and use standards and practices should exceed the usual standards and practices. Information on the additional regulatory oversight of transgenic animals, researchers, and(or) institutions is available in *Guidance for Industry: Regulation of Genetically Engineered Animals Containing Heritable Recombinant DNA Constructs* (FDA, 2009b).

Allergens of Sheep and Goats

Allergens related to sheep are not very common. There are reports of dermatitis due to handling sheep's wool and contact with sheep or wool. There are no known caprine allergens that affect humans.

EUTHANASIA

Severely injured sheep and goats or animals that are ill and have a very poor chance of survival should be killed. The AVMA *Guidelines on Euthanasia* (AVMA, 2007) identify several appropriate methods for sheep and goats, including overdose of anesthetic or injection of a euthanasia solution, penetrating captive bolt and exsanguination, or careful lethal gunshot to the head. Other AVMA-recommended methods may be used if proper equipment and expertise are available. In all cases, a trained and skilled person should kill the animal, and proper animal welfare and handling procedures must be followed throughout the process.

Federal, state, and local laws and ordinances on carcass disposal should be reviewed for guidance and followed. The carcasses of animals that were killed with barbiturates may contain potentially harmful residues, and such carcasses should be disposed of in a manner that prevents wildlife from consuming them.

Lairage and Harvest

Lairage, a place where livestock are kept temporarily, should be constructed and managed to accommodate sheep and goats between the time of delivery at the abattoir and the time of slaughter. Lairage facilities should be designed and managed so that they prevent injuries, and animals can receive proper care and remain safe between delivery and slaughter. Several factors should be considered in relation to animal welfare, food safety, product quality, and research or teaching objectives (Weeks, 2008). Those factors include stocking rates and space per animal; safe and effective fencing; shelter to protect animals during extreme weather conditions; well-drained lying areas that can be cleaned thoroughly between groups of animals; pen surface; air quality and quantity (i.e., ventilation); noise; lighting adequate for monitoring and inspecting animals; isolation pens for sick or injured animals, with easy access to the stunning area; ability to provide adequate feed and water if animals will be in lairage for prolonged periods; design that allows animals to be handled calmly and quietly to avoid unnecessary preslaughter stress; and alleyways that encourage animals to move in the desired direction, have as few right angles as possible, and no physical obstructions or artificial or natural lighting arrangements that cause animals to balk. Because of the number of possible ways to design and manage lairage facilities as well as site-specific considerations, protocols should be developed based on the best available literature and resources and submitted to the local IACUC for review and approval. In the United States, all procedures used to slaughter research and teaching animals that will enter the food chain should comply with US Code of Federal Regulations, Title 7, Chapter 48, Humane Methods of Livestock Slaughter (http://www.access.gpo.gov/uscode/title7/chapter48_.html).

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Chapter 11: Swine

FACILITIES AND ENVIRONMENT

Swine readily adapt to a variety of production systems (Pork Industry Handbooks, undated and 1978 to present; MWPS, 1983; Baxter, 1984; Whittemore, 1993). The level of management applied should be commensurate with the requirements of the production system to assure pig comfort. In certain systems, more stockmanship may be necessary to meet the needs of pigs. Specific attention should be paid to management of effective environmental temperature (Table 11-1), prevention of lengthy exposure to sun, ventilation, vapor pressure, floor condition, area per pig, manure management, quantity and quality of feed and water, and prevention of disease and distress.

A predictable daily management routine allows pigs to develop a routine of their own. Animal care personnel should plan for swine management under climatic extremes and emergency conditions; personnel should be able to provide appropriate husbandry to minimize environmental stressors and animal distress. Animal care staff should be familiar with the behavior of normal pigs and of pigs experiencing stress or reduced well-being so that timely intervention can be applied.

Attention should be given to pig dunging and resting preferences during both the design phase and the daily operation of swine facilities. Movement of manure and urine between pens should be minimized. Similarly, animal care personnel should take necessary precautions to prevent transmission of pathogens between pens and between facilities, even at the same location.

Microenvironment

The microenvironment consists of all factors external to the animal, which includes thermal environment (air temperature, air movement, and moisture); physical environment (pens, walls, and floors); social environment; and microbial environment. The thermal environment is probably one of the most difficult components to manage at times because pigs of different ages have different thermal requirements. Hence, it is important that pigs be managed based on their thermal needs during each stage of production. The lower critical temperature for younger pigs is higher than that of older pigs, thus a higher effective environmental temperature is required. The thermal environment should be managed so that the microenvironment is maintained as close to the zone of thermal neutrality for the age of the pig being housed (Table 11-1).

Ventilation goals differ with changing seasons. A properly ventilated building is free of drafts and provides clean, fresh air without chilling the pigs. A minimal ventilation rate should be achieved in the winter, with air exchange being at its lowest rate but still efficient enough to remove moisture. Excessive moisture (>80%) provides a vehicle for microorganisms, wets the pigs, and damages insulation. As a rule of thumb, ventilation rate in winter should not fall below 6 air changes per hour. In conjunction with minimum ventilation rate, relative humidity and CO_2 are important measures of air quality; one or both of these factors should be considered when controlling ventilation rate (Kephart, 2007). Maximal ventilation rate should be achieved in the summer so that the ventilation system keeps air moving to remove animal heat (and will remove moisture as well).

Lighting

The domestic pig is less sensitive to its photic environment than are some other species. Data are conflicting as to whether light can manipulate reproduction, physiology, and performance of pigs. However, current data indicate that photoperiod can influence productivity and various physiological measures of sows and piglets (Bruininx et al., 2002; Halli et al., 2006; Niekamp et al., 2006, 2007). In the wild, swine do not depend on vision as much as on other sensory systems (Kilgour, 1985), but if pigs are able to control the photoperiod for themselves, pigs prefer some light and some dark every hour of the day and night (Baldwin and Meese, 1977); their apparent light-dark cycle preference is not similar to any natural situation.

Photoperiod manipulation may influence pig immune status (Niekamp et al., 2006, 2007), but data on photoperiodic effects on pig biology are contradictory or unclear. Other factors such as weaning age, light intensity, and other physiological factors may impact the effects of photoperiod on growing; thus, no par-

Table 11-1. Recommended thermal conditions for swine used in agricultural research and teaching[1]

	Preferred range[2]	Lower extreme[3]	Upper extreme[4]
	15 to 26°C (59 to 79°F) for sow	15°C (60°F) sow area	32°C (90°F) for sow
Lactating sow and litter	32°C (90°F) minimum creep area for piglets	25°C (77°F) creep area	No practical upper limit for piglets
Prenursery, 3 to 15 kg (7 to 33 lb)	26 to 32°C (79 to 90°F)	15°C (59°F)	35°C (95°F)
Nursery, 15 to 35 kg (33 to 77 lb)	18 to 26°C (64 to 79°F)	5°C (41°F)	35°C (95°F)
Growing, 35 to 70 kg (77 to 154 lb)	15 to 25°C (59 to 77°F)	−5°C (23°F)	35°C (95°F)
Finishing, 70 to 100 kg (154 to 220 lb)	10 to 25°C (50 to 77°F)	−20°C (4°F)	35°C (95°F)
Sow or boar, >100 kg (>220 lb)	10 to 25°C (50 to 77°F)	−20°C (4°F)	32°C (90°F)

[1]Although recommended air temperatures are given in this table, performance measures would more appropriately determine pig thermal comfort. When pigs are in a comfortable thermal setting, they will rest comfortably, not shiver or pile on one another, not have an elevated respiratory rate, and will generally rest touching other pigs. Some individual pigs may prefer to rest alone. Piling or spreading out widely may indicate the environment is too cold or too warm, respectively. Pig behavioral thermoregulatory behaviors are better indicators of the appropriate air temperature than a thermometer.

