Guide for the Care and Use of Agricultural Animals in Research and Teaching

AMERICAN DAIRY SCIENCE ASSOCIATION®

AMERICAN SOCIETY OF ANIMAL SCIENCE

POULTRY SCIENCE ASSOCIATION 1908

Fourth edition

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PREFACE

This is the fourth edition of the *Guide for the Care and Use of Agricultural Animals in Research and Teaching*, commonly known as the Ag Guide. This edition builds upon and replaces previous versions of the Ag Guide published in 1988, 1999, and 2010.

The Ag Guide is published jointly by the American Dairy Science Association (ADSA), the American Society of Animal Science (ASAS), and the Poultry Science Association (PSA). The Ag Guide comprises subject-oriented chapters covering subjects that pertain to all the agricultural animal species (chapters 1 to 5) and species chapters, which fall under the purview of the respective association(s) dedicated to the species (chapters 6 to 13). Each association appointed a senior editor to steer the revision of their respective species chapters and to collaborate with the senior editors from the other associations to guide the writing and revision of the subject-oriented chapters.

Committees charged with the writing and revision of the species-specific chapters were recruited by the respective professional associations devoted to the species. In addition, up to two individuals identified by each association were selected for each of the subject-oriented chapter committees, which thus comprised representatives from the three associations. The individuals recruited were scientists, veterinarians, or engineers with expertise in the species or subjects covered in their respective chapters. Each chapter committee selected a chairperson from its membership to coordinate revisions and interact with the senior editors.

The chapter committees searched the scientific literature to include new research published since the third edition of the Ag Guide. The Ag Guide senior editors reviewed the chapters before accepting final drafts. Each society was responsible for the peer review of the respective species-specific chapters, with reviewers drawn from peers and the society boards of directors. The boards of directors of each association reviewed and approved final drafts of the general chapters, as well as their respective species chapters. After these approvals, the chapters were compiled into the first draft of the fourth edition of the Ag Guide. All chapters were updated, revised, or rewritten, with the extent of revision of any given chapter determined by progress in the academic literature pertaining to subjects covered in the chapter. Three new poultry chapters were written, covering meat-type poultry, egg-type poultry, and waterfowl to reflect the diversity of species, phenotypes, and uses among avian agricultural animals, replacing the single chapter on poultry in the third edition of the Ag Guide.

The board-approved first draft of the Ag Guide was made available to the membership of ADSA, ASAS, and PSA, institutional animal care and use committees (IACUCs), and other users of the Ag Guide, and to the public for a 75-day period of comment. After all submitted comments had been considered, the 4th edition of the Ag Guide was produced and made available on the ADSA, ASAS, and PSA websites.

The Ag Guide covers agricultural animal species having different phenotypes within species and that are housed in assorted management systems across widely varying climates. The content must be sufficiently broad to cover the diverse research and teaching institutions that use agricultural animals, yet be clear enough to give unambiguous guidance to IACUCs responsible for the care and use of animals in their respective institutions. The terms *must*, *should*, and *recommend*, which were introduced in the third edition of the Ag Guide, have been clarified in this edition to mean the following when used in reference to a specific animal care and use practice: *Must* indicates that the animal care and use must be as stated; *should* indicates that the animal care and use ought to be as indicated unless otherwise justified; *recommend* indicates an appropriate way of doing things but leaves room for other approaches that achieve the same result.

The Ag Guide is not intended to be simply a set of provisions on how agricultural animals are to be housed and managed. Although many of the species chapters have standards for such things as floor space, feeder space, and drinker allocations because these metrics have been verified by scientific study and long practice, other animal care practices do not lend themselves to prescriptive stipulation. It is essential that IACUCs and others who oversee animal care practices exercise professional judgment to encourage appropriate animal welfare outcomes to be achieved, rather than merely seeking to apply specific housing and management requirements. An overly prescriptive approach to animal care and use can stifle research progress and teaching opportunities. The *US Government Principles for the Utilization and Care of Vertebrate Animals Used in Testing, Research, and Training* (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.

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CHAPTER 1: INSTITUTIONAL POLICIES

The *Guide for the Care and Use of Agricultural Animals in Research and Teaching* (the Ag Guide) strongly affirms that scientific and professional judgment and concern for the humane treatment of animals are required for the proper care of animals used in research and teaching. Scientists, veterinarians, and others must assume responsibility for animal welfare and uphold the rigor and integrity of agricultural animal research and instruction. The use of animals for research and teaching, including production research, is governed by numerous federal and local laws, regulations, and standards. In the United States, the *Animal Welfare Act* (AWA, 1990) and Title 9 Part 1A of the *Code of Federal Regulations* (USDA, 1985) apply, whereas in Europe, the *European Convention for the Protection of Vertebrate Animals used for Experimental and Other Scientific Purposes* (ETS123; Council of Europe, 1986) and subsequent amendments apply (Directive 2010/63/EU; European Union, 2010). A repository of international animal research regulations is available (AAALAC, 2018). Compliance with these laws, regulations, policies, and standards (or subsequent revised versions) in the establishment and implementation of an animal care program must be met. Other countries have also developed laws and guidelines for the use of animals in research, with many continuing to evolve (Odgen et al., 2016). 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 and knowledgeable institutional animal care and use committee (IACUC); (3) procedures for self-monitoring of the IACUC through regular (e.g., 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 (Curtis, 1994; Tillman, 1994; ARENA-OLAW, 2002; CIOMS-ICLAS, 2012). This chapter is intended to guide 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, institutional official, or responsible administrative official of the institution should appoint a committee (known as the institutional animal care and use committee or IACUC) to monitor the care and use of agricultural animals in agricultural research and teaching activities within the institution. The IACUC should be composed of individuals who are qualified by experience or training to evaluate the programs and proposals for agricultural animal research and should include individuals from each of the following categories:

- 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 non-science department, a staff member, a student, 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 (e.g., a member of the clergy or a community member). 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 institution; and
- other members as required by institutional needs and applicable laws, regulations, policies, and granting or research funding agencies or groups.

Because of experience and training, one individual may be able to fulfill more than a single role on the IACUC, but the committee should not have fewer than 5 members. This committee may also monitor the care and use of laboratory animals at the institution, provided 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 or unit committees (e.g., departmental, college, or program) that review agricultural and biomedical research that uses agricultural animals. The overriding goal should be to facilitate a centralized, uniform, and high-quality oversight of the institution's animal care program.

The IACUC should meet at regular intervals 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. The IACUC should work with investigators to resolve issues while ensuring animal care, taking into account the investigators' expertise with a particular species. The IACUC is authorized to

- review and approve or disapprove protocols and other proposed activities, or propose significant changes in activities, related to agricultural animal care and use in research and teaching;
- conduct, at minimum, semi-annual inspection of active agricultural animal facilities and study areas, review the overall agricultural animal care and use program, and provide a written report to the responsible institutional official regarding the institution's compliance with this guide (including expected dates of correction for detected issues and minority views of the IACUC, should they occur);
- investigate reports of noncompliance or animal care concerns involving agricultural animals at the facility;
- suspend activities involving agricultural animals when not in compliance with approved protocols or written operating procedures (see section: 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 that may be required by institutional need and by applicable laws, regulations, and policies.

Other useful information about IACUC functions and training can be found in Prentice et al. (1992), the *Institutional Animal Care and Use Committee Guidebook* (ARENA-OLAW, 2002), the *Public Health Service Policy on Humane Care and Use of Laboratory Animals* (NIH, 2015), *Animal Welfare Act* information repository (USDA, 2018), Oki et al. (1996), Silverman et al. (2006), and Greene et al. (2007).

PROTOCOL REVIEW

The review of research and teaching activities using animals is one of the most important functions of the IACUC. Animal use protocol(s) (AUP) 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 AUP may be granted, withheld pending modifications, or denied. The IACUC should perform an annual review and renewal of approved AUP with resubmission and re-approval at least once every 3 years. The IACUC may choose to re-review an AUP at any time as deemed necessary. 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 an important component of agricultural research and teaching (Vemulapalli et al., 2017); additionally, there is no substitute of another animal or simulation for production research.
- Aspects of the proposed experiment or demonstration having to do directly with animal care and use, including justification for the species and strain of animal used; justification for the number of animals used; description of procedures that may cause discomfort, distress, or pain; and methods of alleviating discomfort, distress, or pain 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 (endpoint criteria).
- Unusual husbandry requirements (Note: describing a procedure as a "standard farm operating 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 and disposition of the animal.
- 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" (Vemulapalli et al., 2017). Because IACUCs are NOT 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.

Investigators are encouraged to work with IACUCs for assistance in refining 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 in this guide, 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 such 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 the AUP and be reviewed and approved by the IACUC.

WRITTEN OPERATING PROCEDURES

It is important to develop written animal care and husbandry policies and procedures for each unit in the program. Some husbandry practices may cause temporary discomfort or pain. The IACUC must review and approve all operating procedures that have the potential to cause pain or distress in animal care and husbandry. These procedures would then be available for reference in the AUP without having to be described separately for each study, experiment, or demonstration. To be acceptable as written operating procedures, the procedures should sustain the long-term welfare of the animal and the animal handlers, be performed by or under the direct supervision of proficient personnel, and be conducted with precautions taken to reduce pain, stress, and infection. The written procedures must be filed in the appropriate administrative office and in locations accessible to individuals involved in carrying out these procedures.

Husbandry procedures and production methods at agricultural research facilities should be revised as changes occur in the industry and when research demonstrates improvements.

ANIMAL HEALTH CARE

Adequate health care and records must be maintained 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. All euthanasia methods utilized should follow American Veterinary Medical Association guidelines (AVMA, 2020) or be thoroughly considered by the IACUC before granting approval to ensure the animal incurs no undue pain or stress.

BIOSECURITY

It is essential that the agricultural animal care staff, researchers, students, and other associated individuals maintain a high standard of biosecurity to protect the animals from pathogenic organisms. 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 with training programs appropriate for animal user needs and 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 to minimize the number of animals used and techniques to minimize pain and distress, including the proper use of anesthetics, analgesics, tranquilizers, and nonpharmacologic 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; USDA-APHIS, 2018); 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, 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; https://www.aalas.org/), 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 degree who seek recognition of their expertise in the biology and production of agricultural animals can be certified through examination by the American Registry of Professional Animal Scientists (ARPAS; https://www.arpas.org/).

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 by 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; Kerst, 2003; Wald and Stave, 2003).

General guidelines for occupational health programs have been published by the National Research Council (NRC, 2011). The program for individuals working with agricultural animals may include a physical examination before job placement, periodic medical evaluations for people in identified job categories, assessments of the workspaces to ensure protection from health hazards, and provision for treating illness or injury. The program should also include an educational component to teach personnel about agricultural animal and zoonotic disease, physical hazards, and personal hygiene. Special precautions may be necessary for individuals who are at unusual risk (e.g., immunocompromised, having a temporary or long-term physical limitation, or pregnant). Additional training may be necessary if certain chemicals, radiation, and other hazardous agents are part of an experimental protocol.

It is important that all researchers, students, agricultural animal caretakers, and others be immunized against tetanus every 10 years based on the institution's risk assessment. Prophylactic vaccinations should also be considered when research is being conducted on infectious diseases for which effective vaccines are available. Persons working with animals may develop allergies. The occupational safety and health program should identify high-risk areas with a potential for allergy development. Persons with known allergies should be provided personal protective equipment (PPE) to reduce or eliminate allergen exposure or avoid exposure to animals. Physical injuries constitute health hazards for individuals working with 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 appropriate medical care provided as needed. Air quality assessments are recommended for animal care areas, and appropriate respiratory protection should be provided for these individuals (OSHA, 2011). Caretakers working with agricultural animals in closed buildings should be afforded the option to use respirators or dust masks because they may develop respiratory problems, including chronic and irreversible lung damage (Kirkhorn and Garry, 2000).

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, their waste products, or tissues should be made aware of identified hazards (Acha and Szyfres, 2001, 2003; Fontes, 2008). Zoonotic disease in animal populations should be screened for or monitored regularly as appropriate. Information pertaining to the most common zoonotic diseases found in agricultural animals and the means by which they are spread can be found in the Merck Veterinary Manual (https://www.merckvetmanual.com/).

The noise level in some animal facilities may be high. When personnel are exposed to noise exceeding local, state, or federal standards, appropriate protection programs must be implemented (USDL OSHA, 1995).

Work assignments and health records should be a part of an occupational health program. Occupational health program records are maintained under HIPAA guidelines and requirements. Records should be kept of individual work assignments and should include the date and time of injuries or unusual illnesses. Supervisors must inform personnel of potential health hazards, and personnel must notify their supervisor if a zoonosis occurs.

SPECIAL CONSIDERATIONS

Hazardous Materials

The use of 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 associated with 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-NIH (2000, 2007), CDC-FSAP (2005), and NRC (2011).

Genetically Engineered, Gene Edited, and Cloned Animals

As advancements in research drive the discovery and development of new technologies, consideration needs 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 animal technologies (Dennis, 2000; Wells, 2005). Guidelines for research involving genetically engineered (GE) and gene edited (GEd) animals 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 GEd agricultural animals should be the same as those applied to all agricultural animals in research unless the genetic modification requires alteration in management or environment to maintain animal welfare (Dennis, 2002). Clones of livestock animals that are not GE or GEd do not differ materially from nonclones and require no special considerations (Batchelder et al., 2007).

The animal biotechnology industry has guidelines for research and development with GE animals as a stewardship program (BIO, 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. The European Food Safety Authority (2012) has published an update on the welfare and environmental impact of food animals derived from cloning.

Research Involving Genetic Engineering and Gene Editing of Agricultural Animals

Genetic engineering of agricultural animals is the direct manipulation of an organism's genes, including heritable and nonheritable recombinant DNA constructs. Gene editing is the use of programmable nucleases such as TALENs (transcription activator-like effector nucleases) or the CRISPR/Cas 9 system that allows for the specific site-directed induction of a double-stranded DNA break, which can result in a targeted mutation (GEd) or insertion of a transgene (GE) (Petersen, 2018). 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 (NRC, 2002; CAST, 2003, 2007, 2009; Wheeler, 2007; Laible, 2009; Kues and Niemann, 2011; Tan et al., 2012; Murray and Maga, 2016), with the recent book by Niemann and Wrenzycki (2018) being a useful reference. For animals used in biomedical research, the needs for thermal comfort, humidity control, floor space, and appropriate nutrition and husbandry practices should be based on the standards outlined in this guide. Animals with certain genetic backgrounds may have special requirements that should be researched and documented to enable those responsible for animal care to be able to provide for the animals' comfort. Animal welfare for GE animals used in research is regulated by law in some jurisdictions, with regulations and guidelines established, for example, by the US Department of Agriculture (USDA), the US Food and Drug Administration (FDA), and the US National Institutes of Health (NIH) in the United States, and, by the European Parliament in Europe. Specific information for US institutions can be obtained by reviewing the NIH guidelines for research involving recombinant DNA molecules (NIH, 2002), the *Animal Welfare Act* regulations overseen by USDA, and the US FDA Guidance 187 for industry that may be helpful in the conduct of research with GE animals (FDA, 2009). FDA Guidance 187 does not address GEd animals and is currently in revision, so at this time there are no regulations specifically in force that address GEd animal use, care, or welfare.

Research Involving Cloning of Agricultural Animals

Animal cloning (Vajta and Gjerris, 2006) 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). 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 does not differ from that required for the animal from which the genotype is sourced. In addition, because the progeny of animal clones are not clones, progeny do not require special consideration.

Disposition of GE Animals and Clones

The disposition of GE animals and clones may be of interest to animal agriculture, stakeholders in the food chain, and the US government (FDA) because of issues involving the emergence of new policies by international governments (Codex Alimentarius, 2008). 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 livestock cloning companies to identify cattle and porcine clones in the United States. For more information about the registry, please see https://www.loc.gov/law/help/restrictions-on-gmos/restrictions-on-gmos.pdf.

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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 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 facilities 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 program or 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, nutrition, 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 for preventive and clinical treatments as appropriate for their species 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 veterinarian or their veterinary designee 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. However, some studies, such as comparisons of metaphylactic treatments for bovine respiratory disease post-shipment, 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 program 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 addition of animals should be discouraged in specific-pathogen-free herds or flocks. 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 or their veterinary designee in advance of shipment of the animals.

The program veterinarian, or skilled personnel under the direction of the program veterinarian, should perform an initial examination and subsequent daily observations of newly received 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 or Program Veterinarian

An institution using agricultural animals in research or teaching should have an official with the credentials and authority to manage an institutional animal care program. The housing, feeding, and nonmedical care of such animals should be directed by a veterinarian or scientist trained and experienced in the proper care, handling, and use of each species of agricultural animal used. A qualified veterinarian must be responsible for the agricultural animal health care program. This person may be designated the attending or program veterinarian. Although this model may not be mandated for every institution, it is the position of the Ag Guide that every institution should have a model like it. The Institute for Laboratory Animal Research (ILAR)/National Research Council *Guide for the Care and Use of Laboratory Animals* (The ILAR Guide; NRC, 2011) defines the attending veterinarian as a veterinarian "with sufficient authority, including access to all animals and resources, to manage the program of animal care." The attending or program veterinarian is a resource who can give research personnel advice that ensures that humane needs of animals are met and that is, to the extent possible, compatible with scientific requirements. *Animal Welfare Act* regulations and Public Health Service policy (US Department of Health and Human Services, 2015) require that the veterinarian serving in this role have the authority to oversee other aspects of animal care and use, including animal husbandry and nutrition, sanitation practices, zoonosis control, and hazard containment.

Research and teaching institutions should provide investigators and instructors with access to a veterinarian who has experience in the care of agricultural animals. The veterinarian can be full-time, part-time, or a private practitioner and should have capability to ensure that the provisions of the program are met. This program veterinarian should be provided access to all research and teaching animals and to any related documents including health care records. The program veterinarian should also be involved in development and oversight of the veterinary care program. This includes providing oversight of all aspects of animal care and use such as protocol review, establishment of anesthetic and analgesic guidelines, development of study removal criteria, and responsible conduct of research activities. Veterinary involvement in these activities helps to ensure animal health and welfare. The program veterinarian is not required to be the sole provider of veterinary care and can delegate authority to other qualified individuals. However, the program veterinarian should be responsible for the veterinary care of all animals and should have frequent and direct communications with others providing care. The program veterinarian should utilize the expertise of other professionals when making determinations about agricultural animal care. Trained non-veterinary staff and study personnel listed on the approved IACUC protocol may administer treatments according to standard operating procedures approved by the program 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 welfare, minimize pain and distress, utilize animal production practices, prevent zoonosis, assist 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, production practices, humane and appropriate restraint for the species involved, 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 program 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. When appropriate, 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 or injured animals with unrelievable pain or distress should be killed in the most humane way as soon as possible by trained personnel. Unexpected deaths should be reported to the attending veterinarian or their designee. 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 research data, and can aid in preventing further losses. When warranted and appropriate, waste and bedding removed from a site once occupied by a dead animal should be made inaccessible to other animals and the site disinfected appropriately.

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, as well as outcomes and levels of production. Medical records should comply with the American College of Laboratory Animal Medicine (www.aclam.org) 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 because the animals undergo daily observation or evaluation by trained individuals. The institution, in cooperation with the program veterinarian, should determine the method(s) by which medical records are maintained. Oversight of medical records is the responsibility of the principal investigator, the program 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. Observational information, such as the animal's behavior, results of physical examinations such as weight, and observed abnormalities, illnesses, or injuries;
3. Immunizations and other prophylactic treatments and procedures;
4. Documentation and interpretation of diagnostic tests when required;
5. Documentation of interventions by the researcher;
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* (Field et al., 2007) 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 or veterinary technicians), animal husbandry staff (animal care staff, managers, supervisors), and research staff (e.g., principal investigators, study directors 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."

SURGERY

Multiple Major Surgical Procedures

The ILAR Guide (NRC, 2011) differentiates major from minor surgery as follows: "major survival surgery (e.g. laparotomy, thoracotomy, joint replacement, and limb amputation) penetrates and exposes the body cavity, and may produce substantial impairment of physical or physiologic functions, or may involve extensive tissue dissection or transection. Minor survival surgery does not expose a body cavity, causes little or no physical impairment and would include suturing, peripheral vessel cannulation, and percutaneous biopsy, routine agricultural animal procedures such as castration, 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 surgery 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, as 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, may be appropriate. Likewise, multiple surgical procedures may be justified when they are related components of the same project (e.g., cannulation of the digestive tract at several locations).

Anesthesia and Analgesia

Painful animal husbandry-related procedures (standard agricultural practices), such as castration, dehorning, and tail docking, should be conducted with the use of pain management protocols appropriate for the age and species of animal involved. Details of these procedures are provided in the species-specific chapters. The program veterinarian should advise investigators about the choice and use of analgesics, anesthetics, or any other pain- or distress-relieving measure. This may include recommended times for withholding of food and water to minimize the risk of adverse events such as vomiting or aspiration after anesthesia. 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 distressing 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. In such cases, appropriately validated pain assessment methods should be used in conjunction with analgesic protocols (rescue analgesia) to manage pain and ensure that animal distress and suffering are minimized (Coetzee, 2011).

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

Sedatives and tranquilizers are psychotropic substances that alter mental processes or behavior but do not produce anesthesia or, in most cases, long-lasting analgesia (Coetzee, 2011). However, 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. However, these compounds may not provide long-lasting pain relief, especially when pain is associated with tissue damage and inflammation.

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 their designee, or by research scientists who are trained, highly skilled, and experienced in performing experimental surgery, in accordance with established protocols approved by an IACUC. Researchers should seek input from a veterinarian experienced in basic surgical techniques for the subject species when establishing surgical protocols to be approved by an IACUC. Institutions should 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 program veterinarian or their designee. Training provided must be documented and the competency of personnel ensured.

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 used. Good surgical practice includes the use of surgical caps, masks, gowns, and sterile gloves, as well as aseptic surgical site preparation and draping. Sterile instruments must be used. Manufacturers' recommendations must be followed for chemical sterilants. For non-survival 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 in accordance with standard agricultural 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 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 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 recommended:

- 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 with-

in the normal range during postsurgical recovery; and

- Trained personnel for postsurgical observation to help ensure a safe recovery. Postsurgical observation should be provided until the animal is fully recovered from anesthesia, ambulatory, and able to return safely to its original housing location.

Signs of Pain and Distress

Pain is an aversive feeling or sensation associated with actual or potential tissue damage resulting in physiological, neuroendocrine, and behavioral changes that indicate animal distress. Although pain and distress in animals can often be detected by an experienced observer, these conditions are sometimes unapparent, especially in stoic animals. When unanticipated pain or distress are detected, animal-care attendants or research staff should take immediate ameliorative action as necessary and contact the program veterinarian.

Pain can be one of the earliest signs of disease or injury. Animals in pain may become less active, restless, reduce feed consumption, grind their teeth, vocalize, or appear frightened and 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 inflammation, and should be considered an emergency.

Practices that minimize pain or distress in agricultural animals can be summarized using the 3S approach—suppress, substitute, and soothe (Guatteo et al., 2012). This involves removing or correcting the inciting cause of the pain (*suppress*), finding a less painful alternative (*substitute*), or administering appropriate analgesics, and other corrective steps (e.g., immobilizing a fracture, elevating an injured claw by securing a wood block under the opposite claw) to relieve the pain (*soothe*). Relief of pain should be one of the first tasks of the program veterinarian, adhering to the following principles: (1) relief of pain is a humane act; (2) relief of pain must be initiated promptly once it is deemed necessary; and (3) it may be necessary to protect animals in pain from self-injury.

The program veterinarian must be familiar with analgesics labeled for use in specific 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 reduced or alleviated may need to be euthanized. When experimental outcomes involve pain or distress that cannot be alleviated, humane endpoints must be clearly defined in the approved IACUC protocol.

ZOONOSES

Zoonotic diseases are defined as infectious diseases in animals that can be transmitted to humans, who, in turn, may transmit the infectious agent to another animal. Information pertaining to zoonotic diseases can be found online in the Merck Veterinary Manual (https://www.merckvetmanual.com/). 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 program veterinarian, working in collaboration with scientists or instructors of record, should establish appropriate preventive medicine programs and husbandry practices to decrease the likelihood of transmission of potential zoonotic agents. Each institution must have an appropriate occupational health and safety program for evaluating human health risks associated with animal contact and must take steps to ensure that health risks for each individual are assessed and managed at an acceptable level.

RESIDUE AVOIDANCE

Administration of drugs to animals destined to enter the food chain requires special consideration. Before an animal 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 regulations in the Animal Medicinal Drug Use Clarification Act of 1994, Public Law 103-396 (US Food and Drug Administration, 1994). 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.

Residues of 3 groups of chemicals must be prevented from occurring in research animals if these animals or their products are to enter 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 National Institute of Food and Agriculture (NIFA). 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 pre-slaughter 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 provides estimates of meat and milk withdrawal times for extra-label use of drugs.

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.

In addition to dating the first use of the product, and to minimize the potential for treatment errors, products should be physically segregated according to indicated use. For example, this could involve segregation of drugs by category when intended only for animals of a certain age or production state (e.g., lactating, nonlactating, pregnant, or neonatal). For large inventories, separate storage cabinets for each group of products will further reduce the chance of errors in selection and use. Lockable storage units can 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. 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 confirm that drugs are not outdated and that the directions on the label have been followed. Records should be maintained for at least 2 years or in timelines consistent with state and federal requirements as they apply (21CFR530; https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/CFRSearch.cfm?CFRPart=530).

In the event that animals are given an investigational drug, no meat, eggs, or milk from those animals may be processed for human consumption unless authorization has been granted by the FDA or the US Department of Agriculture 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 will depend on the development of data to show that the consumption of animal products so treated is consistent with public health considerations and that the product does not contain the residues of harmful drugs or their metabolites. 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 drug use (ELDU). 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 (US Food and Drug Administration, 1994). The major principles guiding such use are that (1) there must be a valid veterinarian–client–patient relationship (VCPR); (2) ELDU in feed is illegal; (3) the compound intended for ELDU must be manufactured in an FDA-inspected facility; (4) records of ELDU must be maintained for 2 years; and (5) there must be an adequate safety margin in the withdrawal time based on the most complete pharmacokinetic data available. The FARAD database or FDA should be contacted whenever guidance is needed. All personnel attending to food animals should be aware that the marketing status of medically important antimicrobials for use in feed or water for food animals changed from over-the-counter (OTC) to prescription (Rx) or to veterinary feed directive (VFD) at the end of calendar year 2016.

Organic Farming

Some institutions have organic farming components. The USDA National Organic Program standards [7CFR205.238 (c7); https://www.ams.usda.gov/rules-regulations/organic] state that the "producer of an organic livestock operation must not withhold medical treatment from a sick animal in an effort to preserve its organic status. All appropriate medications must be used to restore an animal to health when methods acceptable to organic production fail." Sick animals must be treated using "all appropriate medications" regardless of their intended "organic" status.

Hazardous Chemicals

Many chemicals used on farms and in agricultural research establishments 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, and expiration dates should be kept. Personnel must be informed of all such potential hazards and be required to 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

Physical restraint of agricultural animals involves the use of manual or mechanical means to restrict an animal's movements for the purpose of examination, collection of samples, administration of drugs, or a variety of other experimental and clinical manipulations. The period of restraint should be the minimum required to accomplish the objective. Physical restraint can be accomplished with devices such as stocks, head gates, stanchions, halters, squeeze chutes, or snares with swine. Species-specific methods of restraint should always be used. 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.

Prolonged physical restraint involves the restriction of normal animal movements for an extended period, typically hours or days. Animals should be conditioned to restraint equipment by a gradual process such as increasing the time of restraint on each occasion. Extended physical restraint, including a description of the conditioning regimen and monitoring of the restraint, should be reviewed and approved by the IACUC. Less restrictive systems that do not limit an animal's ability to make normal postural adjustments should be used when compatible with protocol objectives (Morrison et al., 1996).

HUMANE ENDPOINTS

Euthanasia

Euthanasia is a method of killing that minimizes pain, distress, and anxiety experienced by the animal before loss of consciousness. Protocols for euthanasia should follow the specifications for "acceptable" or "acceptable with conditions" techniques as described in the American Veterinary Medical Association (AVMA) *Guidelines for the Euthanasia of Animals* (AVMA, 2020) and include the method for confirming that death has occurred. Copies of these protocols should be made available to all personnel who euthanize animals. The current edition of the AVMA guidelines should be considered the primary standard for euthanasia.

Euthanasia must be carried out only by trained personnel in accordance with applicable regulations and policies. Where possible, the method used should not interfere with postmortem evaluations. Proper euthanasia includes skilled personnel who ensure that the technique is performed humanely and effectively and that the risk of injury to personnel is minimized or averted. Personnel who perform euthanasia must have training and experience with the techniques to be used. This training must include familiarity with the normal behavior of agricultural animals and how handling and restraint affect that behavior. All equipment and materials required to perform euthanasia should be readily available, and the program veterinarian familiar with agricultural animals or a qualified scientist or technician should ensure that all personnel performing euthanasia have demonstrated proficiency in the use of the techniques selected.

No matter what method of euthanasia is performed, personnel must ensure that death has occurred. Assurance of death is most reliably confirmed with a combination of criteria including lack of pulse, breathing, corneal reflex, and response to firm toe pinch; inability to hear respiratory sounds and heartbeat by use of a stethoscope; graying of the mucous membranes; and rigor mortis.

Slaughter

Protocols for slaughter should follow the AVMA *Guidelines for the Humane Slaughter of Animals* (AVMA, 2016). These guidelines outline procedures for the humane treatment of livestock before and during slaughter. Holding and processing areas must be designed and managed to minimize distress. In accordance with the US Code of Federal Regulations [9CFR§313.2(e)], water is to be accessible to livestock at all times in holding pens, and feed is to be accessible after livestock have been held longer than 24 h. Stunning equipment must be properly maintained, and personnel must be properly trained, including instruction in assessing insensibility. In the United States, all procedures used to slaughter research and teaching animals that will enter the food chain must comply with US Code of Federal Regulations, Title 7, Chapter 48, Humane Slaughter of Livestock (USDA-FSIS, 2011). The USDA's Food Safety and Inspection Service (FSIS) is the agency responsible for ensuring compliance with the Human Slaughter Act. The North American Meat Institute (NAMI) has embraced guidelines (https://animalhandling.org/producers/guidelines_audits) that exceed the regulatory requirements (Grandin, 2017) and the NAMI guidelines (NAMI, 2019) are incorporated here by reference.

Depopulation

Depopulation refers to the rapid destruction of a population of animals in response to urgent circumstances with as much consideration given to the welfare of the animals as appropriate. Urgent circumstances may include emergency situations, such as the need for immediate disease control or a response to natural or human-made disasters. Protocols for depopulation should follow the AVMA *Guidelines for the Depopulation of Animals* (AVMA, 2019). As much attention as possible should be shown to the needs and natures of animals that will be terminated (AVMA, 2019). However, ensuring the welfare of animals is just one of many important considerations during an actual response to an emergency situation. Therefore, the emergency destruction of animals through depopulation techniques may not guarantee that the deaths of the animals are as painless and distress-free as would be expected under other circumstances (AVMA, 2019).

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CHAPTER 3: HUSBANDRY, HOUSING, AND BIOSECURITY

Proper management is essential for the welfare of animals, the validity and effectiveness of research and teaching activities, and the health and safety of animal care personnel. Sound animal husbandry provides systems of care that permit animals to grow, mature, reproduce, and be healthy. Specific operating procedures depend on many factors that may be 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

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 and provided food, water, and appropriate shelter. Individual animals may be moved during their lives from extensive to intensive systems or vice versa.

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 for animals need to be managed 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.

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 the 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 heatwaves may require that animals have access to shelter. If trees or geographic features do not provide enough protection, it is recommended that artificial shelters, windbreaks, or sunshades be provided (Mitlöhner et al., 2001, 2002; Johnson et al., 2008; Marcillac-Embertson et al., 2009; Sossidou et al., 2011; Fanatico et al., 2016). Other methods of combating heat stress are direct wetting of the animals, evaporative cooling of the air, and providing fans. Intervention strategies should be based on individual animal responses. For example, open-mouth panting and drooling are clear signs that cattle are experiencing heat stress. Cattle showing these signs have higher respiration rates and body temperatures than animals that are not heat stressed (Gaughan and Mader, 2014; Tresoldi et al., 2016). Animals affected by hyperthermia or hypothermia should be treated accordingly.

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 may more frequently carry an allele that causes malignant hyperthermia when the animal experiences even mild stress (Bäckström and Kauffman, 1995). Transgenic animals may have special needs for husbandry and care (Mench, 1998); see Chapter 1: Institutional Policies. Animal care practices for a special strain should address the needs of the strain itself.

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 also affect the amount of space sensed, perceived, and used by animals in intensive management systems (Strickland and Gonyou, 1995; Leone and Estevez, 2008).

Determination of area requirements for domestic animals need to consider body size, head height, stage of life cycle, behavior, health, and weather conditions. 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 (Adams and Craig, 1985; Young et al., 2008; Guardia et al., 2011; Callahan et al., 2017), and animals may show altered levels of aggressive behavior (Al-Rawi and Craig, 1975; Winckler et al., 2015).

Temperature and Water Vapor Pressure

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 and genetics affect the thermal balance of animals and thus their behavior, metabolism, and performance. 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 welfare 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 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 the 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 or heat stress index (HSI) describes categories of heat stress associated with different combinations of temperature and relative humidity for livestock and poultry exposed to extreme conditions. Categories requiring management actions are "alert," "danger," and "emergency" (Xin and Harmon, 1998). Because different animal species have different sensitivities to temperature and relative humidity, conditions that constitute heat stress vary among species. The THI has also been developed and used for laying hens (Zulovich and DeShazer, 1990), hen turkeys (Xin et al., 1992), and tom turkeys (Brown-Brandl et al., 1997). Xin and Harmon (1998) described HSI for swine, cattle, laying hens, and turkey hens. For example, lactating dairy cattle may experience heat stress at a THI of 68 (Zimbelman et al., 2009). In addition, Tao and Xin (2003) developed a temperature-humidity-air velocity index (THVI) for broilers. Temperature-humidity indices for today's poultry have been modified due to changes in poultry genetics and current environmental conditions.

Ventilation and Air Quality

Appropriate ventilation of indoor barns is essential in providing acceptable air quality to both humans and animals. 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 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). Because the animals themselves are the major source of water vapor, heat, and (indirectly) odor ous matter, ventilation rate calculated on the basis of animal mass is more accurate than that based on air exchange rate guidelines.

The goal of hot-weather ventilation is to remove heat, whereas during cold weather, the goal is to remove moisture. Relative humidity is ordinarily the metric used to describe 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 in 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 determining 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, pigs, and poultry; however, it can cause death in poultry if inappropriately applied. 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. Animals with outdoor access can be protected from heat stress by correctly designing and maintaining sunshades to reduce solar radiation load. Trees, if available, are excellent sunshades. Artificial, roofed shades are acceptable as well.

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. Cold drafts on young poultry or pigs should be avoided (Curtis, 1983).

In enclosed animal houses, both environmental temperature and air quality depend on the continuous functioning of the ventilation system. It is recommended that an automatic warning system be installed alerting animal care and security personnel to power failures and out-of-tolerance environmental conditions, and an onsite generator should be available for emergency use.