[2]Based on values given by NRC (1981), DeShazer and Overhults (1982), Curtis (1985), and Hahn (1985).

[3]Values represent lower extremes in air temperature when pigs are held in groups. Bedding is recommended when air temperature approaches the lower extreme.

[4]Except for brief periods above these air temperatures, cooling should be provided by means such as evaporatively cooled air for growing pigs or a water drip for lactating sows.

ticular daily photoperiod is necessary for growing pigs (Berger, 1980). Developing breeding animals may benefit from long-day photoperiod (e.g., 16 h of light and 8 h of dark; Zimmerman et al., 1980; Wheelhouse and Hacker, 1982). Gilts managed on long days had higher basal concentrations of luteinizing hormone (**LH**) than did those on short days. Photoperiod had no effect on changes in LH frequency in prepubertal gilts (Halli et al., 2006). Photoperiod in late gestation can also influence endocrine and performance measures of the gestating sow and her offspring (Niekamp et al., 2006). Lactating sows responded positively to 16 h of light and 8 h of darkness, resulting in enhanced piglet performance, and some studies have reported that these sows may return to estrus sooner (Mabry et al., 1982, 1983; Stevenson et al., 1983) but this effect was not observed in a subsequent study using more replications (McGlone et al., 1988). Light regimens oscillating from 9 to 16 h of light on a daily basis had no effect on boar semen quality or fertility, prolificacy, or libido (Rivera et al., 2006; Sancho et al., 2006). Although there are times that a specific light cycle may be a beneficial management tool for pigs, the photoperiod selected may depend on the sex, age, and stage of production of the animal. Changing the photoperiod may affect pig reproduction in some ways, but changes in photoperiod have not been linked to sow or boar well-being.

FEED AND WATER

Pigs should be observed and their well-being assessed at least twice each day. Feeders and waterers must be checked to be sure they are functional. Design and position of feeders and waterers should enable the pigs easy access while minimizing feed waste. Feeders or feeding places should be free from manure, urine, and other contaminants. Pigs may be fed from the floor as long as the surface is dry and clean and individual feed consumption is not limited by social competition. A water medicator may be used for management of enteric infections. When feed is delivered to animal houses and to individual pens, care should be taken to minimize dust. Pigs should be fed to meet or to exceed nutrient requirements as determined by the NRC (1998) for their particular stage of the life cycle. Ad libitum access to water should be provided and special care should be taken to ensure that water devices are accessible for each size of pig.

HUSBANDRY

Social Environment

Young pigs and sows are by nature social animals. In fact, sows are often found in groups in nature, except before and after parturition when they seek isolation.

Feral boars are usually solitary animals, except during breeding season.

Young pigs show behavioral and physiological signs of stress when held in complete isolation from other pigs. The precise relationship between group size and pig performance is neither predictable nor clear (Livingston et al., 1969; Patterson, 1985). Growing pigs are commonly found in group sizes from 2 to 30 pigs per pen, but groups of hundreds or even thousands of pigs per pen have become more common, especially in commercial wean-to-finish systems. In social groups, the level of social stress (fighting) is high and productivity may decline but once social status is established the group often becomes relatively stable. In some cases, adult pigs housed individually may experience less stress than growing pigs. Agricultural research that proposes to house pigs individually or in isolation from other swine should be justified and approved by the IACUC.

Farrowing Systems

Sow Management. Before preparturient sows are moved into indoor farrowing environment, the environment should be cleaned, disinfected, and dried. Outdoor farrowing environments should be treated as described previously (if possible) or the outdoor area should be exposed to sunlight for several days before moving a new group of farrowing sows to the area. Sows may be treated to eliminate internal and external parasites before entering the farrowing area if parasites are present. Laxative additives or a specially formulated diet may be fed before and after parturition to minimize constipation.

The presence of a caretaker during farrowing is not mandatory (Lawrence et al., 1997), but the presence of an individual during farrowing may improve neonatal survival (Friendship et al., 1986; Holyoake et al., 1995).

Behavioral thermoregulation of sows may include postural changes; for example, extension of body contact with a cooler surface, shade seeking, minimizing contact with other animals, or open-mouth breathing (Curtis, 1983; Blackshaw et al., 1994). Sows have a large body weight but a low body surface-to-mass ratio; therefore, it is more difficult for sows to dissipate internal heat (Hansen and Vestergaard, 1984). During hot weather, especially when humidity is high [daily maximum temperature above 29°C (>85°F)], sows may need to be zone cooled. Sows may be cooled by misters, sprinklers (accomplished by dripping water directly on the sow's shoulders), evaporative coolers (Heard et al., 1986), and ventilation fans (McGlone et al., 1988) or by providing directed currents of air (snout coolers; Bull et al., 1997). Effective thermoregulatory methods that can be used in an extensive system include enabling sows to wet themselves with water or mud.

Confinement Before Farrowing

Jensen (1988) proposed that maternal behavior can be divided into 6 distinct parts: 1) isolation and nest site seeking, 2) nest building, 3) farrowing, 4) nest occupation, 5) social integration, and 6) weaning. Isolation and nest-site seeking behavior that occurs 48 to 24 h before the birth of the first piglet has been observed in wild, feral, and domestic sows outdoors. The sow often leaves the social group and seeks isolation. Therefore, some degree of confinement of the periparturient sow is both necessary and preferred by sows (Phillips et al., 1991). Even in extensive housing systems, sows may be provided with a small hut or pen in which they can be confined and excluded from their group mates.

Farrowing Systems. A wide variety of options is available for housing sows during farrowing and lactation ranging from conventional stalls to outdoor paddocks (Collins et al., 1987; Thornton, 1988; McGlone and Morrow-Tesch, 1990; Edwards, 1995; McGlone et al., 1995; McGlone and Hicks, 2000). Farrowing systems should meet the performance standards of minimizing preweaning piglet mortality, providing thermal comfort for sow and piglets (which may require zone heating/cooling), providing a sanitary environment for sows and piglet, and accommodating normal sow and piglet behaviors where possible. Restricting sow movements in the well-designed farrowing stall will improve piglet survival, and this trade-off should be carefully considered in the selection of any farrowing system.

Farrowing Stall. To reduce piglet injury and protect animal care personnel from overly aggressive periparturient sows, indoor sows may be confined in farrowing stalls or free stalls from d 109 of gestation until the piglets are weaned (Curtis, 1995). A variety of farrowing stalls are available. The standard farrowing stall is usually a tubular metal construction fixed within a pen of about 2.2 m × 1.5 m(7.2 ft x 4.9 ft), with recommended dimensions of around 2.2 m long, 0.6 m wide, and 1.0 m high(7.2 ft long, 1.97 ft wide, and 3.28 ft high). If the farrowing stall length can be adjusted, it should be adjusted based on the body length of the sow. Sows should be able to rest comfortably in the farrowing stall without the need for her head to rest on a feeder due to inadequate length of stall.