The relative air pressures between animal areas and service areas of a building 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 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 (2017) has established allowable exposure levels for human workers having 8 h of exposure daily to these gases. The concentration of ammonia to which animals are exposed ideally would be less than 10 ppm and should not exceed 25 ppm, but a temporary excess may 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 air breathed by animals should not exceed 150 ppm (OSHA, 2002), and methane should not exceed 50,000 ppm. Special ventilation is required when waste pits beneath the floor are emptied because of the potentially lethal hazards to animals and humans from the hydrogen sulfide and methane gases that are released. The allowable dust levels specified by OSHA (2017) are based on exposure of human workers for 8 h daily without facemasks; allowable dust levels are 5 mg/m^3 for respirable dust (particle size of 5 μm or less) and 15 mg/m^3 for total dust. Although animals can tolerate higher levels of inert dust with no discernible detriment to their health or welfare (Curtis and Drummond, 1982), the concentration of dust in animal house air should be minimized.

Many factors affect airborne dust concentration, including relative humidity, animal activity, air velocity, and type of feed. Dust concentration is lower at higher relative humidity. 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 (Zhao et al., 2016). Concentrations of microbes in the air should be minimized. Dust and vapor pressure need to be controlled. Proper ventilation should preclude the mixing of air from microenvironments in which infected animals are housed with that from the microenvironments of uninfected animals.

Lighting

Illumination should be sufficient to aid in maintaining good husbandry practices and to allow adequate inspection of animals, the welfare of the animals, and safe working conditions for personnel.

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 research protocol requires otherwise. Long-day lighting schemes during lactation and short-day schemes during the dry period enhance lactation performance by dairy cattle (Dahl et al., 2000). See Chapters 6 through 13 for references on lighting and photoperiod in individual species.

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 need to 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 in MWPS (1993, 2001, 2002).

Proper management of excreta should ensure that the animals are kept reasonably dry and clean. A quick assessment of animal cleanliness can provide insight into the quality of their housing environment (cleanliness and dryness). Good sanitation is essential in intensive animal facilities, and principles of good sanitation must be understood by animal care personnel and professional staff. Animals can harbor microbes that are pathogenic to humans and other species. 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. Waste containers should be emptied and implements cleaned frequently. It is good practice to use disposable liners and to wash containers regularly. 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 sanitized appropriately.

At the conclusion of the animal project, organic debris should be removed from equipment and from floor, wall, and ceiling surfaces for cleaning. At times, complete removal of bedding material and organic debris may not occur as a result of the production system; for example, in broiler and turkey houses. In this case, composting or litter windrowing is a recommended approach to treat the material before the next group of animals is placed into the production environment. If sanitation depends on heat for effectiveness, the cleaning equipment must be able to supply water that is at least 82°C (180°F). When chemical disinfection is used, the temperature of the wash water may be cooler. If no machine is available, surfaces and equipment may be washed by hand with appropriate detergents and disinfectants and using 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). Other methods of waste disposal may be required for manure of animals infected with known pathogens.

Animal health programs should stipulate storage, handling, and use criteria for chemicals designed to inactivate infectious microbes and parasites. An animal health program should include information on 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. Dry-lot 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 of 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 (1994, 2001, 2007a,b, 2012, 2016) and as recommended for the geographic area. Nutrient levels below NRC requirement listings may be necessary for proper evaluation in studies evaluating nutrient requirements or comparing the relative feed value of different diet and/or ration components. When exceptions are required by an experimental or instructional protocol, these must be justified in the protocol and 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; Smith et al., 2004).

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 decrease transmission of microbial- or contaminant-associated disease. It is recommended that non-municipal water sources be periodically tested for quality by an approved agency or laboratory.

Large supplies of feed should be stored in appropriate, designated areas (MWPS, 2017). Bulk feed storage containers and feed barrels should be well maintained to minimize entry of pests, water contamination, and microbial growth. It is recommended that containers and the area around them such as the auger boot area be cleaned regularly to ensure feed quality. Feed in sacks must be stored off the floor and away from the walls on pallets or racks, and each sack must be labeled, as recommended by the Association of American Feed Control Officials, with the contents and manufacture date (AAFCO, 2019). All feedstuffs should be maintained in such a manner as to prevent contamination by chemicals 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 decrease transmission of microbial- or contaminant-associated disease. Feed placed in carts or in other delivery devices needs to 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 must 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). A poor social environment has been linked to illness in farm animals such as cattle, swine, and chickens (Proudfoot et al., 2012). 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, or olfactory contact with other members of their species. Socialization to humans and regular positive human contact can also be 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, with the understanding there may be aggression to the animal from the group.

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 welfare 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 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

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. A qualified veterinarian and animal facility manager should work together to devise housing configurations and husbandry practices that assure animal health and welfare while also meeting research or teaching goals.

HUSBANDRY

Animal Care Personnel

The principal scientist or animal management supervisor must 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.

Personnel caring for agricultural animals used for research or teaching must be appropriately qualified or trained. Qualification by experience or training must be documented. 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 updated regularly. The institution must ensure that emergency services can be contacted at any time by staff members.

The institution must ensure 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 ensure 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 the 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 must name employees or positions that are considered essential for providing proper animal management and care. Those employees should 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, or 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- or leg-banded, or wing- or neck-tagged with clothing tag fasteners. Ear notching, ear tattooing, ear tags, and electronic transponders 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 should not be branded unless legally required. Cattle should be identified by methods that minimize pain; for example, ear tags or collars. Recently, biometric identification (e.g., nose prints, DNA profiling, iris scanning, and retinal scanning) has been investigated as a noninvasive tool that is less prone to fraud than the aforementioned alternatives (Awad, 2016). 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 many protocols that make use of animals. These records may include information about the animal (e.g., birth date, sex), its productivity, protocols the animal is assigned to, and ultimate disposition. Records for individual animals or groups may also include dates of vaccination, parasite control measures used, and blood testing dates and results. 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 13 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, cockroaches, mosquitoes, lice, mites, ticks, grubs, rodents, skunks, and pest birds such as starlings, pigeons, and sparrows). The FDA Egg Safety Rule outlines protocols for monitoring and controlling rodents and flies in egg facilities that contain 3,000 hens or more (FDA, 2009). 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.

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). A pesticide applicator or a commercial service may be used.

In some regions, wildlife (e.g., skunks, raccoons, coyotes, 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 how to safely handle and report potentially rabid animals. Vaccination may be advisable for humans who may come into contact with animals in regions where rabies is endemic.

Although the use of free-roaming cats is a traditional form of pest control for agricultural facilities, cats limit the ability for baiting, present hygiene or accident risks, and serve as disease vectors (Van't Woudt, 1990; Van Sambeek et al., 1995; Vantassel et al., 2005). Therefore, it is suggested that cats not be included as a method of rodent control.

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 cause many serious injuries to humans (Hanford and Fletcher, 1983). Standard agricultural practices for the different species are found in Chapter 2 and Chapters 6 through 13.

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 euthanized (see Chapter 2: Agricultural Animal Health Care and Chapters 6 through 13 for species-specific recommendations) 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, alkaline hydrolysis, 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

Occupational noise limitations have been established for workers. Employees should be provided appropriate hearing protection and monitored for their effects when working in loud circumstances (Mitloehner and Calvo, 2008). Noise is an important husbandry consideration and is discussed further in the section on sensory enrichment in Chapter 4: Environmental Enrichment and on animal perception in Chapter 5: Animal Handling and Transport.

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 et al., 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 may be 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.

There should be a sufficient preconditioning period to ensure adequate adjustment and comfort of the animal to the metabolism stall before sample collection starts. Animal-based measures (e.g., lying time) should be used to determine the animal's adjustment and comfort. 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 greater 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. 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, "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 in the context of preventing the unintentional transfer of pathogens to animals and humans through appropriate facility design, training, and precautions (e.g., immunizations). 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). The USDA publication is designed to prevent both intentional and unintentional introduction of pathogens at the farm level. Additionally, a list of references and resources is provided in the publication 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; Julien and Thomson, 2011; Kerr, 2017). 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 agricultural animal care staff maintain a high standard of biosecurity to protect the animals from pathogenic organisms that can be transferred by humans. Preventing the introduction of disease agents is a continuous challenge, particularly when teaching and research facilities allow public access. Herd and flock 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 and poultry 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. If personnel are around an agricultural or restricted animal, the recommendation is that a period of time should elapse before interacting with animal species in the research setting. Seventy-two hours is a recommended elapse time, but other factors for controlling microorganisms, outlined above, can be used to shorten the elapsed time. In addition, if personnel need to go back and forth between different phases of production, it is critical that they work with younger animals first and then older animals, and work from clean to dirty phases of the farm.

Major disease outbreaks (e.g., porcine epidemic diarrhea, avian influenza) have been appearing in the United States on a regular basis since 2014. One simple way to enter facilities without shower-in/shower-out capabilities is the Danish entry system. Individuals enter the facility and stop at a bench, which creates a physical barrier, requiring them to cross over the bench to enter the animal facility. Dedicated footwear and clothing are located on the “clean” side, and individuals change footwear and clothing before entering the animal facility (Janni et al., 2016). At a minimum, this type of system can provide a line of separation between a “dirty” and “clean” environment, allowing for minimal transmission and transportation of infectious diseases.

Boot Cleaning and Disinfection

The use of boot baths, dry or wet, can prevent or minimize mechanical transmission of pathogens among groups of animals or operations. Visible organic material may be removed from boots using water and a brush or a 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 are recommended to step into and scrub their boots in the boot bath upon entry and when leaving the room or 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

Research or other activities with high-consequence livestock and poultry pathogens causing high morbidity and mortality (e.g., tuberculosis, foot and mouth disease) or the vectors carrying these pathogens (e.g., mosquitoes, ticks) must be conducted in biocontainment. These pathogens 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, 2009). The use of these pathogens requires facilities that 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 Agricultural Research Service (ARS) construction projects. These standards include useful information on the design of containment facilities for agricultural research, addressing hazard classification and choice of containment, containment equipment, and facility design issues for the different levels of biocontainment (USDA-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 Requirements Manual* (NIH, 2016a) contains 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, 2016b). 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 (Veterinary Services 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 National Institutes of Health *Guidelines for Research Involving Recombinant DNA Molecules* (NIH, 2016b) 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 because 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 in certain situations; for example, when opportunities for social interactions are not available or where the animals' physical environment is restricted or lacking in complexity.

Environmental enrichment has wide-ranging physiological and behavioral effects on a variety of animal species (Young, 2003). It can be particularly effective in research settings 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 that the endpoint of enrichment is 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 environmental interactions (e.g., the use of space); or (4) increasing the animal's ability to cope with behavioral and physiological challenges such as exposure to humans, experimental manipulation, or environmental variation.

There are important practical considerations involved in providing animals with enrichments, including those related to animal safety (Bayne, 2005). For example, animals can sustain injuries from environmental enrichment, such as 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). In addition, perches are an often-recommended method of enrichment for laying hens. However, research has found that 80% of hens housed in systems that provided perches had keel bone damage (Wilkins et al., 2011). Thus, it is very important to monitor environmental enrichments on a regular schedule specific to the situation for both health and safety concerns. Other enrichment considerations are related to facility design, cost, sanitation, ease of management (including the amount of time and effort that caretakers put into maintaining the enrichment program), and potential effects on research outcomes. Genetic differences between breeds, lines, or strains of agricultural animals may also be present that affect their use of or responses to enrichment (e.g., Hill et al., 1998). To determine which type of enrichment is best suited for a particular situation, it is important to seek input from institutional animal care and use committees (IACUC), veterinarians, researchers, and the caretakers who will be responsible for the day-to-day implementation of the enrichment program (Weed and Raber, 2005).

Ideally, enrichment strategies should be science-based and based on species-specific behavior and physiology, as well as sufficiently sustained attractiveness (e.g., rotate enrichment items) and utility to the animals to achieve the desired outcomes. Bloomsmith et al. (1991) provided a useful categorization of enrichment types, adapted below:

1. Social enrichment involves 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 involves stimuli that are visual (e.g., television or video), auditory (music, vocalizations), or in other modalities (e.g., olfactory, tactile, taste).
5. Nutritional enrichment involves either presenting varied or novel food types or changing the method of food delivery.

Various studies have assessed all of these types of enrichment for use with agricultural animals. Nonetheless, continued assessment of outcomes is critical to ensure that the enrichment program is effectively meeting the intended goals. It is also essential to be aware that when an enrichment type (i.e., nutritional evaluation) is part of the experimental study, it is contraindicated. Observations of animal behavior, health, performance characteristics, and use of the enrichments are essential components of such an assessment. For outcomes to be assessed adequately, it is important that individuals who are making the observations be appropriately trained in sampling methods and that these methods are standardized across raters.

In the following sections, discussion focuses on validated or potential enrichments for each species as appropriate. All agricultural animals are social (except for the adult boar), and social behavior and management of social groups are covered in the respective species chapters.

CATTLE

Social Enrichment

Calves. Dairy calves, which are conventionally separated from the cow at birth, should be kept in social contact with at least one other calf for the majority of the milk-feeding period. Welfare benefits of social contact are well-supported by literature (as reviewed by Costa et al., 2016; see also Chapter 7: Dairy Cattle). For dairy calves, individual housing has historically been recommended to reduce disease transmission. However, evidence suggests that housing calves in small, well-managed groups (<8 calves) does not increase morbidity compared with individual housing (Svensson et al., 2003; also reviewed by Costa et al., 2016). Social contact encourages greater solid feed intake and weight gain in preweaning calves (Jensen et al., 2015), allows for social bonding and the development of social behaviors (Færevik et al., 2006; Duve et al., 2012), and improves cognition (Gaillard et al., 2014) and ability to adapt to postweaning grouping more readily (De Paula Vieira et al., 2010). Cross sucking can occur in group-housed calves but can be reduced by feeding calves a high milk allowance through a nipple or the provision of hay (Jung and Lidfors, 2001; Castells et al., 2012). Group housing of calves also may reduce tongue rolling in cattle (Seo et al., 1998).

Cattle. It is recommended that adult cattle be provided with social housing (see also Chapter 3: Husbandry, Housing, and Biosecurity and Chapter 7: Dairy Cattle). Dairy cattle that are isolated from conspecifics for 15 min will show physiological and behavioral signs of stress, including increased heart rate, cortisol concentrations, defecation/urination, and high-frequency vocalizations (Rushen et al., 1999). Beef cattle separated from conspecifics in a restraint device for 6 h are more likely to have dark-cutting meat, a physical sign of stress (Apple et al., 2005). If cattle must be isolated, it is recommended that they have at least visual and auditory contact with other cattle.

Cattle benefit from group living, but moving cows between groups (regrouping or remixing) can be stressful. Dairy cows moved into a new social group are more likely to experience physical displacements from the feed bunk, spend less time lying, and produce less milk on the day of regrouping than on previous days (von Keyserlingk et al., 2008). Thus, minimizing regrouping is recommended, and cattle should be kept in stable groups when possible. If regrouping is necessary, it is recommended that cattle be moved into low-stocked pens and by moving more than one animal at a time into a new pen, as these practices can limit stress-related behavior (Neisen et al., 2009; Talebi et al., 2014).

Human–Animal Interactions. See Chapter 5: Animal Handling and Transport for a detailed summary of animal handling and transport for beef and dairy cattle. Research on cattle–human interactions indicates that animals benefit from gentle and confident handlers using low-stress handling techniques (Hemsworth et al., 2000). Negative human behavior, such as hitting, shouting, and rough handling, should be avoided, as it is stressful for cattle and may lead to the development of a conditioned fear response to handlers (Pajor et al., 2000, 2003). Positive human behavior such as gentle stroking on the animal's neck is recommended when it is safe and practical, as this can reduce fear- and stress-related behaviors in beef calves and dairy cattle (Schmied et al., 2008; Probst et al., 2012).

Occupational Enrichment

Calves. Calves should be housed in pens that provide them enough space to turn around and lie down comfortably. Exercise is important at all stages of life for cattle. Young animals obtain exercise by engaging in physical play behavior directed at conspecifics or objects (Held and Špinka, 2011). Calves are strongly motivated to engage in play behavior (Jensen, 2001). Play behavior is facilitated by group housing compared to individual housing (Jensen et al., 1997; Valníčková et al., 2015) and by increasing pen space allowance (Jensen and Kyhn, 2000).

Cattle. All cattle should be provided some daily exercise, including the ability to walk or run around their pen, lot, pasture, range, or other types of loose-housing (Veissier et al., 2008). Tied cattle should also have daily exercise, such as outdoor access to walk, run, and groom themselves. Dairy cattle kept in tie stalls given daily exercise had fewer illnesses requiring veterinary attention and fewer hock injuries (Gustafson, 1993), as well as lower incidences of lameness, teat injuries (Regula et al., 2004), and mastitis (Popescu et al., 2013) compared with animals that were not exercised. A lack of exercise may increase the time it takes cows to lie down and stand up, suggesting negative effects on joints and tendons due to lack of movement and exercise (Gustafson and Lund-Magnussen, 1995).

Access to pasture or range is also beneficial to cattle when it is well managed, and shade is provided for thermal comfort (see Chapter 6: Beef Cattle and Chapter 7: Dairy Cattle). Dairy cows are highly motivated to access pasture when given the opportunity (von Keyserlingk et al., 2017). Access to pasture during summer has been shown to reduce the risk of injuries and lameness in tied dairy cows (Corazzin et al., 2010) and lameness in dairy cows housed in freestalls (Chapinal et al., 2013).

Physical Enrichment

Calves. Providing a more complex physical environment for calves can have benefits. For example, housing a group of calves in a pen divided by a wall can decrease agonistic interactions between calves compared with an open pen (Ninomiya and Sato, 2009). Providing calves with more complex and variable environments may also encourage play behavior and exercise. Adding fresh bedding (e.g., sawdust or straw) to a group pen can stimulate play behavior (Jensen et al., 1998). Providing calves with other physical enrichments such as a brush or hanging balls can encourage grooming and play behaviors (Bulens et al., 2014; Pempek et al., 2017; Toaff-Rosenstein et al., 2017).

Cattle. Providing beef and dairy animals that are due to give birth with physical barriers that allow them to separate themselves from the other cows may be beneficial. In nature, beef and dairy cows will seek a secluded area in which to give birth (Lidfors et al., 1994), and dairy cows housed singly indoors are also motivated to seek seclusion at calving (Proudfoot et al., 2014a,b). For dairy cattle, hospital and sick pens should be in a quiet area and provide cattle with the opportunity to seclude if they choose; these pens should also allow for easy access for caretakers (described in more detail in Chapter 7: Dairy Cattle). Research has shown that dairy cows will seek a more isolated space when they have an infectious disease after calving (Proudfoot et al., 2014a) but not when they are lame (Jensen et al., 2015). Allowing cattle the opportunity to physically separate from other animals may reduce agonistic behaviors in a group setting. For example, dairy cows given access to a loafing area outside of their pen experienced fewer agonistic behaviors than those in pen without a loafing area (Haskell et al., 2013).

It is recommended that cattle have access to an outlet for grooming. When cattle are on pasture, they use trees or other objects to groom parts of their bodies that they cannot reach themselves. Indoors, cattle groom themselves on fences, metal gates, and other objects in pen. Cattle can benefit from access to a grooming apparatus that allows them to groom all parts of their bodies without having to use various parts of the pen. Grooming devices such as stationary and rotating brushes are used by cattle (DeVries et al., 2007; Mandel and Nicol, 2017), but rotating brushes are preferred (Gutmann, 2010). Giving dairy cows access to a brush can result in better hygiene and improved milk yield (Schukken and Young, 2009).

Nutritional Enrichment

Calves. Young calves have a strong motivation to suckle. An artificial teat should be provided to help satisfy this drive for functional consequences of sucking (release of hormones involved in digestion; de Passillé et al., 1993) and to reduce the occurrence of redirected oral behaviors and cross sucking (Jung and Lidfors, 2001) if and whenever possible.

In addition to free access to pelleted starter diet, provision of chopped low-quality hay to dairy calves has been shown to encourage greater solid feed intake and reduce nonnutritive oral behavior (Castells et al., 2012), suggesting that chopped hay is a beneficial addition to the diet of preweaning calves. However, Hill et al. (2010) found that as roughage in the diet increased, growth in weaned calves declined. Thus, roughage may have benefits for behavioral enrichment but impair other biological functions dependent upon the age and stage of production. Further, preweaning dairy calves will select within a mixed diet in favor of chopped hay, suggesting they may be motivated to obtain it (Miller-Cushon et al., 2013).

Cattle. Cattle are at risk of developing oral stereotypic behavior such as tongue rolling, tongue playing, bar-biting, chain chewing, and biting other objects. Restricted feeding regimens and low levels of forage and fiber in the diet may drive these behaviors in dairy cattle (Redbo et al., 1996, Redbo and Nordblad, 1997), although dietary effects on nonnutritive oral behavior are less well studied in beef cattle (reviewed by Ridge et al., 2020). Providing dairy cows with ad libitum access to feed and diets high in forage can reduce oral stereotypic behavior.

Weather permitting, access to well-managed pasture or range is beneficial and recommended for all cattle (see previous section on Occupational Enrichment).

Dairy cattle do not exhibit stereotypic tongue rolling while at pasture, as their motivation to graze has been satiated (Redbo, 1990).

Sensory Enrichment

Dairy and beef cows have sensitive hearing due to their large pinnae that amplify sound waves, and cows can hear at much higher frequencies than humans (Heffner and Heffner, 1983). Loud noises such as human shouting or metal clanging are aversive stimuli and cause stress in both beef and dairy cattle (Waynert et al., 1999; Pajor et al., 2000). Quiet environments may be especially 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), dairy cows will avoid noise, such as noxious radio music and sounds of the milking machine or sounds associated with milking when given a choice (Arnold et al., 2008). High-pitched noises should also be avoided because these can damage hearing and alter feeding behavior (Kıyıcı et al., 2013). Providing quiet, low-pitched music during noisy procedures such as milking may have benefits for dairy cows. For example, when classical music was played in the milking parlor, cows had higher milk let-down speed than those not exposed to music in the parlor (Kıyıcı et al., 2013).

Fewer studies have assessed the effects of other sensory enrichments, such as vision and olfaction. Limited research shows that cows may not specifically benefit from seeing outdoor pasture spaces when housed indoors (e.g., Haskell et al., 2013). Olfactory enrichment may also be important for cattle, as they have a keen sense of smell and can detect scents that are not detectable by humans. However, there is limited research to date evaluating possible benefits of olfactory enrichments (reviewed by Mandel et al., 2016).

HORSES

Social Enrichment

When housing horses, they should be provided with visual and auditory contact with conspecifics. As a herd species, horses are highly motivated to interact with individuals of their species for comfort, play, access to food and shelter resources, and as an anti-predator 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 behavior compared with horses kept in pairs or groups (Houpt and Houpt, 1988). Horses housed singly also display more aggression toward human handlers and learn new tasks more slowly than horses housed in groups (Søndergaard and Ladewig, 2004). Confining horses for extended periods may produce behavioral problems (depression or aggression) that sometimes progress to exhibiting stereotypies. Examples include stall weaving, cribbing, or wind sucking. Thus, horses should be given access to a pasture or paddock regularly. Management efforts to minimize stereotypies due to social deprivation have included the provision of companionship such as that provided by another horse or pony, or even a goat, cat, dog, or chickens.

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. However, 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). Mutual grooming and maintaining proximity characterize social relationships among females (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. Stallions, except after periods of social deprivation, rarely groom each other (Crowell-Davis et al., 1986; Christensen et al., 2002). Colts and geldings 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 (Snorrason et al., 2003).

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

When horses are housed singly or in isolation facilities, horses should be provided visual contact with other equids to prevent distress associated with social deprivation. 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 posters of horse face images (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 grooming by humans; heart rate is reduced when horses perform mutual grooming (Feh and de Mazieres, 1993) and when humans brush or scratch the withers and neck regions (Lynch et al., 1974; Hama et al., 1996). However, this positive association with tactile stimulation by humans appears to be learned rather than innate (Henry et al., 2006). In the absence of positive interactions, foals begin to avoid humans at 3 wk of age (Lansade et al., 2007).

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 homemade devices such as plastic jugs hanging on ropes. Scientific evidence regarding the efficacy of these products is lacking. Bulens et al. (2013) provided horses with a plastic bottle filled with sand and a rope. They found very limited use of the items, with the least use observed when hay was not provided. They found similar results (Bulens et al., 2015) when providing a ball with an apple odor or a rope, noting that non-edible items do not appear useful as enrichments.

Physical Enrichment

Horses should be given the opportunity to exercise on a regular basis. 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 (Jørgensen 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 turnout 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). Interestingly, Whisher et al. (2011) found that horses that were exercised for 20 min in a round pen cribbed more than horses that were not exercised. When comparing horses turned out individually 3 times per week with those turned out daily in a group, Lansade et al. (2014) found that horses that had daily turn-out in a group had decreased fearfulness, better learning, a decreased stress response, and increased immune responsiveness.

Sensory Enrichment

In stables, it is common for background radio noise to be provided, with the assumption that this noise has 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). Those authors speculate that background music may indirectly affect equine behavior through the attitudes of their human caretakers.

Nutritional Enrichment

Horses should be given forage material daily. 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 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 or licking. Undesirable oral behavior can be suppressed 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), dividing concentrate feed into smaller and more frequent meals throughout the day (Cooper et al., 2005), and feeding oats instead of a sweetened grain diet (Whisher et al., 2011). Horses provided with straw bedding perform less stereotypic behavior than those bedded on paper or shavings (Cooper et al., 2005). Jørgensen et al. (2011) provided horses with 1 of 7 different enrichments, including edible items (such as straw, branches, feed ball) and non-edible items (such as ball, cone, and pole); they found that horses directed their behavior toward edible items more, and access to straw decreased agonistic behavior in group-housed horses. 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). Providing these toys in the manger can prevent horses from ingesting pathogens and nonnutritive materials from the stall bedding.

SWINE

An enriched environment may enhance the well-being of pigs by increasing behavioral diversity, adaptability, and learning while reducing aggression, fearfulness, stereotyped behaviors, and other inappropriate behaviors (e.g., belly-nosing, tail-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; Manciocco et al., 2011; Nowicki and Klocek, 2012; Scollo et al., 2013). It is important that the material or object provided as a form of enrichment meet at least some of the following attributes: edible (or feed-like), chewable, investigable, or manipulable, so that the item remains novel and is safe for the pig (Guy et al., 2013; AHDB, 2017). The substrates that are most beneficial to pig welfare include substrates made of straw or a composite mix (Bracke et al., 2006), whereas other items such as synthetic ropes, tires, and treated wood or wood that may contain nails may be unsafe and should not be used (AHDB, 2017); however, if ropes are used, they need to be of natural fiber as consumption of synthetic materials is not acceptable.

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 recommended (Stolba and Wood-Gush, 1984; Newberry and Wood-Gush, 1986; Wechsler, 1996; Weary et al., 1999b; Parratt et al., 2006). Social contact, both direct and indirect, may also be considered a form of enrichment in and of itself. For example, DeBoer et al. (2013) found that a conspecific located on the other side of a fence resulted in increased investigatory behavior and, in the presence of a human, pigs preferred access to a mirror instead of the human. These authors suggest that pigs may be using the mirror as a form of social support during the perceived threat of the human's presence.

When pigs are isolated from conspecifics for experimental purposes, friendly social contact with familiar caretakers can be beneficial. Pigs recognize familiar caretakers using visual (body size and facial features), 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, while other times aversive) handling, and stroking or scratching any pig that approaches them (Hemsworth et al., 1996). If pig–caretaker interactions are positive, pigs will confidently approach and seek interaction with them. Positive pig–caretaker interaction may enhance the handling experience for both pig and caretaker. Moreover, when piglets are weaned at an early age (14 d of age) for experimental reasons, providing companionship by grouping together with familiar pen-mates and providing a warm, artificial udder with flexible nipples if possible may decrease distress in these early-weaned piglets (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, and it is recommended that some form is used. Most research has focused on the use of straw as an enrichment material. Straw is a good choice because it safe, edible, chewable, investigatable, and manipulable. Moreover, access to pasture, soil, peat, mushroom compost, hay, bark, branches, logs, and other manipulable materials helps 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. Also, even if straw is used as bedding, providing additional straw can be used as a form of enrichment.

Pigs are initially attracted to materials that are odorous, deformable, and chewable, but for sustained occupational enrichment, the best materials by day 5 for sustaining attention are complex, ingestible, destructible, and contained but not particulate or rootable (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, or fir branches. Long straw is a useful enrichment material and tends to be more effective than chopped straw, sand, or ropes, and other 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; van de Weerd and Day, 2009). 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). Negative behaviors toward other pigs are reduced when pigs have access to long straw that is provided via a rack (Bulens et al., 2015). Others have found that providing straw only after tail biting has started can reduce the behavior, but 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). Lahrmann et al. (2018) also found that when weaner pigs were given increased access to enrichment at the start of a tail-biting outbreak, tail biting was reduced by the provision of extra straw or haylage compared with controls, who were given 2 wooden posts and 400 g of straw daily. Fu et al. (2018) provided 8 rubber toys per pen and found that weaned pigs had fewer injuries on their ears, docked tails, and the front of their bodies, and a decrease in respiration rate. Conversely, Chou et al. (2018) gave finisher pigs a choice of 4 different types of wood as enrichment; the pigs preferred spruce to the other types, but none of the wood types was effective in reducing tail, ear, or flank biting. Moreover, it is important to note that the risk of tail biting can be elevated, and activity depressed, if pigs initially reared with straw are subsequently housed without straw (Day et al., 2002; Bolhuis et al., 2006).

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). 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, providing 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 introducing mycotoxin molds. Biosecurity is always a concern when introducing enrichments from outside of a premise. A balance between effective biosecurity and effective enrichments can be challenging but should be the goal. It is recommended that bedding be managed to avoid wet litter and high ammonia emissions. Research has shown that sows housed in systems with pens enriched with straw during farrowing and lactation had shorter deliveries, higher oxytocin concentrations, and lower salivary cortisol (Chaloupková et al., 2011). Moreover, prepartum nest building by sows resulted in improved colostrum intake by the piglets during early lactation (Yun et al., 2014a) and positively affected piglet survival and performance (Yun et al., 2014b).

At least 24 h before farrowing, provision of an earth or sand substrate along with straw, branches, or other nesting materials enables sows to express their strong motivation to engage in nest-building behavior. Under natural conditions, nest building 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). Nest-building behavior was increased among gilts housed in straw-bedded pens while abnormal behaviors were reduced, especially oral manipulation of the pen bars (Yin et al., 2016). Providing nest-building materials can also favorably influence maternal behavior (Herskin et al., 1998; Ringgenberg et al., 2012) and may contribute to early piglet survival (Herskin et al., 1998; Jarvis et al., 1999; Damm et al., 2005). In fact, Oostindjer et al. (2011) reported that providing loose-housed lactating sows with environmental enrichment improved piglet performance and health before and after weaning.

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. Providing pigs fed a liquid diet with a small amount of straw resulted in increased exploratory behavior and reduced tail biting and ear chewing (Scollo et al., 2013). 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). Unattached objects at the floor level may be more attractive to pigs than hanging objects but become less engaging when these objects become soiled with excreta (van de Weerd et al., 2003). Manciocco et al. (2011) studied the simultaneous use of 4 enrichments (ropes, balls, chains, and hoses) over an 11-wk trial and found that enriched pigs had a lower neutrophil-to-lymphocyte ratio and less tail and ear biting. Enrichment materials should be monitored to reduce the occurrence of health problems (e.g., strangulation, choking, poisoning, obstruction of the digestive tract, transmission of pathogens) or compromised food safety. Supplying ample free access to preferred enrichment materials and objects will minimize aggressive competition for these resources.

Interestingly, ice blocks may be more interesting to pigs than rubber toys, but ice blocks have no effect on other behaviors (Peralta and Rizzo, 2015). However, Nannoni et al. (2016) found that hanging chains were just as effective at maintaining "welfare status" as were edible blocks or wood bricks for post-weaning pigs for a duration of 45 d. Nowicki and Klocek (2012) found that hanging vanilla-scented cloth strips was effective in reducing aggression in newly weaned pigs. Use of 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; Scollo et al., 2013). Others have found that different forms of enrichment materials such as corn silage or alfalfa hay have no effect on the incidence of tail biting (Veit et al., 2016).

Moreover, 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 type of environmental enrichment was shown to stimulate the immune system and speed up wound healing (Ernst et al., 2006). More specifically, pigs that had access to a specialized feeding system in which they located the feeding site acoustically and were rewarded with feed had smaller wounds and a more activated immune response at d 5 post-biopsy compared with control pigs (Ernst et al., 2006), implying that under certain circumstances some enrichment may have health benefits.

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, providing limit-fed sows a small food reward does not appear to cause stereotyped behavior when combined with loose housing in straw-bedded pens (Terlouw et al., 1993; Haskell et al., 1996), even though it is recommended that sows receive their feed allotment in a single meal. 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.

Physical Enrichment

The welfare implications of housing during gestation, individually in crates versus group housed in pens, is discussed in Chapter 9: Swine.

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. Two-level pens that subdivide the pen space, thereby increasing exercise and movement opportunities, may facilitate easier handling and herding of pigs because the pigs already experience more movement (Fraser et al., 1986; Pedersen et al., 1993). Moreover, habituating pigs 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, it is recommended that calculation of stocking density and feeder space 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.

Certain types of artificial lying mats may also increase lying (Phillips et al., 1995; Tuyttens et al., 2008) and thermal comfort (Boyle et al., 2000; Tuyttens et al., 2008), and reduce lesions (Elmore et al., 2010). Previous work by Elmore et al. (2010) indicated that sows prefer to rest on rubber mats, but sows in stalls are not motivated to access a rubber mat (Elmore et al., 2012). Others have shown that sows prefer compost and straw over other substrates (Bench et al., 2013). 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 can be used 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 harmless 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.

Pigs communicate through odors; therefore, it is recommended that decisions about cleaning regimens consider this if inter-animal communication will affect research or teaching objectives. 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 can 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).

Noise from fans and other equipment is unavoidable in commercial swine facilities, but to facilitate vocal communication between pigs, continuous loud noise (e.g., radios and human activity) should be kept to a minimum. 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 distressed vocalizations. When significantly stressful procedures are performed (e.g., castration, tail docking), handling piglets outside the hearing range of sows is recommended. 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). Habituation to a variety of environmental sounds can 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. Pregnant sows housed in individual stalls and pens with stalls and subjected to music had a higher percentage of relaxation behaviors and reduced expression of stereotypies compared with groups of sows without music (Silva et al., 2017).