Most farrowing stall floors are slatted or perforated so that sows and piglets are effectively and quickly separated from their excreta and the environment dries quickly. Acceptable types of slatted floors include perforated metal, woven metal, plastic-coated metal, metal bars, fiberglass, concrete, and combinations of materials. The floor surface should be nonabrasive, nonporous, and not slippery (Fritschen and Muehling, 1984). Slots between slats should be wider behind the sow [usually 2.5 cm (1 in)] to allow passage of excreta. These wider openings may be covered during parturition to enable piglets to walk easily. In addition, narrower perforations or slots prevent piglets from getting their feet caught in the floor openings. Rubber mats may be provided in the creep area for the first few weeks. Floor materials should be free of exposed or projecting materials to avoid injury to the leg, foot, or hoof. Bedding should be provided for farrowing crates equipped with solid floors. Flooring materials should meet the performance requirements that 1) animals are supported and not slippery, 2) slatted floors should not trap feet and legs, 3) slats should provide a clean environment by separating the manure from the animals, 4) floors in combination with other features of the room should provide thermal comfort, and 5) floors must be able to be sanitized or to provide a clean surface. A creep area is usually set to the side or front of the stall with a heat source that provides a warm lying area for the litter. Good disease management practice dictates that all sows should enter and leave the farrowing accommodation at the same time (all-in, all-out) and thus the number of farrowing places in a room should be related to the number of sows that are due to farrow in a given cycle. The partitions between the pens should be high enough to prevent piglets from escaping.

Indoor Farrowing Pens. Farrowing pens may be used for sows and litters only if preweaning mortality is not increased relative to preweaning mortality in well-managed farrowing crates. Acceptable indoor pen designs include ellipsoid farrowing crates (Lou and Hurnik, 1994), modified triangular farrowing crates (McGlone and Blecha, 1987; Heckt et al., 1988), rectangular pens with side rails that allow piglet escape (McGlone and Blecha, 1987; Blackshaw et al., 1994), and farrowing pens with sloped floors or walls (McGlone and Morrow-Tesch, 1990; Cronin et al., 1996; Marchant-Forde, 2002). Turn-around systems are similar to conventional stalls, in that they are made out of tubular metal and the system incorporates a piglet creep area. These systems may be installed on a fully slatted floor for hygiene reasons.

Heated creep areas are used when the farrowing room is zone heated or cooled. The creep area may be either in one corner, along one of the pen short sides or centrally placed in pens that are divided into nesting and dunging areas. Some systems are still straw-based, but open pens have been developed with fully or partly slatted floors (Heckt et al., 1988; Johnson and Marchant-Forde, 2008).

Farrowing Huts. As with indoor farrowing pens, some outdoor farrowing huts provide acceptable levels of preweaning mortality. Several farrowing hut designs are available made from wood or plastic including A-frames, steel English-style arcs, and plastic and plywood models. Each hut differs in shape; for example, the A-frame is taller and triangle shaped (Penner et al., 1996; Honeyman et al., 1998a). For all types, some versions have a solid plywood floor and others have no floor. In both cases, it is common to use large amounts of straw bedding or other material. There is no heated creep area and no water supply for the sow or her litter in many well-managed farrowing huts. Some arcs incorporate rails to help prevent piglet crushing, whereas others do not have inside rails. Some farrowing huts may have insulation to reduce extremes of temperature, although the benefits of insulation have been questioned in controlled studies (Edwards and Furniss, 1988; Johnson and McGlone, 2003).

Fenders can be fixed onto the front of farrowing huts to help keep the piglets close to the farrowing hut, keep the straw in the huts longer, and allow unrestricted movement of the sow (Honeyman et al., 1998b; Johnson and McGlone, 2003). Fender design may influence the length of time that piglets are confined to the hut and the work efficiency and safety for the stockperson carrying out routine tasks (i.e., litter processing; Johnson and McGlone, 2003).

Sows kept outdoors should be observed regularly; bedding should be provided unless the thermal environment is adequate, and fences should be sturdy and well constructed. Electrified wire may be used. Proper health care for sows and piglets should be provided, and feces and urine should be removed from such systems as the need arises. Sows and litters kept outdoors should be rotated among pastures to avoid accumulation of pathogens and parasites. The farrowing huts or pens should be cleaned and disinfected before each use. If sows farrow outdoors, appropriate sanitation procedures (e.g., moving huts and burning bedding) should be followed to ensure a clean farrowing environment. When supplemental zone heating is not provided, farrowing houses on pasture and pens in central farrowing houses should be bedded with a suitable material such as straw. Bedding should be kept reasonably dry by the addition of more bedding material and by partial removal of soiled bedding at regular intervals as needed.

Litter Management. Piglets require special attention because they are born with low body reserves of energy and immunoglobulins, thermoregulate poorly, and are vulnerable to being crushed. Until weaning, piglets should be provided with an area that is warm, dry, draft-free, and zone heated, and piglets should be protected from being crushed or injured by the sow.

The lower critical temperature of the piglet is about 35°C (95°F) at birth. However, the entire space in the house should not be heated to an air temperature approaching the lower critical temperature of the piglets because the sow will become heat-stressed. Zone heating, zone cooling, or both, should be provided to meet the disparate thermal needs of the sow and piglets.

Any of the following procedures may be performed on piglets within a few days after birth: navel disinfected (if farrowing was attended); needle teeth trimmed with a disinfected sharp device; tail trimmed to no less than 2.5 cm (1 in) from the body with a disinfected device (if piglets are to be raised indoors); supplemental iron injected (if piglets are to be nursed indoors); and individual identification made (usually ear notches).

Nursery Systems

Weaning pigs is a common stressful event that involves sudden change in social and environmental conditions and a change in diet. Thus, weaning at night may be less stressful than weaning during the early morning (Ogunbameru et al., 1992); however, this is often not practical. Typically, nursery systems have included housing and management arrangements for newly weaned pigs until 8 or 9 wk of age, but it is now more common to wean pigs directly into a wean-to-finish building.

Piglets may be weaned at any age, but the younger the piglets are at weaning, the greater is the need for specialized facilities and care, a high degree of sanitation, and high-quality diets (Lecce, 1986; Owen et al., 1995). Segregated early weaning is a production practice that has been implemented to reduce the incidence of disease and to improve pig health and well-being in herds with chronic disease. In a segregated early weaning system, piglets are weaned at 10 to 20 d of age and then transported to a facility that is geographically separated from other swine facilities (Dewey, 1995). This technology reduces the transfer of disease microorganisms from sows to nursery pigs by removing piglets from the sow before passive immunity decreases and sow can infect her offspring. Segregated early weaning is less effective for some diseases, but works well for others. However, segregated early weaning is a management tool used from time to time, not a routine, ongoing management practice.

The lower critical temperature of a 4-wk-old piglet (once it is eating at the rate of approximately 3 to 3.5 times thermoneutral maintenance) is around 26°C (79°F; Table 11-1); therefore, nurseries should be able to meet the ambient temperature needs of the weaned pig, which may require (but not always) supplemental heating equipment, which may include heat lamps, mats, or bedding. When piglets continue suckling (and thus obtaining heat from) the sow beyond 3 wk of age, or when deep bedding is used to create a microenvironment in the range of thermoneutrality, then supplemental heat may not be required in a nursery building. The key is to provide an environment that provides thermal comfort for the pigs by meeting their needs for an appropriate effective environmental temperature.

Environmental management is critical to the success of wean-to-finish buildings. Ventilation is similar to typical finishing facilities but it must be possible to adjust fans for minimum ventilation for the newly weaned pigs. Zone heating is recommended to meet the needs of the young pig. Pig behavioral thermoregulation should be used to determine if the temperature is too high or too low.

In addition to having supplemental heat, nursery houses should be maintained at a higher degree of sanitation than is required for older pigs. Nurseries should be operated on an all-in, all-out basis, and the facility should be cleaned, disinfected, and dried thoroughly between groups of pigs. Room air should be warmed to the proper environmental temperature before pigs enter the building.

Weaned pigs should be self-fed a nutritionally complete and balanced diet unless the experimental protocol dictates otherwise (NRC, 1998). Feeding space should be provided that allows all pigs to eat to their appetite over a 24-h period. Four or more pigs may share a feeder space as long as feed intake is not limited. Feeders that supply water as a part of the feeder (wet/dry feeder) may support more pigs per feeder space. Pigs should be provided ad libitum access daily to clean water. One watering device is needed per 10 to 20 pigs with at least 2 watering devices per pen located far enough apart that one pig cannot dominate both. The height of the waterer should be set so that pigs can readily drink from the watering device. When possible, pigs should be allocated to pens based on body weight and age to facilitate effective feeding and water management (Patience et al., 2004).

The general nature of pig growth is rapid early growth followed by a leveling-off of growth rate. Groups of pigs have different space requirements than individually housed pigs. The bodies of pigs require a certain amount of space called the *occupied space*, and the space in the pen that remains is the *free space*. The amount of space a pig occupies depends on posture and behavior. The amount of unused or free space increases with increase in group size, but research has shown that if all the free space is removed, reduced feed intake and reduced body weight gain will result. McGlone and Newby (1994) showed that removal of 50% of the free space has no effect on pig performance, but removal of more than 50% results in a slow-down in average daily gain. Space needs for pigs in outdoor lots should be based on local performance standards, not on hard-and-fast numbers. Floor area recommendations are in Table 11-2.

Slatted floors are common in nurseries as well as wean-to-finish buildings. The flooring material may be similar to that in farrowing crate units. Pens with solid floors should be bedded with straw or a material with similar thermal and absorbent properties. If partly slatted floors are used, the waterer should be located over the slots.

Growing and Finishing Systems

The growing-finishing stage refers to pigs from 8 or 9 wk of age to market age of about 20 to 25 wk and finished body weights between 114 and 136 kg (250 to 300 lb). The management of growing and finishing pigs differs from that of weanling pigs in that a lower standard of sanitation is required, units may be run with a continuous flow of pigs, and older pigs can tolerate a much wider range of environmental temperature than younger pigs (Table 11-1). Although growing-finishing systems may use a continuous flow of pigs, an all-in, all-out system is preferred. Restricting the number of

Table 11-2. Minimum floor area recommendations for the animal zone for swine used in agricultural research and teaching[1]

Stage of production	Individual pigs (per pig) (m^2)	Individual pigs (per pig) (ft^2)	Groups of pigs (per pig)[2] (m^2)	Groups of pigs (per pig)[2] (ft^2)
Litter and lactating sow, pen	3.15	35	—	—
Litter and lactating sow, sow portion of crate	1.26	14	—	—
Nursery, 3 to 27 kg (7 to 60 lb) of BW	0.54	6	0.16–0.37	1.7–4.0
Growing, 27 to 57 kg (60 to 125 lb) of BW	0.90	10	0.37–0.56	4.0–6.0
Finishing, 57 to 104 kg (125 to 230 lb) of BW	1.26	14	0.56–0.74	6.0–8.0
Late finishing, 105 to 125 kg (231 to 275 lb) of BW	1.26	14	0.74–0.84	8.0–9.0
Mature adults[3]	1.26	14	1.49	16.0

[1]Floor area guidelines here are general recommendations. The minimum space needs for growing pigs follows the general formula of area = 0.33 × $BW^{0.67}$, where BW is in kilograms and area is in square meters. Pigs given adequate floor space will lie comfortably without needing to raise their head while resting or constrict their body during normal postures.

[2]Group area allowances for growing pigs range from starting to ending BW in each phase. The needed floor area per pig decreases as group size increases (McGlone and Newby, 1994). The data presented here are for typical group sizes from 5 to 20 pigs per pen. For small group sizes (2 to 4 pigs), the pens should be longer than the body length of the largest pig in the pen.

[3]Stall size minimum width should be 56 cm (22 in), and minimum length should be 2.2 m (7 ft). Young adult females may be housed in stalls of 2 m (6.5 ft) length.

times pigs are moved or mixed is desirable because mixing pigs generally results in aggression, increases health problems, and causes performance setbacks.

Typically, growing-finishing pens are rectangular and contain 20 to 1,000 pigs per pen (or more). Up to 10 pigs may share a feeder space, and up to 20 pigs may share a waterer in the grow-finish phase. In most situations, pigs should have ad libitum access to water. There are systems that provide water in fixed watering bouts and some systems provide water only when feed is delivered. When water is available in intervals, it should remain on for at least 30 to 45 min at one time (McGlone, 2003). Water should always be available when pigs are feeding. The height of the waterer should be adjusted appropriately as pigs grow. Specialized feeding and watering equipment may accommodate different pig densities.

Penning materials should be sturdier than those used in nurseries. Flooring can be solid, solid and bedded, partly slatted, or totally slatted. Solid floors should be sloped (e.g., 1 to 3%) to allow water and manure to flow to a drain or a pit. Slatted floors need not be sloped. Although many flooring materials are acceptable, concrete slats are recommended for slatted floors. Concrete slats should allow support of pig's feet and allow manure to fall easily between the slots. Edges of the slats should be rounded to preclude foot-claw injuries, and sharp edges should be avoided. Open flush gutter systems are acceptable, but risk of contamination between pens is significant.

Floor-space allowance is a complex issue within swine production. Floor area recommendations are in Table 11-2. Traditional space requirements were established with relatively small group sizes, with larger group sizes, there is a greater amount of shared, unused, or free space. Thus, 0.65 m^2/pig(7 ft^2) is adequate for maintenance of economical pig growth (Brumm and Dahlquist, 1997). Pigs up to 250 lb of body weight and in small groups sizes (<20) require 0.74 m^2/pig (8 ft^2), and larger group sizes, especially those over 50 pigs/pen and up to 300 lb may need only 0.74 m^2/pig (8 ft^2) as well. Floor space allowance may be determined using the following equation [$A = k \times BW^{0.667}$, where A = floor space allowance, and k = represents a space allowance coefficient], which converts pig body weight into a 2-dimensional concept (Gonyou et al., 2006). A k value of 0.336 was the minimum space allowance for grow-finishing pigs on fully slatted floors.

Space needs for pigs in outdoor lots should be based on performance standards, not on hard-and-fast numbers. In cold weather, less space in outdoor lots is acceptable. Less space is needed in hot and dry weather than when the weather is hot and wet. Many factors must be taken into consideration when selecting the type of housing for finishing pigs.

Several alternative non-environmentally controlled finishing systems are acceptable for housing growing-finishing pigs. The most common alternative system is the bedded, naturally ventilated, open-air hoop building; these buildings are often bedded. Another alternative is indoor-outdoor lots. The floors in these types of facilities may be earthen or concrete. If the floor is concrete, it should be sloped to the outside. Bedding is often used in the sheltered areas of these open-front buildings but not in the run areas.

Breeding and Gestation Systems

Sows, if managed properly, may be housed individually or in groups (McGlone et al., 2004b; AVMA, 2005). Both field and controlled studies (McGlone et al., 1994; PIC USA Inc., 1994; McGlone, 1995; McGlone et al., 2004b; AVMA, 2005) support the idea that the individual crate or stall promotes high reproductive success and does not induce a distress response, based on endocrine and immune data. A properly designed individual stall or group system is an acceptable production system for teaching and research units. Newer systems, presently under development, require extensive evaluation before being introduced as standard housing systems. All housing systems have advantages and disadvantages associated with them (McGlone et al., 2004b; AVMA, 2005). Several gestation housing systems may be reasonable choices, including individual crates and variations of group pens (outdoor, individual feeders, electronic feeders, floor feeding, or trickle feeding). The tether system is not widely used throughout the United States and has been banned in the European Community member countries as of 1997; it is not a recommended housing system for gestating sows. Some individual states in the United States have banned or will phase out the use of gestation crates for sows. Teaching and research activities in states where gestation crates have been banned must comply with state regulations.