Nutritional Enrichment

During pregnancy, sows may be fed a limited amount of a nutritionally balanced feed to prevent excessive weight gain, which may result in difficulties during farrowing and lactation. Although the ration fulfills their nutrient requirements, the sows eat it quickly and may be hungry later in the day, especially if the entire feed allotment is offered once a day. The sows' normal response to hunger is to express foraging behavior. It is recommended that cotton rope be used as an alternative to straw for expression of oral behaviors associated with foraging (Feddes and Fraser, 1994) for feed-restricted sows in intensive systems; however, based on motivation behaviors, a cotton rope is not valuable enrichment for all sows housed in gestation stalls (Elmore et al., 2012). The motivation for access to a cotton rope varies greatly across sows and may be partially linked to a lack of satiety (de Jonge et al., 2008). Sows housed in stalls valued compost in a trough and straw in a rack over hanging cotton ropes (Elmore et al., 2012). 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). Providing straw and other low or ingestible foraging substrates that occupy the sows in diverse foraging activities reduce these behaviors. Feeding a diet high in fermentable nonstarch polysaccharides (e.g., sugar beet pulp, soybean hulls) to increase satiety may also promote desirable foraging behaviors (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). When sows are housed in group pens during gestation, the use of straw and other manipulable objects may help to reduce aggression and incidence of injuries that commonly occur among group-housed sows (Andronie et al., 2010). Feeding a high-fiber diet to sows does not always affect stereotyped oral-nasal-facial behaviors among group-housed sows (McGlone and Fullwood, 2001). However, recent data indicate that it is plausible to reduce oral-nasal-facial behaviors among small group-housed sows when kept at 1.7 m^2 per sow instead of 2.3 m^2 and fed a high-fiber diet, which may be reflective of altering oral behaviors associated with pre- and post-feeding behaviors, but does not affect satiety (DeDecker et al., 2014).

Zwicker et al. (2013) compared restricted-fed finishing pigs with full-fed finishers that were all provided with 8 enrichment materials, finding that pigs fed ad libitum spent less time exploring pen enclosures and flooring. The incidence of gastric lesions may be reduced in pigs given straw compared with those lacking access to roughage (Bolhuis et al., 2007). Overall, these edible sources of enrichment for pigs affect some behaviors but do not necessarily serve as a nutritional source of enrichment per se.

SHEEP AND GOATS

Social Enrichment

Sheep. Sheep are highly social animals and develop abnormal behaviors, including pacing and oral stereotypic behavior, when penned individually (Lauber et al., 2012). If social contact is limited, sheep should have 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).

Goats. Goats are highly gregarious and social animals (Miranda-de la Lama and Mattiello, 2010). Social isolation can result in physiological and behavioral signs of stress (Kannan et al., 2002), and social isolation of the doe during gestation can result in higher stress reactivity in her subsequent offspring (Duvaux-Ponter et al., 2003; Roussel et al., 2005). If social contact is limited, goats should be provided visual contact with other goats.

Human–Animal Interactions. Goats and sheep can develop strong bonds with humans when they are handled positively (Anderson et al., 2004). Goat kids that are handled gently are calmer and easier to approach and are able to cope with stressors better (Boivin and Braastad, 1996).

Occupational and Physical Enrichment

Goats should have access to objects that they can climb. They 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, using vehicles and tires for climbing, has been shown to increase feed consumption and reduce aggression in goats in feedlots (Flint and Murray, 2001). The provision of appropriate climbing space that is ample for the number of animals in the group may not be feasible but can prevent dominant animals from displacing subordinates. Also, climbing devices should be placed in such a manner as to prevent the goats from vaulting out of the enclosure.

Goats will seclude themselves from the group when they are preparing to give birth (Ramirez et al., 1995). Providing does with the opportunity to hide, such as a wall in an indoor pen, access to an outdoor area, or bush/tall grass on pasture, may be beneficial. Because many animals lie down during obstetrical procedures, sufficient space should be provided to permit adequate freedom of movement. Goat kids have been found to seek hiding spaces during the week after birth in a natural and indoor setting (Lickliter, 1984). Thus, providing kids with appropriate hiding areas may be important.

Nutritional Enrichment

Sheep. Confined sheep can develop oral stereotypic behaviors, such as wool biting (and eating wool of other sheep; Vasseur et al., 2006; Lauber et al., 2012). Wool biting has been described as a redirected behavior, and lack of environmental stimulation and diet may contribute to the onset of wool biting (Sambraus, 1985; Lynch et al., 1992). Increasing the roughage content of the diet by providing supplemental forage has been shown to reduce wool biting (Vasseur et al., 2006; Huang and Takeda, 2018), particularly when the supplemental forage is rolled hay (Huang and Takeda, 2018).

In addition to wool biting, pacing is observed in individually penned sheep, predominantly immediately before feeding (Lauber et al., 2012), suggesting that it may also be related to frustrated feeding motivation.

Goats. Goats are browsers and therefore eat much of their food from a level above their head. Neave et al. (2018) found that goats prefer to eat from feeders above head level compared with floor feeders; however, the preference for elevated feeders increases aggression at the feed bunk. Goats are prone to develop abnormal repetitive oral stereotypies. Dairy goats have been found to generally direct their abnormal oral behavior to objects in the pen, such as walls or bars (Anzuino et al., 2010).

POULTRY

Social Enrichment

Poultry are generally gregarious and benefit from social interaction. Young birds develop food preferences through social learning (Johnston et al., 1998; Nicol, 2004), and the separation of socially housed birds causes distress (Jones and Williams, 1992). Chickens are generally tolerant of flock-mates, even when housed in large flocks, where they are unlikely to form stable social hierarchies. Ensuring that group-housed birds do not have to compete excessively for resources facilitates social tolerance and decreases the likelihood of aggressive interactions. Social tolerance and resource sharing has commonly been observed among group-housed ducks (Jones and Dawkins, 2010; Makagon et al., 2011; Rice et al., 2014).

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, may confer advantages for ease of later handling of birds and increase feed efficiency, body weights, and antibody responses (Gross and Siegel, 1983). However, not all studies have linked handling to feed efficiency or body weight (Nicol, 1992). Gross and Siegel (1982) also 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. However, the type of handling delivered matters. For example, gently lifting broiler chicks resulted in a heightened willingness of chicks to approach people and reduced fear responses after stressful events, but stroking chicks did not (Nicol, 1992).

Occupational and Physical Enrichment

Perches and Elevated Spaces

Laying Hens: Adult hens should be provided with 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 majority of the flock (up to 100% of hens) will utilize perches if sufficient perch space is provided (Appleby et al., 1993; Olsson and Keeling, 2002). When housing hens in floor pens, perches provide them with an opportunity to seek refuge from other birds to avoid aggressive pecking (Wechsler and Huber-Eicher, 1998; Cordiner and Savory, 2001). Housing hens at an early age with perches has been associated with a reduction in the prevalence of cannibalism (Gunnarsson, 1999). Perches can also minimize bird flightiness and fearfulness (Brake, 1987), and the exercise facilitated by vertical movement can improve bone strength (Whitehead, 2004).

Although perches provide many benefits for the hen, they have been associated with the development of bumblefoot (a painful foot condition) and keel bone lesions (Tauson and Abrahamsson, 1994, 1996). Keel bone lesions may present as deviations or fractures of the bone (Casey-Trott et al., 2015). It is important to design perches and place them within the environment in ways that promote their use in an attempt to minimize these problems. Perch space of 12 and 15 cm (4.7 and 5.9 in) per bird should be provided to light and medium hybrid hen strains, respectively (Appleby, 1995; Struelens and Tuyttens, 2009; Hester, 2014). Perch space of at least 15 cm (5.9 in) is recommended, but may be adjusted based on bird size. For example, studies have shown that 12 and 15 cm (4.7 and 5.9 in) per bird are sufficient for light and medium hybrid hen strains, respectively (Appleby, 1995; Struelens and Tuyttens, 2009; Hester, 2014). Perches should be free of sharp edges and 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. Perches made of softer materials are associated with a lower incidence of keel bone fractures; however, they can be more difficult to disinfect than those made of PVC or metal (Sandilands et al., 2009; Struelens and Tuyttens, 2009). When multiple perch levels are provided, it is recommended that installation of the higher perch be at an angle no greater than 45° relative to the one beneath it (Lambe et al., 1997; Scott et al., 1997). Alternatively, the addition of ramps can be used to assist hens with transitioning onto elevated spaces (Stratmann et al., 2015; Pettersson et al., 2017). Clearance of 19 to 24 cm (7.5 to 9.4 in) between the highest perch and cage top or ceiling is suggested (Struelens et al., 2008). Early exposure to perches during rearing facilitates perching behavior in adult birds (Faure and Bryan Jones, 1982; Heikkilä et al., 2006) and increases bone mineral content (Enneking et al., 2012). For more details about perches, refer to Chapter 12: Egg-Type Poultry.

Broiler Chickens and Turkeys: The effects of elevated spaces on activity time budgets and physiological outcomes of meat-type birds are unclear. Bird strain (e.g., slow vs. fast growing), group size, and the type and number of enrichments have confounded interpretation of available research. Broiler chicks and turkey poults, and laying strains of chickens, are rarely observed perching during their first few weeks. Perching behavior peaks when chicks are between 3 and 6 wk of age (LeVan et al., 2000; Martrenchar et al., 2001; Enneking et al., 2012). The use of elevated spaces among broiler chicks and turkey poults declines from approximately 6 wk of age (LeVan et al., 2000; Martrenchar et al., 2001; Norring et al., 2016). Designs that facilitate access and the bird's ability to balance, such as platforms (Norring et al., 2016; Bailie et al., 2018), are more often used than perches. Barrier perches (low perches that are anchored to the ground) have been associated with a greater incidence of perching compared with use of perch positioned over a stabilizing foot (Ventura et al., 2012). Straw or hay bales may be used to provide an elevated surface for broilers and turkeys but older or less mobile birds may have trouble accessing the tops of the bales. Additionally, because these substrates can promote foraging, the bales may be pecked apart and scattered (Martrenchar et al., 2001; Vasdal et al., 2019).

Broiler Breeders: Relatively few studies have evaluated the effects of environmental enrichments on the welfare of broiler breeders (Estevez, 2009; Riber et al., 2017), but broiler breeders use elevated spaces when offered. The initial increased use of perches levels off or decreases as the birds increase in size and weight (Gebhardt-Henrich et al., 2017, 2018). Like that in laying hens, perch use by broiler breeders is affected by perch arrangement and design (Muiruri et al., 1990; Gebhardt-Henrich et al., 2018). Perch provision may improve leg health and have positive effects on the reproductive output of broiler breeders (Rodriguez-Aurrekoetxea et al., 2015). Its relationship with keel bone damage is unclear (Gebhardt-Henrich et al., 2017).

Nests

Laying Hens and Broiler Breeders: Hens should be provided with a nest site when cage space allows. Nests are an important physical enrichment for egg-laying hens and breeding flocks (Appleby et al., 1986). 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. When provided with inadequate nest site (e.g., with intermittent or no access to nest boxes), hens display increased pacing and spend less time settled in their eventual laying position during the pre-laying period (Appleby et al., 1993; Yue and Duncan, 2003), which has been interpreted as an indication of frustration. A hen's motivation for nest use increases as the time of oviposition approaches (Cooper and Albentosa, 2003), and is not dependent on previous experience with a nest box (Cooper and Appleby, 1995). Nest boxes that offer seclusion are associated with more settled pre-laying behaviors and promote nest-building behaviors (Appleby and McRae, 1986; Struelens et al., 2008) and are therefore recommended. See Chapter 12: Egg-Type Poultry for more information about nests.

Turkeys and Waterfowl: Although it has not been evaluated, it is likely that turkey and waterfowl breeder birds have similar motivation to lay their eggs in a nest and therefore should be provided with access to nest boxes. For ducks, the provision of highly enclosed nests can promote nest use, decreasing the number of eggs laid on the floor (Makagon et al., 2011). Turkeys have been shown to prefer nest boxes that are less well lit, at least when initially selecting a nest site (Millam, 1987).

Loose Substrate

Chickens and Turkeys: The provision of loose substrate that provides birds with dustbathing and foraging opportunities is recommended. If an appropriate substrate is provided, chickens (all strains) and turkeys will dustbathe in long bouts on most days. During dustbathing, loose particles are worked through the feathers and then shaken out. This improves feather condition by dispersing lipids (van Liere, 1992). Dustbathing substrate has also been postulated to serve to remove ectoparasites, although the relationship between parasite load and dustbathing behavior remains unclear (Martin and Mullens, 2012; Vezzoli et al., 2015). Chicks engage in some components of the dustbathing sequence within the first week after hatch. The full sequence of actions that make up dustbathing is visible by the second week. By 3 wk of age, most chicks engage in dustbathing behavior that closely resembles the adult form (Larsen et al., 2000).

Laying hens prefer to dustbathe in fine-particle, friable substrates, such as sand and peat moss, than in coarse-particle substrates, such as wood shavings or sawdust, or Astroturf (Petherick and Duncan, 1989; Alvino et al., 2013). The dispersal of feed also promotes dustbathing; however, it leads to accumulation of feather lipids (Scholz et al., 2014). Hens will perform the dustbathing behavioral sequence on wire (sham dustbathing; Appleby et al., 1993). It has been suggested that hens develop sham dustbathing when dustbathing substrate is not accessible, and continue to sham dustbathe out of habit even after a friable substrate is provided (Olsson et al., 2002). Performance of sham dustbathing behavior does not seem to satisfy the hen's motivation to dustbathe in litter (Olsson et al., 2002) or to work for access to litter for dustbathing (Wichman and Keeling, 2008). Ensuring that adequate space and substrate are provided for multiple hens to dustbathe at once can reduce the occurrence of sham dustbathing (Louton et al., 2016).

Broiler chickens and turkeys typically have access to litter in which they can dustbathe. Supplementation with additional substrate is therefore not necessary. In addition to litter, access to dustbathing substrate in the form of sand, peat, oat or rice hulls, straw pellets, and clean wood shavings can stimulate dustbathing behavior of broilers to various degrees (Baxter et al., 2018a,b; Shields et al., 2004).

In addition to stimulating dustbathing behavior, the provision of suitable substrate, such as friable litter material, for chickens and turkeys facilitates foraging. Increasing foraging opportunities can, in turn, help to reduce the incidence of 2 abnormal behaviors, feather pecking and cannibalism (Newberry, 2004; Rodenburg and Koene, 2004). These behaviors are not related to aggression. 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). Once outbreaks of feather pecking and cannibalism start, they are difficult to control because the behaviors are socially transmitted among birds in the flock; therefore, it is best to prevent their occurrence through early intervention. For example, providing substrate during the early rearing period can reduce feather damage (Tahamtani et al., 2016); however, the age at which the substrate is provided and the type of substrate provided matters (Hartcher et al., 2015). Due in part to strong genetic effects (Kjaer and Hocking, 2004), these behaviors can be more difficult to control in some species or strains than in others.

Waterfowl: Waterfowl maintain their plumage condition by wet preening; loose substrate is not used for dustbathing. Water and friable substrates promote foraging behaviors and reduce feather pecking. However, they have been ineffective in preventing cannibalism (Riber and Mench, 2008), which is more prevalent among Muscovy ducks than other duck strains (Gustafson et al., 2007a,b).

Pools, Water Troughs, and Showers

Waterfowl will swim and wet preen when provided with a pond or pool. In addition to enhancing behavioral opportunities, these resources help waterfowl maintain good plumage condition. Ducks will also wet preen using troughs and showers, and to a lesser degree using water from nipple drinkers (Jones et al., 2009). When provided, open water sources should be cleaned regularly to maintain cleanliness and bird health, as they may harbor bacteria (Schenk et al., 2016). If swimming water is made available to ducklings, it should be provided in a manner that reduces drowning risk; for example, by keeping the water level low and ensuring that the ducklings can easily come out of the water.

Objects

In addition to the effects of objects on fearfulness, providing birds with objects that promote exploratory or pecking behaviors can also reduce feather pecking or aggressive behaviors. For example, providing laying hens with empty boxes, concrete blocks, or shell at 16 wk of age reduced gentle feather-pecking behavior (Tahamtani et al., 2016). Chickens were attracted to and manipulated hanging strings (Jones, 2004), and providing these in cages was found to reduce feather damage, presumably because of reduced feather pecking (Jones et al., 2004). The success of provision of pecking substrates, such as hay bales or string, for broiler breeders is not as clear (Hocking and Jones, 2006). Improved feather quality was reported in Pekin ducks that were provided with environmental enrichment consisting of wiffle balls threaded with colored cable ties (Colton and Fraley, 2014). Duggan et al. (2014) reported no difference in injurious pecking between turkeys provided with plastic balls and turkeys that did not receive plastic balls. On the other hand, Martrenchar et al. (2001) reported reduced pecking injuries in both toms and hens after providing growing turkeys with straw and hanging chains. Sherwin et al. (1999) reared turkeys with a variety of pecking substrates (e.g., vegetable matter, rope, flexible plastic conduit, and chains) and found that this reduced injuries caused by wing and tail pecking. Taken together, available evidence suggests that the success of enrichment with objects depends on the object provided, timing of provision, and poultry species. Notably, novel objects can themselves cause fear reactions (Murphy, 1977; Nicol, 1992). Fear reactions can be reduced by introducing novel objects when chicks are young (Jones, 1982) or rearing birds in more complex environments (Brantsæter et al., 2016).

Cover and Partitions

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, 1997; Cornetto et al., 2002). Transparent panels with opaque stripes that provided 67% cover were reported to be more effective and preferred by chickens to solid, transparent, or less fully striped panels (Newberry and Shackleton, 1997). When provided to broiler breeders, vertical panels promoted space use of males and led to greater reproductive outputs (Leone and Estevez, 2008). Among male turkeys, visual barriers, in addition to supplemental UV light and straw, were effective at reducing injuries due to injurious pecking (Moinard et al., 2001). The provision of shelters and canopies on free-range areas has been found to increase range use by chickens (Dal Bosco et al., 2014; Gilani et al., 2014; Stadig et al., 2017) and decrease feather damage due to injurious pecking (Bright et al., 2011).