According to AVMA policy (2005), all sow housing systems should attempt to minimize sow aggression and competition especially at mixing and during feeding; provide sow protection from environmental extremes and hazards; provide feed and water; and allow sows to express normal behaviors. Moreover, if sows are to be housed in small groups they should be managed as a static group, whereas if they are to be housed in large groups they may be managed as a dynamic group. If possible, sows should be moved to new pens when new animals are introduced or mixed into the group. If no individual feeding system is provided and if possible, animals should be sorted and grouped based on established eating behavior. Sows in group pens (e.g., 5 to 10 per pen) and on restricted feed rations should be of uniform size and temperament. In extensive production systems, larger group sizes can be managed because feeding space per sow can be increased to reduce competition for feed.

Building Environment for Breeding and Gestation. Suggested optimum range of air temperatures for gestating gilts and sows is 15 to 20°C (60 to 68°F). Nevertheless, it is important to remember that the effective temperature experienced by the gestating animal is a function of air temperature, relative humidity, air speed, wall and ceiling temperature, floor characteristics, body weight, feed intake, huddling, and number of animals housed together. Pregnant sows will start to experience heat stress when the air temperature is greater than 29°C (84°F). The lower critical temperature of a normally fed pregnant sow is between 20 and 23°C (68 and 73°F) for individually crated animals and approximately 14°C (57°F) for group-kept sows. The animal's behavior should be observed as an indicator of thermal comfort.

Individual Stall Management. Variation in physical size of sows exists not only within groups of sows at one location, but also occurs among farms (McGlone et al., 2004a). Data from a large sample of sows indicates that the size of the traditional gestation crate would have to be increased to accommodate the average sow (McGlone et al., 2004a) and it has been shown that a small increase in stall dimensions can reduce injuries and improve well-being of sows considerably (Anil et al., 2002). Sows should be in a pen or stall that allows them to lay down without parts of their body (not including their limbs) extending into the neighboring stall. Standing sows and gilts should not be forcibly in contact with the sides, ends, or top of the stall (Curtis et al., 1989), and sows housed in individual stalls should be able to lay down in full recumbency without their heads lying upon a raised feeding trough. This performance standard is consistent with standards of the National Pork Board (2002).

Group Housing Management. In the case of group housing systems, much of the aggression and competition associated with group housing can be influenced by feeding method, social status, and floor space per animal, group size, genetics, and management procedures. Thus, some of the many factors that should be considered when designing and implementing group-keeping systems are group size, floor space allowance, group composition (static vs. dynamic), diet type and method of feed delivery, genetics, and sow temperament (Levis, 2007). Group housing for sows may be indoors or outdoors, drylot or pasture, and insulated, mechanically ventilated frame structure, or hoop structure. Floor types may be solid or slatted, with or without bedding. Most importantly, group-keeping systems differ in terms of feeding, group management, and floor type. Some of the feeding systems include electronic sow feeders, drop or trickle feeding, and individual feeding stalls.

Social interactions are facilitated when sows are kept in groups, thus groups must be managed to reduce social stress. Aggressive behavior in swine is common, and serious injury can result if swine are left unattended. The social interaction among females in the pen is influenced by the number of females per pen, the area of space per female, variation in body size among females, duration of time together, and most importantly, method of feeding. When the group is fed a limited daily ration, competition for feed can be intense and, without intervention from animal care personnel or a physical system, aggressive sows overeat and subordinates ingest inadequate amounts of feed. Several feeding systems and management schemes can be used to minimize the aggressiveness of sows during feeding. Group housing systems include but are not limited to drop-feeding, trickle-feeding, and electronic sow feeding systems. An alternative is a group pen equipped with individual feeding stalls used only at feeding time.

In addition, there are 2 basic management schemes for group management—static or dynamic. When sows are kept in small groups or groups up to 35 or 40 sows, they should be maintained as a static group (sows in same production phase), whereas groups of 80 to 200 sows may be maintained as a dynamic group (sows enter and leave the group every week). Minimizing social stress by keeping sows in individual stalls for the first 25 to 35 d post-breeding or grouping all sows at one time improves well-being.

Specific genetic strains of sows may differ in their ability to adapt to particular housing environments (Beilharz, 1982), but this hypothesis has not been fully investigated. Inputs from managers, proper habituation, and selection of appropriate genetic stock appear to be primary contributors to the well-being of sows, independent of the gestation systems used.

Floor Space Allowance and Group Size. Floor space allowance will vary with group size. Space for accessing necessary resources, opportunity to avoid or escape from potential aggressors, and avoidance of chronic physiological stress are essential for the well-being of low-ranking sows in group housing. Space should be adequate space to avoid physical injury. The minimum floor space allowance should be 1.49 m^2 per sow (16 ft^2) on partly slatted floors (Salak-Johnson et al., 2007). For larger sows (based on body weight), floor space allowance should be 1.77 m^2 per sow (19 ft^2); thus, as body weight increases, floor space allowance increases slightly. No optimal group size has been determined. Farrowing rate and litter size were not different when 10 sows per pen were housed at 1.95 m^2 per sow (13 ft^2) compared with housing 5, 10, 20, or 40 sows per pen at 1.49 m^2 per sow (21 ft^2) (Taylor et al., 1997).

Mating Facilities. Recommended areas for breeding sows and boars of different types and sizes are listed in Table 11-2. Sexual development of gilts that have been selected to enter the breeding herd is hastened when they are kept in groups (10 to 12 per pen recommended in intensive production systems) with the opportunity for contact with mature boars for at least 30 min/d. Individual housing of mature boars is recommended to preclude interactions among boars. When mature boars that are unfamiliar with one another are penned together, intense fighting usually occurs. In systems in which boars reside in small groups, boars should be of similar size, and it is highly desirable that they be reared together from the time of puberty. Stalls for boars should meet the same performance standards as for sows. However, larger stalls or pens may be required for extremely large boars.

Specialized facilities or areas are needed for breeding. Breeding may be by natural service or artificial insemination. Boar breeding areas should be slip-resistant. Artificial insemination areas include boar semen collection and sow insemination areas. Boar semen collection areas should be designed to consider boar and worker safety as well as animal comfort and sanitation. Sow insemination areas may be the same as gestation facilities for sows. The flooring surface in mating pens should be considered during the planning and construction of the facility. In pens with an area of solid concrete, floors may be made slip-resistant by applying a wood float or broom finish or by placing grooves in the concrete. A 2.5-cm (1-in) diamond pattern has proved satisfactory (Levis et al., 1985). In pens used for hand mating but without good footing, absorbent substances or rubber mats may be placed on the floor.

Pen mating (placing a boar with sows unattended) and hand mating (personnel attending boar-sow matings) are mating options. With pen mating in pasture and drylot systems, primary considerations are to minimize extremes in environmental temperature, rest boars between mating sessions, and avoid putting young boars with old sows or old boars with gilts. For pen mating in intensive production systems, area allowance and flooring are additional considerations. Pens should meet the same performance standards for space and allow for ease of movements during breeding. One boar per pen is recommended. Slip-resistant, dry floors are required to prevent injury. With hand mating, the sow usually is mated in a designated mating pen but may be mated in the pen of either the sow or the boar.

Sows kept for several parities may require special attention. Animal caretakers should be aware of the possibility of shoulder sores, long hoof growth, and thin body condition. These and other health problems should be treated as soon as they are identified.

Metabolism Stalls

Metabolism stalls are used to pen individual pigs for certain investigations of nutrition and physiology, with the approval of the IACUC. The metabolism stall usually (but not always) keeps pigs in a manner that precludes them from turning around and soiling feed or eating feces. If the flooring and penning materials are appropriate for the size of the pig to be used, and if the space allowances for individual pigs are met (Table 11-2), then pigs may be penned for extended periods in metabolism stalls without problems. The precise width of a metabolism stall may require adjustments to provide total urine and fecal collection while preventing the pigs from turning or flipping. Slightly smaller space allowances may therefore be needed to accomplish these objectives. In studies requiring the use of metabolism stalls, twice-daily interaction between the animal care staff and the pigs is especially important. Visual and vocal interactions with other pigs also support the well-being of individually housed pigs. Pigs should be held in metabolism stalls no longer than required by the approved animal care protocol.

STANDARD AGRICULTURAL PRACTICES

Castration

Boar taint, defined as a specific objectionable odor and flavor in meat, often occurs when boars are slaughtered at 100 kg (220 lb) of body weight or heavier. In view of the demand by US packers for heavier market hogs, almost all male pigs are castrated before slaughter. If teaching and research pigs are to be marketed in commercial chains, castration is recommended. If the research intends to reflect commercial pork production, castrated males are appropriate model animals. Castration causes clear signs of pain and discomfort for pigs (McGlone and Hellman, 1988; McGlone et al., 1993; White et al., 1995, Taylor and Weary, 2000; Hay et al., 2003; Prunier et al., 2005; Carroll et al., 2006). Signs of pain and discomfort may include reduced times spent nursing or feeding, increased vocalization (apart from that induced by handling) as pigs increase in age, inflammation and swelling at the castration site, acute reduction in performance, and hormonal responses. It is important to note that, while all authors reported some evidence of pain and discomfort, results were not consistent across experiments. To minimize stress on the pig, castration should be performed as early as possible and preferably between 1 and 14 d of age. After 14 d of age, local anesthetic or a combination of local and general anesthetic (Haga and Ranheim, 2005) should be administered before castration under prescription from the attending veterinarian. For boars of any age, trained personnel should use disinfected instruments, and a pre-castration disinfectant should be applied to the incision site. To allow proper drainage, the incision should be in the ventral scrotum and should not be sutured. Topical anesthetic may be used for short-term pain alleviation. Further information on castration can be found in Chapters 1 and 2 of this guide.

Nose Rings

Outdoor swine production systems may have undesirable environmental consequences due to pig rooting behavior. Nose rings reduce rooting behavior (Horrell et al., 2001; Eriksen et al., 2006); however, pigs experience pain when fitted with nose rings and nose rings reduce rooting behavior by making it a painful experience. This presents an issue of environment versus welfare (McGlone, 2001). Nose rings have been shown to affect eating behavior (Horrell et al., 2000), and pigs will engage in other exploratory behaviors if they cannot root (Studnitz et al., 2003). Pigs should be fitted with nose rings only when the expected deleterious impact to the environment outweighs concerns regarding the welfare of the pig.

Other Standard Practices

Several standard agricultural practices that cause only brief pain or distress but prevent more serious distress or injury later in the pig's life may also be performed. Thus, teeth of pigs may be clipped at a very young age to reduce damage to littermates and to the sow. No more than one half of the tooth should be trimmed. Ears may be notched to provide permanent individual identification. Tails may be docked to reduce the potential for tail-biting. Tusks of boars may be trimmed to prevent them from harming humans or other pigs. Sows and boars may have their hooves trimmed to allow them to walk with greater ease and to avoid injuries.

ENVIRONMENTAL ENRICHMENT

Refer to Chapter 4: Environmental Enrichment for information on enrichment of swine environments.

HANDLING AND TRANSPORT

Refer to Chapter 5: Animal Handling and Transport for information on handling and transportation of swine.

SPECIAL CONSIDERATIONS

Housing of Swine on Biomedical Protocols in Agricultural Facilities

The *Guide for the Care and Use of Laboratory Animals* (NRC, 1996), also known as the ILAR Guide, states "Uses of farm animals in research, teaching, and testing are often separated into biomedical uses and agricultural uses because of government regulations (AWRs), institutional policies, administrative structure, funding sources, or user goals. That separation has led to a dual system with different criteria for evaluating protocols and standards of housing and care for animals of the same species on the basis of perceived biomedical or agricultural research objectives (Stricklin and Mench, 1994)." The ILAR Guide goes on to state "use of farm animals in research should be subject to the same ethical considerations as the use of other animals in research, regardless of an investigator's research objectives or funding source (Stricklin et al., 1990)." The ILAR Guide refers to this document (*Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching*, known as the Ag Guide) for farm animals in a farm setting. The USDA-APHIS also accepts the Ag Guide in their policy 29 (http://www.aphis.usda.gov/animal_welfare/downloads/policy/policy29.pdf).

Farm animals used for the purpose of agricultural research and teaching are covered by the Ag Guide. For the researcher, having 2 sets of standards for swine seems to be overly burdensome. It is therefore, reasonable to consolidate these 2 sets of guidelines into a single workable set of guidelines for both the researcher and the IACUC. This idea has been suggested by others (Curtis, 1994) and, to some extent, by regulators such as USDA-APHIS.

For pigs used in biomedical research, their needs for thermal comfort, humidity control, floor space, and husbandry practices should be based on the performance standards outlined in this chapter. Pigs in certain biomedical settings and with certain genetic backgrounds may have special requirements that should be understood so that pigs are comfortable. The same performance standards that indicate adequate animal welfare for pigs in an agricultural setting will apply for pigs in a biomedical setting.

Pigs with Small Mature Body Size

Some specific species of *Sus scrofa* or *Sus vittatus* have, naturally or through selection, a small mature body size. These include but are not limited to mini, micro, and potbellied pigs. These pigs may be used in commercial agricultural production, but are more often kept as pets or used as biomedical research models. However, the husbandry requirements of these pigs are generally similar to those of traditional domestic pigs, with some exceptions.

Thermal and nutrient requirements should be carefully considered. Pigs with small mature body size are more sensitive to cool temperatures than are larger pigs because of their sparse hair coat and small body size. Because they are smaller and eat less per day, their nutrient requirements per weight of feed may be higher, although they must be limit-fed to control body condition (avert obesity). The physical environment (e.g., flooring and penning materials) should be appropriate for their body size.

Genetically Engineered and Cloned Pigs

A transgenic animal is one that carries a foreign gene that has been deliberately inserted into its genome. The foreign gene is constructed using recombinant DNA methodology. A cloned animal is made by a process in which an entire organism is reproduced from a single cell taken from the parent organism and in a genetically identical manner. Essentially, cloning involves removing the nucleus of a cell from an adult animal that will be copied and inserted into an animal egg whose nucleus has been removed. This technically means that the cloned animal is an exact duplicate in every way of its parents; it has the exact DNA. Cloning happens in nature when twins develop from a single fertilized egg. There are three major types of cloning technologies: recombinant DNA technology, reproductive cloning, and therapeutic cloning. The first successful genetically modified animal was a mouse (Gordon et al., 1980) and several years later, other transgenic animals were produced, including pigs (Pursel et al., 1987). The first successful animal cloning was that of Dolly the sheep, who not only lived but went on to reproduce naturally (Wilmut et al., 1997).