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 reduces 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 showed less fear of novel food (food neophobia) and consumed that food sooner if it was associated with the familiar odor. Providing chickens with auditory enrichment in the form of classical music has also been suggested to reduce stress as indicated by lower heterophil-to-lymphocyte ratios in chicks reared with classical music compared with chicks reared without classical music; however, the effects of classical music on stress responses depend on the breed of chicken (Dávila et al., 2011).

Nutritional Enrichment

As discussed above, the provision of appropriate loose substrate, such as wood-shavings litter for fowl or water for ducks, facilitates foraging behavior. Other methods of increasing foraging time or frequency include placing objects in water containers (for ducks) or in the feed troughs (Sherwin, 1995; Riber and Mench, 2008) or scattering feed in the litter when birds are housed on substrate. The effectiveness of scatter feeding as an environmental enrichment likely depends on bird strain and the item scattered. Although laying hens will sort for feed when also simultaneously offered a freely available food source (i.e., feed in their feeders; Jensen et al., 2002), broiler chickens do so to a much lesser extent (Lindqvist et al., 2006). This decrease in willingness to peck through shavings for food is thought to reflect a shift toward energy conservation, which has accompanied selection for high productivity or growth. Indeed, scattering of feed and other substrates was shown to improve activity of broilers for no more than a few minutes and only when mealworms were scattered (Pichova et al., 2016). The implications of providing scattered feed to broiler breeders are also not straightforward. Although scattering of feed reduced object pecking, it did not alleviate other indicators of hunger (de Jong et al., 2005). Scatter feeding of a high-fiber diet with a high ratio of insoluble fiber yielded more promising results but still failed to relieve all indicators of hunger (Nielsen et al., 2011). Similarly encouraging but mixed findings resulted from feeding high-fiber diets (with oat hulls, or feed-grade or purified-grade fiber additive) and calcium propionate, an appetite suppressant (Sandilands et al., 2006; Morrissey et al., 2014).

GENERAL CONSIDERATIONS

Close monitoring is required when introducing new objects 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.

Care must be taken to monitor the worth, effectiveness, and safety of the enrichment used. It is suggested that the use of the enrichment by the animals as well as animal behavior, health, and performance be monitored on a regular basis to assess the effectiveness of the enrichment program. It is also important to consider that animals can sustain injuries from enrichment. For example, swine, calves, and laying hens can sustain injuries if aggression and other unwanted behaviors are not managed appropriately in social housing environments. Also, intestinal obstruction due to the provision of foraging enrichments or items that can be chewed or ingested (Hahn et al., 2000; Seier et al., 2005) can be harmful. The safety characteristics of potential enrichment devices should be evaluated utilizing several considerations suggested by Young (2003):

- Does the enrichment have sharp edges?
- Can the animal's limbs or other body parts be trapped in any part of the enrichment?
- Can the animal break or dismantle the enrichment, 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 disease transmission be prevented through adequate cleaning or sterilization of the enrichment?
- Could the animal use the enrichment to damage its cage- or pen-mates or its enclosure?

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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 and movement between pastures or housing locations. Transport involves movement of agricultural animals by vehicle or vessel from one place to another.

Performance standards during handling include careful, safe, considerate, gentle, and calm human interactions with animals. Animals handled in this way will be calmer and easier to handle than animals handled in a rough or harsh manner. Outcome-based performance measurements are recommended to monitor animal handling practices (Dalmau et al., 2016; Losada-Espinosa et al., 2018). This helps people maintain high standards of animal care. Handling problems that can be measured easily include the percentage of animals falling, running, turning back, vocalizing, those moved with electric prods, and mis-caught in squeeze chutes (Grandin, 1998a, 2001; Edge and Barnett, 2009; Correa et al., 2010; Hulgren et al., 2014; Barnhardt et al., 2015; Simon et al., 2016; Woiwode et al., 2016). Poultry handling practices and transport can be monitored by measuring bruises and broken legs or wings (Grandin, 2015; Grilli et al., 2015; Kettelsen et al., 2015)

Whenever possible, it is recommended to move animals at a normal walking speed. Acclimating animals to handling and close contact with people will reduce stress (Fordyce, 1987; Boandl et al., 1989; Grandin, 1997a; Cooke et al., 2009, 2012; Kutzer et al., 2015). It is recommended that acclimation of animals with a more excitable temperament to handling facilities should be done carefully to prevent increased animal agitation and fearfulness. Sutherland and Huddart (2012) stated that acclimation of dairy heifers to the milking parlor had greater benefits for heifers with calmer temperaments. Research clearly shows that animals that are handled in a negative manner, such as those subjected to hitting or tail twisting, or that fear humans have reduced performance, such as lower weight gains, fewer piglets, lower milk production, or reduced egg production (Hemsworth et al., 1981, 2000; Barnett et al., 1992; Grandin and Shivley, 2015). 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 animals that are less agitated or have lower chute exit velocities (Voisinet et al., 1997a,b; Curley et al., 2006; King et al., 2006). Beef cattle handled quietly had lower cortisol levels (Petherick et al., 2009). Training of people who handle livestock is strongly recommended. When trained handlers were compared with untrained handlers, they were more likely to avoid using negative behaviors toward animals such as shouting or hitting (Ceballos et al., 2018). They also had a more positive attitude toward livestock handling. Untrained handlers of pigs had more nonambulatory pigs arriving at a packing plant (Fitzgerald et al., 2009).

Socialization of agricultural animals with humans, which is more feasible with smaller than larger numbers of animals, reduces handling stress. Socialization can be carried out with relative ease by frequent exposure to 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 (Siegel and Honaker, 2014). For example, Gross and Siegel (1982a,b) and Jones and Hughes (1981) found that chickens positively socialized to humans had reduced responses to stressors and decreased disease compared with nonsocialized birds. When large numbers of animals are housed under commercial conditions, socialization may not be possible, but flightiness can be reduced if a person walks through the flock, herd, or group of animals daily. Stroking of piglets after weaning resulted in animals that were more willing to approach people (Tallet et al., 2014).

PREVENTING DISTRESS IN ANIMALS

In research settings, animals should be handled and restrained using low-stress handling. Aggressive handling should be avoided for farm animals. Handlers should be trained to recognize signs of distress or behaviors that may result in injury or stress to the animals. Signs of distress may include kicking, struggling, or attempting to jump out of a handling facility. Vocalizations (moos, bellows, or squeals) are often associated with aversive events such as electric prod use, slipping on the floor, or excessive pressure from a restraint device (Grandin, 2001; Edwards et al., 2010; Bourguet et al., 2011). Vocalization is associated with higher physiological measures of stress (Dunn, 1990; Warriss et al., 1994; Edwards et al., 2010; Hemsworth et al., 2011).

Calm animals will also provide more accurate research results that are less confounded by handling stress because lactate and glucose levels will be lower (Benjamin et al., 2001; Edwards et al., 2010). Handling and restraint stresses can significantly alter physiological measurements. Beef cattle not accustomed to handling had greater cortisol levels after restraint than dairy cattle that were accustomed to handling (Lay et al., 1992a,b). Prolonged (6-h) restraint of sheep resulted in extremely high cortisol levels (Apple et al., 1993). Multiple shocks with an electrical prod more than doubled the levels of lactate and glucose in pigs compared with careful handling without electric prods (Brundige et al., 1998; Benjamin et al., 2001; Brandt and Aaslyng, 2015). Even moderate use of electric prods increases livestock handling stress (Edwards et al., 2010). Electric prod use in pigs is associated with higher lactate levels, higher percentages of pigs falling, and high-pitched squealing (Correa et al., 2010; Edwards et al., 2010).

Transportation performance standards include movement of animals that are injured, nonambulatory, or dead (Ritter et al., 2007; Berry et al., 2012). Transportation should only be performed when necessary and done carefully to minimize risks of injury or death. Making the transport experience comfortable for each species should be a priority for animal handlers. Loading animals onto a vehicle is a critical stage when extra care is required (Goumon and Faucitano, 2017). Stress indicators, such as heart rate and blood lactate, will increase when electric prods are used (Correa et al., 2010).

Research and teaching are conducted on either commercial farms or in facilities operated by educational institutions or commercial companies. 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 are most appropriate. An agricultural animal may also be housed for various research or instructional purposes in other facilities, such as small indoor pens, that are not similar to commercial conditions where there is need or opportunity for greater human–animal interaction. Researchers have trained animals to cooperate with injections, restraint, and other procedures. For example, pigs, sheep, and other animals can be easily trained to voluntarily enter a restraint device or hold out a limb for various procedures (Panepinto, 1983; Hutson 1985; Grandin, 1989a; Phillips et al., 1998; McKinley et al., 2003; Schapiro et al., 2005; Graham et al., 2012). 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 improves welfare and removes some effects of restraint stress on physiological data.

FLIGHT ZONE AND BEHAVIOR PRINCIPLES

People who handle cattle, bison, sheep, horses, and other grazing animals should have knowledge of flight zone principles (Grandin, 1987, 2017; Smith, 1998; Cote, 2003; Figure 1). Flight zone principles also work effectively with pigs. 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 (164 ft), but intensively raised cattle (e.g., those raised in a feedlot) may have flight zones only 2 to 8 m (6.6 to 26.2 ft; Grandin, 1989b, 2014a). The size of an alley can change flight zones. Sheep in a 2-m-wide (6-ft-wide) alley had a smaller flight zone than sheep in a 4-m-wide (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. For example, when the handler is outside the flight zone, cattle will turn and face the handler. Flight zones can be used by handlers to move cattle and other livestock efficiently and quietly. To move a single animal forward, the handler positions themself at the edge of the flight zone and behind the point of balance (located at the shoulder). A common mistake made by many handlers when an animal is confined in a single file chute 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 stands behind the point of balance (Kilgour and Dalton, 1984; Grandin, 1987, 2017). Figure 1 presents the concept of flight zone and point of balance. Figure 2 shows how to move an animal forward in a single file chute by walking quickly past the point of balance at the shoulder in the opposite direction of desired movement (Grandin, 1998b, 2017; Grandin and Deesing, 2008). To induce cattle to stop or back up, handlers position themselves 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 confined in a single file chute will often stop rearing if the handler backs up and gets out of the flight zone.

Extensively raised grazing animals that arrive at a research facility may have a large flight zone. This is more likely to occur if they have been handled exclusively by people on horseback. The person on foot is perceived as something novel and frightening (Grandin and Deesing, 2008). Animal learning is specific: habituating a horse to a blue and white umbrella does not transfer to an orange tarp (Leiner and Fendt, 2011). The size of the flight zone will gradually diminish if the animals are handled calmly and have frequent contact with people.

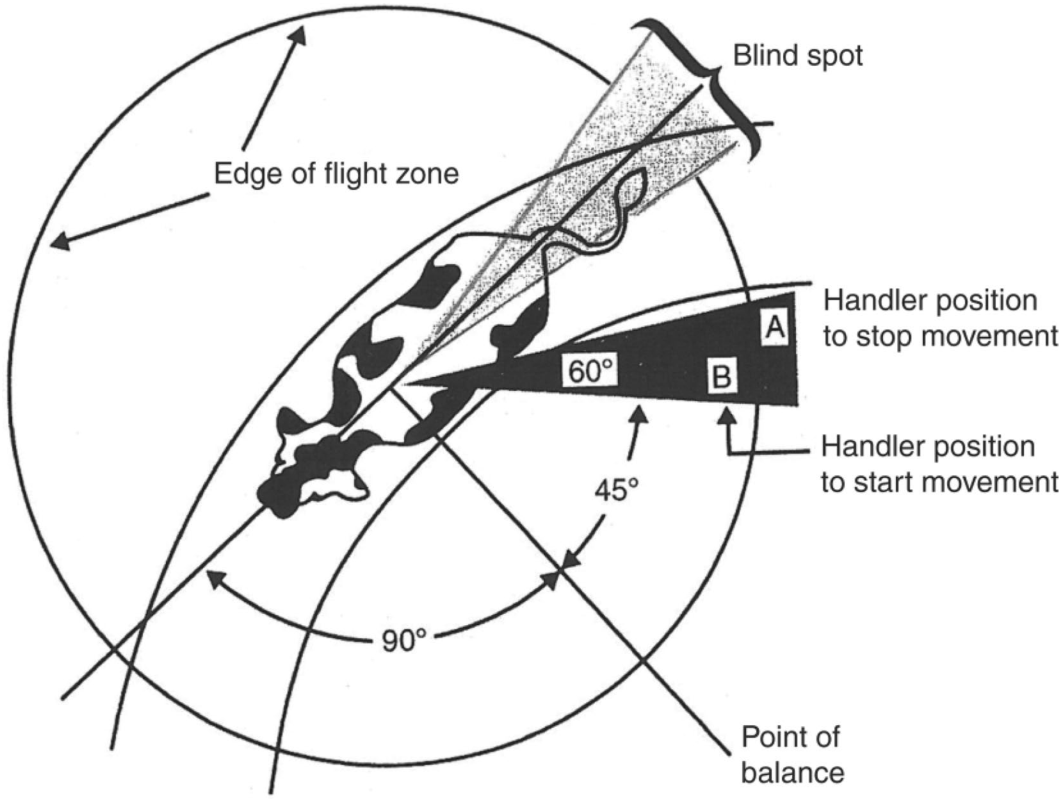

Figure 1. Flight zone diagram showing the most effective handler positions for moving an animal forward. Reproduced with permission of T. Grandin.

Farm animals are social, and a lone animal separated from its herd-mates often becomes severely agitated and more difficult to handle. 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 other animals 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 backs up and stops putting pressure on the flight

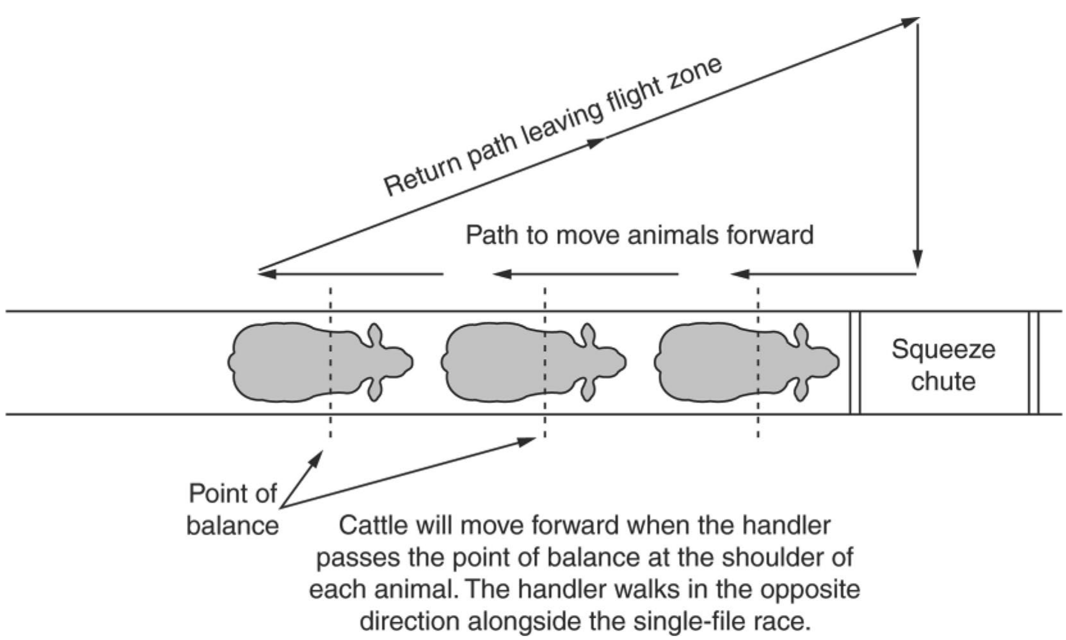

Figure 2. Handler movement pattern to induce cattle to move forward in a race. Reproduced with permission of T. Grandin.

zone. Continuous pressure on the flight zone may cause animals to start running, which is undesirable. Cattle, pigs, and goats will move more easily into a single file chute if the crowd pen that leads up to it is only half full. Wait until there is space in the single file chute before refilling the crowd pen. This will enable the handler to use an animal's following behavior.

AIDS FOR MOVING ANIMALS

Handlers should be trained in the proper use of each driving aid, which should be appropriate to the species. Animals in properly designed and well-maintained facilities may be moved by skilled handlers using their natural behavior without the use of aids. Both the handlers and the facility should be evaluated (NCBA, 2019). When necessary, nonelectrical driving aids such as paddles, flags, and panels (sort boards) may be an adjunct to the use of natural behavior and handling skills. One study with pigs showed that panels (sort boards) and large flags were most efficient compared with electric prods (McGlone et al., 2004).

An electric prod should only be used in the specific situation when it is needed and then put away. Some examples of specific situations where an electric prod may need to be used are given in the list below. In all other situations, electric prods should not be used during teaching and research. When an electric prod needs to be used, it should be applied to the hindquarters of the animal. It must never be applied to sensitive areas of an animal such as the eyes, ears, genitals, udder, or anus (NAMI, 2019; NCBA, 2019; OIE, 2019). Electric prods must not be used on newborn, young, or nonambulatory animals. Handlers have a better attitude toward animals when electric prods 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). Data collected at beef feedlots indicated that the average percentage of cattle moved with an electric prod was 4% or less (Barnhardt et al., 2015; Woiwode et al., 2016). Usually 1 to 2 brief shocks are needed. In pigs, electric prod use should be limited to 2 brief (1-second) shocks (Ritter et al., 2009b). If the animal does not respond, the use of the electric prod should be discontinued immediately. Battery-operated prods are recommended because they administer a localized shock between 2 prongs. 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:

1. To move an animal after repeated attempts with nonelectrified driving aids such as a pig panel (sort board), a plastic bag on the end of a stick, flags, slappers, rattle paddles, or streamers tied to the end of a stick have failed. In this situation, the use of an electric prod is preferable to beating, dragging, pushing, or hard tail twisting of animals. Smaller animals may be gently lifted or rolled onto a transport mechanism. Sheep must never be picked up by the wool because severe bruising will result.
2. To get a downed (fallen) animal up when it is in a truck located at a truck stop or on the side of a highway. In this situation, opening up the truck gates or unloading the animals is not possible.
3. To move an animal that is choking in a head stanchion or head gate or has become jammed in a chute or other equipment. In this situation, the electric prod is used to make the animal immediately stand up. This is essential to prevent death from pressure on the throat area or serious injury.