Transgenic animals provide tools for exploring biological questions related to agriculture, medicine and industry. More specifically, using transgenic animals enables scientists to understand the role of genes in specific diseases, thus the use of transgenic animals yields a number of highly significant benefits. Despite the importance of transgenic animals in biomedical research, some concerns and misconceptions have been raised about their use in research. Transgenic animals may develop more abnormalities than non-genetically modified research animals because introduction of DNA into an animal can be very complex and possible side effects can be difficult to predict. Transgenic pigs with high levels of bovine growth hormone turn out to have no compromised welfare in the first two generations, but in the third generation infertility, nephritis, cardiomegaly, and arthritis were all reported (Pursel et al., 1989, 1993). Nevertheless, changes and improvements in growth hormone constructs have eliminated these problems in pigs (Nottle et al., 1999). However, it must be noted that some of these abnormalities are species-specific: cloned piglets (Carter et al., 2002) appear to have normal birth weights, whereas cloned calves and lambs have large birth weights (Wilson et al., 1995; Walker et al., 1996). There is some suggestion that immune function may be compromised in cattle (Renard et al., 1999), but cloned pigs appear to respond to vaccination (Carter et al., 2002). Although some groups have reported abnormal phenotypes in swine, others have seen few problems. In fact, transgenic pigs expressing human complement regulatory protein CD59 were all found to be healthy because there were no specific pathomorphologic phenotypes associated with the presence of the transgene in all pigs evaluated (Deppenmeier et al., 2006). Therefore, where transgenic animals are concerned, it remains important to expect the unexpected. Extra vigilance is required by researchers, animal technicians, and IACUC staff to ensure potential causes of pain and distress to experimental animals are quickly detected and treated or eliminated.

In January 2008, the FDA concluded that meat and milk from cow, pig, and goat clones and offspring of any animal clones are as safe as the food we eat every day. Despite the FDA response, it is still extremely important to track transgenic animals. The following methods are suggestions that have been shown to be successful for tracking: genetic and permanent identification processes should be used. From a genetic standpoint, a readily assayable sequence should be used for screening purposes. Also, transgenic pigs should be permanently identified in conjunction with specific color-coded ear tags. This permanent identification system should be unique and different from the conventional identification system commonly used in pigs. For example, a hole in the middle of each ear is not typical of the conventional system. Each animal within the herd should have a unique number and numbers should never be reused. Each individual pig must be traceable to a particular founder sire and dam. The place, date, and time of birth; use of the pig in production; incidence of disease; and final disposition should be recorded for each pig. Animals that have incorporated the transgene DNA but are not producing the transgene product should be distinguished from animals that have not incorporated any exogenous DNA (FDA, 1995). If an animal's genotype is in question, then it should be considered transgenic and disposed of following the proper guidelines. If cross-fostering is used, animals should be cross-fostered only within the transgenic herd. The genetic background and history of the animals that will provide gametes (donors) and of the foster or recipient animals should be known in detail and should include the species, breed, country of origin, general health, and other available genetic and pedigree information. The pigs to be used should have detailed health evaluations, including specific tests for species- and breed-related disease problems. For the control of disease agents, the donor and recipient animals should meet the same criteria used for all other outside animals entering the herd (FDA, 1995; http://iets.org/pdf/HASAC-HealthAssessmentCare.pdf).

Detailed plans for maintaining transgenic animals should be developed. Plans for periodic monitoring of pig health and housing facilities for transgenic animals as well as plans for removal from production and disposal of the animals or their byproducts should be carefully described in the experimental protocol and approved by the IACUC, in accordance with the Animal Welfare Act (7 U.S.C., Sec. 2131 et seq.) and, the Public Health Service Act (42 U.S.C., Sec. 289(d)) where applicable (FDA, 1995). For cloned pigs, the International Embryo Transfer Society (IETS) has developed guidelines titled "Health Assessment and Care for Animals Involved in the Cloning Process" (IETS, 2008; http://iets.org/pdf/HASAC-HealthAssessmentCare.pdf). "The containment and confinement practices for production operations involving transgenic animals should be in accordance with applicable portions of the NIH guidelines for Research Involving Recombinant DNA Molecules. The physical surroundings where the transgenic animals will be maintained should be described in detail, see requirements at 21 CFR 600.11. Information should include herd size, physical isolation and containment, breeding isolation, and biosafety-containment (when appropriate). If the facility is not a single-species-dedicated breeding and maintenance facility, the adventitious agents of the other species must be considered. The surroundings should be capable of containing the animals and of preventing the accidental entry of other animals. Transgenic animals should be neutered after breeding to lessen the chance of escape or inadvertent breeding into the nontransgenic population(s)" (FDA, 1995).

The founder animals should be evaluated to determine whether the transgene is being expressed in a site-specific manner if that is the intent of the transgene introduction. The high levels of tissue-specific protein expression of certain transgenes may cause adverse side effects or may affect expression levels of endogenous proteins, (i.e., by interfering with or modifying their function) leading to adverse consequences that compromise the health and usefulness of the animals (FDA, 1995). Finally the disposition of pigs to be used as food is regulated by both the FDA (CVM or CFSAN) and the USDA Food Safety and Inspection Service (FSIS) when they are of an inspected species being offered for human food (FDA, 1995). In general, disposal of transgenic animals, including retired or dead animals, should be in accordance with the applicable portion of the NIH guidelines for Research Involving Recombinant DNA Molecules; contact the FDA CVM for guidance.

EUTHANASIA

The National Pork Board in collaboration with the American Association of Swine Veterinarians developed guidelines titled "*On-Farm Euthanasia of Swine—Recommendations for the Producer*." This document, which may be viewed online (http://www.aasv.org/aasv/documents/SwineEuthanasia.pdf) describes 6 accepted methods of euthanasia and clearly notes which methods are most appropriate for pigs from newborns to adults. Human safety risks associated with administering each method of euthanasia are addressed. Blunt trauma is acceptable for pigs weighing less than 5.5 kg. Carbon dioxide is a suitable method for euthanatizing pigs less than 10 wk of age providing that residual oxygen is removed quickly from the CO_2 chamber. Carbon monoxide is not recommended because it is a potential human health hazard. An overdose of anesthetic, injection with a euthanasia solution, and electrocution are suitable for pigs of all ages and are humane methods that may be practiced after careful training. Barbiturates require special handling and licensing. Gunshot and captive bolt with exsanguination are appropriate for pigs weighing more than 5.5 kg. Other recommended methods may be used if proper equipment and expertise are available.

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Appendix I

US Government Principles for the Utilization and Care of Vertebrate Animals Used in Testing, Research, and Training

The development of knowledge necessary for the improvement of the health and well-being of humans as well as other animals requires in vivo experimentation with a wide variety of animal species. Whenever US Government agencies develop requirements for testing, research, or training procedures involving the use of vertebrate animals, the following principles shall be considered; and whenever these agencies actually perform or sponsor such procedures, the responsible Institutional Official shall ensure that these principles are adhered to:

I. The transportation, care, and use of animals should be in accordance with the Animal Welfare Act (7 U.S.C. 2131 et. seq.) and other applicable Federal laws, guidelines, and policies.*

II. Procedures involving animals should be designed and performed with due consideration of their relevance to human or animal health, the advancement of knowledge, or the good of society.

III. The animals selected for a procedure should be of an appropriate species and quality and the minimum number required to obtain valid results. Methods such as mathematical models, computer simulation, and in vitro biological systems should be considered.

IV. Proper use of animals, including the avoidance or minimization of discomfort, distress, and pain when consistent with sound scientific practices, is imperative. Unless the contrary is established, investigators should consider that procedures that cause pain or distress in human beings may cause pain or distress in other animals.

V. Procedures with animals that may cause more than momentary or slight pain or distress should be performed with appropriate sedation, analgesia, or anesthesia. Surgical or other painful procedures should not be performed on unanesthetized animals paralyzed by chemical agents.

VI. Animals that would otherwise suffer severe or chronic pain or distress that cannot be relieved should be painlessly killed at the end of the procedure or, if appropriate, during the procedure.

VII. The living conditions of animals should be appropriate for their species and contribute to their health and comfort. Normally, the housing, feeding, and care of all animals used for biomedical purposes must be directed by a veterinarian or other scientist trained and experienced in the proper care, handling, and use of the species being maintained or studied. In any case, veterinary care shall be provided as indicated.