Large tame animals, such as cattle, can sometimes become dangerous if they push and shove around people during feeding or moving through a gate. Pushy animals can often be trained to stop pushy behavior if the person waits for them to stand still for a few seconds before putting out the feed or opening the gate. This will reward calm behavior (Grandin, 2017). Sometimes the handler may have to tell the animals to "get back" in a stern voice.

Animal Perception

Hearing. All species have sensitive hearing. Cattle and horses have hearing that is more sensitive to high-pitched sounds than humans (Heffner and Heffner, 1983). The human ear is most sensitive at 1,000 to 3,000 Hz and cattle are most sensitive at 8,000 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 one experiment, the sounds of people yelling caused a greater increase in heart rate than the sounds of gates clanging (Waynert et al., 1999). Normal talking will have no effect but yelling is stressful (Hemsworth et al., 2011).

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). Good handlers are observant of the position of an animal's ears. Horses and cattle will point their ears directly toward things that attract their attention (Grandin, 2014a, 2017).

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; Adamczyk, et al., 2015). 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, which ex-plains why they stop and put their heads down when they see a shadow on the floor. Grazing animals have a horizontal band-shaped area on the retina that is most sensitive to visual stimuli (Shinozaki et al., 2010). This enables them to scan the horizon while grazing.

Grazing animals are dichromatic (i.e., have 2 cone-cell types in the retina to mediate color vision). The retinas of cattle, sheep, and goats are most sensitive to bluish-purple light (444–455 nm) and yellowish-green light (552–555 nm; Jacobs et al., 1998). The dichromatic vision of the horse is most sensitive at 428 and 539 nm (Carroll et al., 2001). Pigs have difficulty discriminating red from gray (Eguchi et al., 1997).

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 that of humans (Prescott and Wathes, 1999). Birds can see UV light that humans cannot see (Tsukahara et al., 2014).The broader spectral sensitivity of poultry may make them perceive many light sources as being brighter than a human would see. As birds grow, eye sensitivity to UV light may decrease (Olsson et al., 2016). 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); they struggle less under dim lighting. 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, 2014a, 2017). 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 or animals repeatedly balk and refuse to move forward. In facilities where animals move easily and quietly and electric prods are seldom used, removal of distractions may not be needed. Animal behavior should be carefully examined to determine whether the facility needs to be modified. A modification such as adding a solid side or changing lighting should be temporarily tested to determine whether it improves livestock flow.

Facility Design Principles for All Species

Flooring. For all mammals, nonslip flooring is essential (Grandin, 1990, 2014a; 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 must have nonslip floors and good drainage. Problems with slippery flooring in livestock and horses can be detected by measuring slips and falls. If more than 1% of the animals fall during handling, a problem exists that must be corrected (Grandin, 2005). Three surveys of cattle handling on ranches and feedlots indicated that falling during exiting from the squeeze chute was under 1% (Barnhardt et al., 2015; Simon et al., 2016; Woiwode et al., 2016).

Equipment Maintenance. Surfaces that contact the animals such as fences, gates, and restraint devices should be designed with animals in mind. Sharp edges cause bruises (Grandin, 1980c) and injury. Managers should routinely inspect equipment, including latches on restraint devices, and have a program of regular maintenance based on use.

Table 5-1. Visual distractions that may cause livestock 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 nonreflective surfaces.
• Moving people in front of approaching animals. It is best if people 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, 1996), van Putten and Elshof (1978), Kilgour and Dalton (1984), Tanida et al. (1996), Grandin and Johnson (2005), Grandin and Deesing (2008), and Grandin (2017).

GENERAL PRINCIPLES OF RESTRAINT AND HANDLING

Proper training of animal care personnel in handling procedures includes consideration of both animal and handler well-being. During the handling and restraint of animals, care is exercised to prevent injury to animals or personnel and to handle animals quietly. Properly designed and maintained facilities operated by trained personnel greatly facilitate efficient movement of animals.

Prolonged restraint of any animal should be avoided unless such restraint is essential to the research or teaching objectives. Electrical immobilization must not be used as a method of restraint; it is highly aversive to cattle and sheep (Lambooy, 1985; Pascoe and McDonnell, 1985; Grandin et al., 1986; Rushen, 1986). Electrical immobilization is a completely different technology from, and not to be confused with, electric prods or electrical stunning equipment that is used to induce instantaneous unconsciousness before slaughter.

The following are important guidelines for the use of animal restraint equipment:

- Animals to be placed in restraint equipment, such as a squeeze chute, head gate, or sling, should be conditioned to such equipment before initiation of the project, unless the preconditioning itself would increase the stress to the animals or alter the objectives of the teaching or research.
- The period of restraint should be the minimum required to accomplish the research or teaching objectives.
- Restraint devices are not to 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. Provide health care if these or other serious problems occur; if necessary, remove the animal either temporarily or permanently from the restraint device.

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 use of several acceptable restraint devices (e.g., hobbles, squeeze chutes, and stanchions) and practices. Use only the minimum restraint necessary to control the animal and to ensure the safety of attendants. Handling and restraint is best done in facilities and using equipment appropriate for the species, animal temperament, and procedure. For example, horses, cattle, sheep, and goats that are trained to lead may be easily restrained with a halter for procedures such as injections. In contrast, facilities such as head gates, single file chutes (races), and other equipment designed for the species may be necessary for livestock with large flight zones that are not acclimated to close contact with people. This will help avoid injuries to both people and livestock.

The following guidance is provided to prevent behavioral agitation during restraint for all species:

- Nonslip flooring must be provided (Grandin, 1990; Albright, 1995). Repeated small, rapid slips may cause agitation.
- Avoid sudden jerky motions 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 uses this principle (Panepinto, 1983; Grandin, 2014a).
- A calm, confident tone of voice will help keep livestock calmer.
- Use optimum pressure—not too loose and not too tight. An animal needs to be held tight enough to feel restraint but not so tight that it feels discomfort or 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 when they are restrained (Mitchell et al., 2004). Solid sides on cattle restraining chutes or a fully enclosed dark box have a calming effect (Grandin, 1980a,b, 1992; Pollard and Littlejohn, 1994; Müller et al., 2008). The solid side is especially important when a handler has to stand inside the animal's flight zone to either operate the restraint device or administer a procedure.

GUIDELINES FOR EACH SPECIES

Beef Cattle

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 that animals do not see people who otherwise would be deep in their flight zone. In handling chutes with open-barred sides, handlers standing outside the animal's flight zone will prevent cattle from becoming agitated. When they need to move an animal, the handler can step forward into the flight zone to make it move. After it has moved, the handler can back up and retreat from the flight zone. Signs of behavioral agitation in cattle include restless movements, tail switching, defecation, and visible eye white (Sandem and Braastad, 2005; Core et al., 2009; Grandin, 2014a, 2017). Cattle that are frequently moved between pastures will become calmer (Ceballos et al., 2018). Further information on facility design is given in Grandin (1990, 1997b, 2014b) and Grandin and Deesing (2008).

There are many different designs of restraining (squeeze) chutes. Well-designed squeeze chutes permit all animals to stand in a balanced position. The best squeeze chutes have squeeze sides that are applied evenly from both sides. Squeeze chutes may be manual or hydraulic. Settings of pressure relief valves for hydraulic restraint chutes should be adjusted to prevent excessive pressure from being applied (Grandin, 1989b). Well-designed chutes 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 is set at a lighter pressure than other parts of the chute. Applying pressure slowly will avoid exciting the animal. Excessive pressure can cause injury and incite cattle to fight the restraint. If cattle bellow the moment that pressure is applied by a hydraulic device, this is an indicator of excessive pressure (Grandin, 2001; Bourguet et al., 2011). Bellowing during restraint is associated with higher cortisol levels (Dunn, 1990). Another outcome to watch for is that cattle should be able to breathe normally during restraint. In 2 feedlot surveys, the average percentage of cattle vocalizing in hydraulic squeeze chutes was 1.4% (Woiwode et al., 2016) and 0.9% (Barnhardt et al., 2015). On ranches, the percentage of cattle vocalizing in a squeeze chute was 14.5% (Simon et al., 2016). The greater percentage of cattle vocalizing on ranches may have been due to use of hydraulic chutes that were not properly adjusted. The reduced vocalization of cattle being processed in feedlots may be due to managers being more aware of good cattle handling procedures. The results of the ranch study clearly show the importance of proper adjustment of the pressure control to prevent excessive force being used in restraint. Excessive pressure by a restraint device will increase the percentage of cattle that vocalize (Grandin, 2001; Bourguet et al., 2011). 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. Very young or tame calves restrained for routine procedures can be handled by means of a calf chute equipped with a calf cradle or a halter.

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 the animal and possible harm to personnel from the suddenly unrestrained animal, and therefore should not be used as the sole method of restraint.

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, 2014a, 2017). Cattle temperaments vary among individuals and among breeds (Tulloh, 1961; Grandin, 1993; Curley et al., 2006). It is important for handlers to understand that certain animals may become agitated more easily than others.

Dairy Cattle

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 for most procedures. For foot trimming, either a squeeze chute or a specialized foot trimming chute is recommended. Diagrams and pictures in Sheldon et al. (2016) and Beaver and Hoglund (2015) 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.

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 (de Passillé 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 herds that had cows that were more willing to approach people had lower somatic cell counts (Fulwider et al., 2008). Stockmanship training and positive human interactions are associated with higher milk production and animals that are calmer during milking (Hemsworth et al., 2002; Bertenshaw et al., 2008; Sorge et al., 2014).

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 or nursed and raised with a mother 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 is always kept with other animals. Bulls that are kept in groups with other cattle are less likely to perceive people as rivals. If a bull is going to become dangerous, he is most likely to show aggression toward people at 18 to 24 mo. It is recommended that handlers 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), Albright and Fulwider (2007), and Grandin (2017).

Neonatal dairy calves should be supported by the body either in both arms or placed in a wheelbarrow or special cart when being moved (Clark et al., undated).

They must never be dragged by the legs, head, tail, or other body part nor thrown (Botheras, undated).

Horses

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., 2016). 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 use of these 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

Snaring by the nose is a common method for holding swine for blood testing and other procedures. Good descriptions are given in Battaglia (1998) and Sheldon et al. (2016). Snaring is more stressful for pigs than restraint with sort boards or panels (Buzzard et al., 2012). Squealing in pigs during handling is associated with physiological measures of stress (Warriss et al., 1994; Edwards et al., 2010; Brandt and Aaslyng, 2015). Pigs will attempt to avoid the snare after they have experienced snaring. Small pigs can be trained to enter a Panepinto sling (Panepinto, 1983). The pig is fully supported in the sling, and its legs protrude out through leg holes. For pigs used in biomedical research, the Panepinto sling or a similar device is recommended for blood sampling from the jugular vein. The use of snares should be avoided for most procedures. Snares should be reserved for situations where there is a concern for human safety. A panel (sort board) is the best device for moving pigs (McGlone et al., 2004). Nonelectric driving aids such as panels, cattle paddles, and flags should be used by properly trained people. Guidelines on electric prod use are in the section on driving aids. Previous experience 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).

Pigs may be reluctant to move through facilities that are novel (Lewis et al., 2008; McGlone et al., 2014a; Goumon and Faucitano, 2017). When market-size pigs (115–130 kg; 250–290 lb) are being moved through alleys that are ≤1 m (≤3 ft) wide, the recommended group size is 4 (Berry et al., 2012). Pigs will usually walk over floor surfaces they are familiar with. They will be more willing to walk across a concrete floor if they are allowed to first explore it. When a young pig has to be isolated for a research procedure, the presence of one of its littermates may reduce stress. Kanitz et al. (2014) found that a familiar conspecific reduced the stress response more than a strange pig.

Sheep and Goats

Sheep show strong flocking behavior in pens as well as on pasture. Good stockmanship is essential. If sheep are handled roughly by one person, then they may become fearful of all people (Destrez et al., 2013). 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. Sheep that tend to bunch tightly are also more likely to vocalize when they are separated from the flock (Ligout et al., 2011). If a sheep must be isolated, it will be less stressed if it can see another sheep within 2 m (Yates et al., 2010). Separation from the flock, herd, or social companions is an important factor that causes sheep and goats to try to escape. Sheep tend to follow one another even in activities such as grazing, bedding down, reacting to obstacles, and feeding (Hutson, 2014). When handling sheep, these characteristic behaviors should be considered and used advantageously in the interest of the animals' health and welfare. Scoring of vocalization during handling and restraint does not work in sheep. Sheep vocalize when they are isolated but they seldom vocalize when they are restrained or handled.

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. (2016) 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 (2014), American Sheep Industry Association (2016), and Grandin (2017).

There are some behavior differences between sheep and goats when they are being moved. Due to their intense following behavior, sheep can be moved in large groups when they are handled through a chute. When one sheep starts moving through the chute, the others will follow. Goats should be brought up to the crowd pen in small separate bunches. Goats can be handled in most facilities that are designed for sheep. Surfaces must be smooth, and crevices where horns can become caught may need to be blocked.

Goats are very sensitive to how people treat them. They respond well to positive daily contact with people (Miranda de la Lama and Mattiello, 2010). When they have positive interactions, they will be more willing to approach people (Battini et al., 2016; Mersmann et al., 2016). Compared with sheep, goats will spend more time close to people (Price and Thos, 1980).

When a goat has its tail in the up position, its interaction with people is more likely to be positive (Briefer et al., 2015). Goats react by vocalizing, trotting, and rearing when a single goat is separated from the flock (Carbonaro et al., 1992; Siebert et al., 2011; Patt et al., 2013). If a goat has to be housed singly for a research procedure, it should be able to hear and see its flockmates (Patt et al., 2013) unless research and teaching protocols prohibit it. Separation of goats in a pen adjacent to other goats was less stressful than total isolation in a separate building (Siebert et al., 2011).

Poultry

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 nonambulatory birds should be euthanized on the farm and not transported. People handling birds should be 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 the 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 is needed when handling caged laying hens, which are prone to osteoporosis (Rennie et al., 1997; Webster, 2004; Stratmann et al., 2016). To minimize the risk of bone fracture, egg-type laying hens should be held by both legs when removing them from the cage (Gregory and Wilkins, 1989; Gregory et al., 1993). Another good method for removing a hen from a cage is to place one hand over her wings and use the other hand to support her body. She is then removed from the cage without holding her legs. 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 (Lister et al., 2013). It is acceptable to briefly lift ducks by the base of the neck (Lister et al., 2013).

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 a 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 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. Appropriate driving aids are flags and plastic bags. They should be used to gently move the birds; vigorous waving of these aids should be avoided. However, some birds such as older turkeys will not walk on unfamiliar 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 intraocular 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. More complex procedures—for example, obtaining blood, intraperitoneal and venous puncture, or artificial insemination—often require 2 people. Skilled operators should 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, 2014). A source of concern is the manner in which birds are caught, carried, and placed in new quarters or crates. Birds are at risk of injury if they are caught and placed in a transport container by grasping a single wing with subsequent exertion of excessive force in moving the bird. Picking up birds by a single wing, if necessary, requires care, as described above. On commercial broiler farms, chickens are usually picked up by a single leg and carried several birds per hand. Leg injury can be prevented if the birds are not handled roughly and carried only a short distance to the transport cage.

TRANSPORT

The transport of livestock involves a complex series of components, including handling, loading and unloading, unfamiliar environments, and, in some cases, isolation and social disruption. Other variables include vehicle vibration, 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. Animals that are in poor condition may further deteriorate when transported (Stojkov et al., 2020). Transport to livestock markets should be avoided for all weak or injured animals. In-depth reviews and research on transport 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; Schwartzkopf-Genswein et al., 2012; Norton et al., 2013), sheep (Cockram et al., 1996; Knowles et al., 1998; González et al., 2012; Schwartzkopf-Genswein et al., 2012), pigs (Guise et al., 1998; Warriss, 1998; Whiting and Brandt, 2002; Ritter et al., 2006, 2007, 2009a,b; Sutherland et al., 2009; Kephart et al., 2014; Xiong et al., 2015), poultry (Mitchell and Kettlewell, 1998, 2009; Knezacek et al., 2010; Burlinguette et al., 2012; Wichman et al., 2012), and horses (Stull, 1999; Whiting, 1999; Friend, 2000a,b; Haley et al., 2008; Fitzgerald et al., 2009; Padalino, 2015). In addition, the National Research Council (2006) recommendations (*Guidelines for the Humane Transportation of Research Animals*, also known as the *ILAR Transportation Guide*) for the transport of research animals includes space requirements during transport that are consistent with this guide. In the absence of data supporting specific space requirements of farm animals during transport, formulae from the *ILAR Transportation Guide* (National Research Council, 2006) may be useful in determining space allowances during transport. The minimum areas per animal for cattle, pigs, and sheep of different weights when shipped in groups are given in Table 5-2. For poultry, the recommended minimum area will allow all birds to lie down at the same time without being on top of each other. The recommended space requirements will vary depending on temperature. In extreme cold conditions, broiler chickens had increased death losses if they were stocked too loosely (Caffrey et al., 2017; Cockram and Dulal, 2018). During hot conditions, providing additional space to help keep birds cool is recommended.