VIII. Investigators and other personnel shall be appropriately qualified and experienced for conducting procedures on living animals. Adequate arrangements shall be made for their in-service training, including the proper and humane care and use of laboratory animals.

IX. Where exceptions are required in relation to the provisions of these Principles, the decisions should not rest with the investigators directly concerned but should be made, with due regard to Principle II, by an appropriate review group such as an institutional animal care and use committee. Such exceptions should not be made solely for the purposes of teaching or demonstration.

*For guidance throughout these principles, the reader is referred to the Guide for the Care and Use of Laboratory Animals (The ILAR Guide) prepared by the Institute of Laboratory Animal Resources, National Academy of Sciences, Washington, DC.

Appendix 2

Table A-1. Zoonotic diseases of agricultural animals[1]

Disease in humans	Causative agent	Common hosts	Means of spread
Acariasis	*Sarcoptes scabei*	Cattle, pigs	Direct contact
Animal pox	Pox virus	Livestock	Contact
Anthrax	*Bacillus anthracis*	Cattle, sheep, goats, horses	Contact, inhalation, or ingestion
Avian influenza	Influenza A virus	Poultry	Aerosol, fecal-oral, fomites, flies
Balantidiasis	*Balantidium coli*	Pigs	Ingestion of feces
Botulism	*Clostridium botulinum*	Cattle, sheep, horses	Ingestion of (food borne) toxin, direct contact with spores, spores in a wound
Brucellosis	*Brucella suis*	Pigs	Contact and ingestion of milk, milk products, raw meat
	Brucella abotus	Cattle, sheep	Direct contact, particularly with semen, aborted fetuses, fetal membranes, amniotic fluid
	Brucella melitensis	Sheep, goats	
	Brucella ovis	Sheep	
Campylobacteriosis	*Campylobacter fetus*	Cattle, sheep, pigs	Ingestion of raw meat and raw milk
	Campylobacter jejuni	Poultry	
Chlamydiosis	*Chlamydophilia* spp.	Poultry	Inhalation
	Chlamydophilia abortus	Cattle, sheep, goats, pigs	Contact with uterine fluid
	Chlamydophilia pneumoniae	Horses	
Clostridiosis	*Clostridium septicum*	Cattle	Wound infection
	Clostridium perfringens	Sheep	
Coccidiodomycosis	*Coccidioides immitis*	Cattle	Contamination of food
Colibacillosis	*Escherichia coli*	Livestock	Ingestion
Crytosporidium	*Cryptosporidium parum*	Cattle	Fecal-oral
Eastern, Western, and Venezuelan equine encephalitis	Eastern equine encephalitis, Western equine encephalitis	Horses	Mosquito bites
Ehrlichiosis	*Ehrlichia chaffeensis*, *Anaplasma phagocytophilium*	Horses	Tick bite
Erysipeloid	*Erysipelothrix rhusiopathiae*	Sheep, pigs, poultry	Contact
Foot and mouth disease	Picornavirus	Cattle, sheep, goats, pigs	On rare occasions can cause mild lesions in humans
Gastroenteritis	*Yersinia enterocolitica*	Pigs	Accidental ingestion
Giardiasis	*Giardia lambia*	Cattle, sheep, goats, pigs, horses	Fecal-oral, food borne, contaminated water
Glanders	*Burkholderia mallei*	Horses	Contact with skin exudates and respiratory secretions
Histoplasmosis	*Histoplama capsulatum*	Poultry	Inhalation of organisms
Hendra virus	Paramyxovirus	Horses	Body fluids and aerosols
Hydatid disease	*Echinococcus* sp.	Cattle, sheep, goats, pigs, horses are all intermediate hosts	Egg ingestion
Leptospirosis	*Leptospira* spp.	Cattle, sheep, goats, pigs, horses	Contact, urine contaminated soil or water
Listeriosis	*Listeria monocytogenes*	Cattle, sheep, goats, poultry	Possibly contact with mucous membranes, skin penetration, ingestion of unpasteurized milk
Lymphocytic choriomeningitis	*Arenavirus*	Pigs	Contamination of food, contact
Melioidosis	*Burkholderia pseudomallei*	Cattle, sheep, goats, pigs, horses	Contact with blood or bodily fluids (urine, nasal secretions, milk)
Milker's nodules	Paravaccinia virus	Cattle	Contact with teats and udders
Nematodiasis	Roundworms	Cattle, pigs, horses	Ingestion, contact
Newcastle disease	Paramyxovirus	Poultry	Direct or indirect contact
Nipah virus encephalitis	Nipah virus	Sheep, pigs, horses	Rare, direct contact
Orf (contagious ecthyma)	Parapox virus	Sheep, goats	Direct contact
Pasteurellosis	*Pasteurella multocida*	Ruminants	Inhalation, bite wounds
Plague	*Yersinia pestis*	Cattle	Bites from infected fleas, direct contact with wounds or mucous membranes
Pneumocystis	*Pneumocystis carinii*	Cattle, sheep	Inhalation
Pseudocowpox	Parapoxvirus	Cattle	Direct contact
Pseudotuberculosis	*Yersinia pseudotuberculosis*	Cattle, sheep, turkeys	Contact, contaminated food and water, ingestion
Psittacosis	*Chlamydia psittaci*	Poultry, waterfowl	Contact with birds or fecal material
Q fever	*Coxiella burnetii*	Cattle, sheep, goats	Inhalation, ingestion of contaminated raw milk, contact with amniotic fluid or placenta, blood-sucking arthropods

Continued

Table A-1 (continued). Zoonotic diseases of agricultural animals[1]

Disease in humans	Causative agent	Common hosts	Means of spread
Rabies	Rhabdovirus	Livestock	Bite wound, saliva in open wound
Rain Rot	*Dermatophilus congolensis*	Livestock	Direct contact
Ringworm, dermatomycosis	*Trichophyton* spp. *Microsporum* spp. Other dermatophytes	Livestock	Direct contact; soil may be reservoir
Salmonellosis	*Salmonella* spp.	Livestock and poultry	Ingestion, inhalation, contact
Sarcocystis	*Sarcocystis neurona*	Cattle, sheep, goats, pigs, horses	Cyst ingestion
Sporotrichosis	*Sporothrix schenckii*	Horses	Occupational contact, inhalation
Staphylococcal infections	*Staphylococcus* spp.	Livestock, especially dairy cows	Contact, consumption of unpasteurized milk
Streptococcal infections	*Streptococcus* spp.	Livestock, especially dairy cows	Contact, consumption of unpasteurized milk
Swine influenza	Orthomyxoviridae	Pigs, horses, fowl	Inhalation
Tetanus	*Clostridium tetani*	Sheep, horses	Bite wounds, contaminated puncture wounds
Toxoplasmosis	*Toxoplasma gondii*	Sheep, goats	Ingestion/inhalation of cysts
Trichostrongylosis	*Trichostrongylus* spp.	Cattle, goats, pigs, horses	Fecal-oral, contamination of food
Tuberculosis	*Mycobacterium tuberculosis*	Cattle	
	Mycobacterium bovis	Cattle	
	Mycobacterium avium	Sheep, pigs, poultry	Contact, ingestion, inhalation
Tularemia	*Francisella tularensis*	Sheep	Contact, bites of blood-sucking arthropods
Variant Creutzfeldt-Jakob Disease	Prion protein (bovine spongiform encephalopathy)	Cattle	Ingestion
Vesicular stomatitis	Rhabdovirus	Cattle, horses, pigs	Contact
West Nile Virus	Flavivirus	Horses	Mosquito bites
Whipworm	*Trichuria*	Pigs	Insertion of embryonated eggs in contaminated soil and water

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