The safety and comfort of the animal should be primary concerns in the transportation of any animal or bird. Nonambulatory or weak, debilitated animals or poultry must not be loaded or transported unless necessary for medical attention. Animals that are nearing the time of parturition should not be transported (OIE, 2019). An exception to this is when moving an animal a short distance by trained personnel to a site to give birth. Nonambulatory animals or poultry in research and teaching facilities must be euthanized using approved procedures unless they are receiving medical treatment (see Chapter 2: Agricultural Animal Health Care and the species-specific chapters) before removal from the facility (Grandin, 2015; AVMA, 2016, 2020). Nonambulatory poultry or other small animals such as piglets can be carried by a person or placed in a container to be moved to a euthanasia station. Cattle, pigs, or other large animals that become nonambulatory must not be dragged (AVMA, 2016, 2020).

If young or newborn calves are to be transported, individual care and colostrum should be provided within 6 h after birth (National Dairy Farm Program, 2020). Calves should have a dry hair coat, dry navel cord, and be able to walk easily without assistance before being transported to auctions, livestock markets, assembly yards, or slaughter plants. 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.

Transportation of sheep and goats should take into consideration the climatic conditions and productive stage of the animals (e.g., late pregnancy or dams with young offspring). Care should be exercised in the transport of animals, and special consideration should be given during conditions of temperature extremes and high humidity. In large vehicles, when possible, animals

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

Species	Average weight (kg)	Average weight (lb)	Area per animal (m²)		Area per animal (ft²)	
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 (m²)	Horned (ft²)	Hornless (m²)	Hornless (ft²)
Cattle (mature)	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 (m)	Dimensions (ft)	Area (m²)	Area (ft²)
Loose horses	250 to 500	550 to 1,100	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
Adult horse			1.2 × 2.0	3.9 × 6.6	2.4	25.8

[1]Adapted from data of Grandin (1981); Schwartzkopf-Genswein and Grandin (2014); González et al. (2012); Cregier (1982); Whiting and Brandt (2002); Whiting (2000); Ritter et al. (2006); Pilcher et al. (2011); and McGlone et al. (2014c).

((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 and pretransport vaccinations may also be administered in an effort to minimize diseases associated with shipping. With current concerns about antibiotic resistance, prophylactic antibiotics are discouraged.

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 and species. Transport 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 et al., 2014) and sheep (Cockram, 2007).

Animal injuries, bruises, and carcass damage can result from improper handling of animals during transport (Strappini et al., 2013). Grandin (1980a) 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, 1990; Grandin and Deesing, 2008). Good driving practices such as smooth acceleration and no sudden stops will help reduce injuries from animals being thrown off balance.

Thermal Environment on the Vehicle for All Species

Transport and handling stresses can be aggravated greatly by adverse weather conditions, especially during rapid weather changes. Both hot weather and extremely cold weather are times for particular caution. Temperature can vary greatly in different parts of a vehicle (Knezacek et al., 2010). Animals should be protected from heat stress while in transit. For poultry transported under hot summer conditions, it is recommended to keep side curtains open (Burlinguette et al., 2012). The Heat Stress Safety Index is useful as the basis for handling and shipping decisions for swine during periods of weather extremes (National Pork Board, 2020). The index shows the relationship between temperature and humidity. A combination of high temperature and high humidity increases the index. In heavy (160-kg) market-weight pigs, death losses were highest in the summer months (Vitali et al., 2014). However, Heat Stress Safety Index values are conservative for cattle, especially for heat-tolerant Brahman and Brahman crosses (Grandin. 1981, 2015).

For all species, heat will build up rapidly in a stationary vehicle unless it has mechanical ventilation (Weeks et al., 1997; Kettlewell et al., 2000). During hot weather, vehicles should be promptly unloaded upon arrival at the destination 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 (Ritz et al., 2005). Meat-type chickens, turkeys, 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. Additional 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. Further information on the thermal environment can be found in the *Guidelines for Humane Transportation of Research Animals* (National Research Council, 2006). The thermal neutral zones for different animals can be found in Robertshaw (2004).

During transportation, animals should also be protected from cold stress (Hunter et al., 1999; Burlinguette et al., 2012). Wind protection 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 NAMI (2019), the National Pork Board (2020) *Transport Quality Assurance Handbook*, (version 7) and McGlone et al. (2014a,b,c). Pigs require greater protection from cold than sheep or cattle, which have heavy coats of wool or hair. Table 5-3 shows cold protection recommendations for pigs transported in an aluminum trailer with numerous ventilation holes. When cattle are transported in this type of trailer, more of the ventilation holes can be left open. 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. When wood shavings are used for pigs, six 22.7-kg (50-lb) bags are recommended for a trailer of approximately 40 m^2 (430 ft^2) when the temperatures is −11.7°C (11°F) or lower (McGlone et al., 2014a,b). This is especially important for pigs to reduce death losses (Sutherland, et al., 2009, 2014). Based on neutrophil:lymphocyte ratio and behavior (Sutherland et al., 2009), space allowances of 0.06 and 0.07 m^2/pig were preferable to 0.05 m^2/pig when transporting weaned pigs between 60 and 112 min in summer (28.4 ± 1.2°C; 83 ± 2°F) and winter (10.5 ± 6.15°C; 51 ± 11°F). However, the effect of space allowance on the welfare of weaned pigs may differ when transport durations exceed 112 min. Sufficient bedding should be used to help the piglets stay dry.

Table 5-3. Recommended bedding allowances and coverage of side slats as a function of air temperature for trailers of approximately 40 m^2 (~431 ft^2) hauling market pigs weighing 114 to 136 kg (250 to 300 lb)[1]

Air temperature (°F)	Air temperature (°C)	Bedding (50-lb/22.7-kg bags of wood shavings)	Side slats/panels to cover ventilation holes (% closed)
≤11	≤−12	Heavy (6 bags)	90–95%
11 to 20	−12 to −7	Medium (4–6 bags)	75–90%
21 to 30	−6 to −1	Medium (4–6 bags)	50–75%
31 to 40	−1 to 4	Medium (3–4 bags)	50–75%
41 to 50	5 to 10	Medium (3–4 bags)	25–50%
51 to 60	11 to 16	Medium (3–4 bags)	0–25%
61–90	16 to 32	Medium (3–4 bags)	0%
≥90	≥32	Light (1–2 bags)	0%

[1]Source: McGlone et al. (2014a,b,c).

Vehicle Guidelines for Livestock

Truck beds for livestock transport should be clean and dry and equipped with a well-bedded, nonslippery floor. Animals should be loaded and unloaded easily and promptly. Chutes and ramps should be well designed with nonslip flooring (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 and Wickens, 2014). Livestock should not be transported on trucks that do not have sufficient clearance to accommodate their height (Grandin et al., 1999; Stull, 1999; Gray et al., 2012; Houpt and Wickens, 2014; Lee et al., 2017). International guidelines state that animals should be able to be stand in a normal position without coming into contact with the roof or upper deck (OIE, 2019).

Many teaching and research activities require the frequent transport of animals. 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 space from 0.39 to 0.48 m^2/pig reduced transport deaths from 0.88 to 0.36% on trips lasting approximately 3 h (Ritter et al., 2006). On longer trips when all the pigs will lie down, there should be sufficient space so they will be in normal lying posture without being on top of each other. 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, in the case of cattle, sheep, and horses, may be haltered and tied.

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 to the side of the vehicle in a manner that can be released quickly. The recommended height for tying is approximately even with the top of the shoulder (withers). The tie should be short enough so that animals cannot step over the lead. Quick-release methods, such as quick-release knots, panic snaps, and other safety release latches, should be used.

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 of a height that exceeds an animal's ability to step up onto the vehicle. Loading ramps should provide nonslip footing to prevent slipping and falling or damage to the dewclaws (van Putten and Elshof, 1978; Grandin, 1983, 1990, 2014c; Phillips et al., 1988). On concrete ramps, stair steps provide good footing (Grandin, 1990). For cattle, it is recommended that each step be 10 cm (4 in) high with a 30-cm (12-in) tread width. For all species, if the animals are not completely tame, solid sides are recommended on the loading ramp.

Pigs will often be reluctant to step up onto a high step that is 20 cm (8 in) high (Goumon et al., 2013). Ramps that are too steep are stressful for pigs, so a slope of 15° or less is recommended (Berry et al., 2012; McGlone et al., 2014a). When more gradual slopes are used, the ramp becomes excessively long when used to load the top deck of a truck (Goumon and Faucitano, 2017). In these situations, the ramp slope should not exceed 20°. Conveyors can be used to load weanling and nursery pigs but do not reduce the work required to load the animals or reduce stress (Lay et al., 2017).

Horse Transport

The typical vehicles designed to transport horses by road are vans, trailers, and trucks. Transport vehicle capacity ranges from transporting a single horse to multiple horses. During transportation, attempts should be made to minimize the trauma and anxiety of the horse. Considerations include 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). Table 5-4 shows recommended height and width requirements for horses. 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 they deteriorate with use and exposure.

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 a horse from exiting 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 a horse to spread its legs enough to

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

	Trailer or van dimension	
	(m)	(ft)
Height of ceiling for horse		
Up to 1.5 m (15 hands)[1]	1.7–2.0	5.6–6.5
>1.5 m (>15 hands)	2.0–2.2	6.5–7.0
Width		
Single or tandem	1.2	4
Two horses abreast: ≤16 hands	1.7–2.0	5.6–6.6
Two horses abreast: >16 hands	1.8–3.1	5.9–10.2

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

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 injuries. Leg 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. A recent survey showed that injuries were the most common transport problem (Padalino, 2015; Padalino et al., 2016). Lighting at night in the trailer and loading areas facilitates safe handling and loading of horses.

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 to allow for quick release. Tying horses limits the movement of the head and neck. Elevation of a 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 may experience fatigue and dehydration when traveling more than 24 h at one time, 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. Appropriate ventilation is crucial during extremely hot or cold weather (Purswell et al., 2006). In hot, sunny weather, it is recommended that horses not be left in parked trailers for long periods. They should be checked regularly to prevent heat stress. In cold weather, horses in moving trailers may need to be provided with blankets, especially if air flow cannot be controlled (e.g., in stock trailers that are not fully loaded).

Poultry Transport

Unlike the loading ramp and chute system used for livestock, broiler chickens on commercial farms are either caught manually or with automated catching machines and loaded into transport crates/cages that are then stacked on an open flatbed truck. Special attention to developing skilled staff for the catching, loading, and transport of poultry is important. Increased fear (Jones, 1992), leg injury (Gregory and Wilkins, 1989), and mortality have been associated with poor catching and loading techniques (Weeks, 2014). Also, poorly feathered birds have greater body heat loss than well-feathered birds. The thermal neutral zone ranges from 8 to 18°C (46 to 64°F) and 24 to 28°C (75 to 82°F) for well-feathered chickens and poorly feathered chickens, respectively, under typical transit conditions of low air movement and high humidity (Webster et al., 1993). Increased time in transit, feed and water deprivation, and fatigue can cause increased death loss and stress (Vecerek et al., 2006). Therefore, these factors should be minimized. Ducks and turkeys are usually driven to a loading conveyor (Weeks, 2014). They are usually not picked up.

Transport Distance and Duration for Livestock and Poultry

Most animals transported for use in research and teaching will be transported short distances with 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 animals will be transported for less than 2 h. United States regulations require that livestock (does not include poultry) be unloaded, fed, and watered after 28 consecutive hours on a vehicle without food or water during interstate transport (USDA, 1994). The US *Humane Slaughter Act* requires that livestock in the lairage (stockyards) of a slaughter plant must have access to water (USDA-FSIS, 1979). People who use agricultural animals in research and teaching need to minimize the time that livestock or poultry are on vehicles. 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 or the time that the livestock or poultry remain on the vehicle.

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 been

Table 5-5. Space requirements per animal for lairage at a slaughter plant[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)
Sheep (market-weight lamb)	62 (135)	0.4 (5)

[1]Larger animals require additional space. Further information on the design of lairage facilities and welfare at the slaughter plant can be found in the North American Meat Institute Recommended Animal Handling Guidelines and Audit Guide (NAMI, 2019).

summarized (*ILAR Transportation Guide*; National Research Council, 2006).

Lairage Recommendations Before Slaughter for Livestock

After the animals are unloaded from the transport vehicle, lairage pens must be provided. Pigs should always have sufficient space so that all the pigs can lie down without being on top of each other. Livestock must have sufficient space to all lie down if they are held overnight (USDA-FSIS, 2017; NAMI, 2019). All livestock must have access to water. Table 5-5 shows recommended space requirements for cattle, pigs, and sheep.

Emergency Procedures for the Research Facility and Transporters

Both research facilities and people transporting animals should have a list of emergency contact phone numbers.

- Police (telephone number)
- Fire (telephone number)
- Ambulance (telephone number)
- Emergency contacts 1 and 2: work, home, and mobile numbers.

When livestock or poultry are transported more than a few miles, local police and fire department numbers will not be usable. It is recommended to either call 911 or carry other numbers for first responders along the route. It is also recommended to carry the numbers of local people along your route who could assist with handling or euthanizing animals after an accident. Other useful information includes the locations of fairgrounds, auction markets, and other facilities where the animals could be unloaded during an emergency.

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CHAPTER 6: BEEF CATTLE

Beef cattle include all animals of the genus *Bos* and their close relatives that are raised primarily for meat production. Beef cattle have enjoyed a long and mutually beneficial association with humans (Rollin and Thompson, 2012) and are uniquely positioned, along with other ruminants, to make effective use of feedstuffs that are not used to feed humans (Lardy and Caton, 2012; NASEM, 2016; Mottet et al., 2017). *Bos* animals that are used for milk production are covered in Chapter 7: Dairy Cattle of this guide. As ruminants, beef cattle are capable of using a wide range of feedstuffs and consequently are maintained in an array of situations, from extensive grazing conditions to confined feedlot pens and intensive laboratory environments (NASEM, 2016). Regardless of the housing system, good animal husbandry dictates that needs for food, water, shelter, and comfort that are based upon the best available science and practical experience should be met.

FACILITIES AND ENVIRONMENT

Ideal Thermal Conditions

Heat production in cattle is from metabolism and fermentation within the digestive tract (NASEM, 2016). Cattle dissipate heat through radiation, evaporation, convection, and conduction. The regulation of both heat production and dissipation allows a nearly constant body temperature to be maintained in healthy cattle. Within the thermoneutral zone (TNZ), and certainly within the narrower thermal comfort zone (TCZ), heat production by cattle is essentially independent of environmental temperature, and body temperature is regulated primarily by heat dissipation (NASEM, 2016). As the effective ambient temperature (EAT) moves out of the TNZ and either below the lower critical temperature (LCT) or above the upper critical temperature (UCT), cattle experience cold or heat stress, respectively, which may, depending upon the severity and duration, dictate management strategies to offset environmental extremes (NRC, 1981; Mader, 2014; NASEM, 2016). When temperatures move outside of the TCZ and TNZ, cattle metabolism and behavior can change to partially offset temperature extremes and effectively move the EAT experienced by cattle back toward the TNZ (NRC, 1981; NASEM, 2016). For example, cattle familiar with their environment will make use of windbreaks and sunny slopes (Keren and Olson, 2006a,b, 2007; Caton and Olson, 2016) during cold extremes, and use shade (Mader, 2014; Hagenmaier et al., 2016) during heat extremes in an attempt to mitigate the consequences of weather extremes. Additional energy requirements associated with cold or heat stress are discussed in the *Nutrient Requirements of Beef Cattle*, 8th revised edition (NASEM, 2016).

Under most environmental conditions, temperature represents a major portion of the driving force for heat exchange between cattle and their environment. 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 of EAT, to which cattle respond (NRC, 1981; NASEM, 2016).

Environmental conditions that provide maximum comfort (i.e., TCZ) and require little or no energy expenditure for maintenance depend on cattle age, metabolic size, body mass, surface area, animal behavior, and the degree to which cattle have been adapted to the environment. It should be noted that the TCZ and TNZ are often confused in the literature and sometimes mislabeled. The TCZ is the temperature range where the animal is most comfortable and no (or very little) additional energy from the altered metabolic rate is needed to maintain body temperature. The TNZ is the range of temperatures within which cattle can maintain temperature homeostasis through normal physiological, metabolic, and behavioral processes (NRC, 1981; Federation of Animal Science Societies, 2010). The TCZ generally ranges between 15 and 25°C (59 and 77°F) for most cattle less than 1 mo old; between 5 and 20°C (41 and 68°F) for mature beef cows consuming a maintenance diet; and between −10 (14 and 68°F) and 20°C for yearlings with ad libitum access to energy-dense feedlot diets (NRC, 1981; Federation of Animal Science Societies, 2010). 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 that is shifted upward by 5°C (9°F) compared with that of typical *Bos taurus* cattle.

Encompassing the TCZ is the TNZ. Within the TNZ, an animal can maintain homeostasis through normal physiological and metabolic processes; energy expenditure and behavior modifications may be required when the animal is exposed to conditions outside the TCZ (Hahn, 1985; Young et al., 1989; Caton and Olson, 2016). The TNZ generally ranges between 10 and 30°C (50 and 86°F) for most cattle less than 1 mo old; between −15 and 28°C (5 and 82°F) for mature beef cows consuming a maintenance diet; and between −35 and 25°C (−31 and 77°F) for yearlings with ad libitum access to energy-dense feedlot diets (NRC, 1981; Federation of Animal Science Societies, 2010; University of California-Davis, 2012). Even though the upper end of the TNZ for most *Bos taurus* cattle is between 25 and 30°C (77 and 86°F), for high-producing cattle with high intakes of metabolizable energy, the upper limit may be closer to 20°C (68°F) on sunny days when little or no wind is present (NRC, 1981; Brown-Brandl et al., 2006). When provided sufficient time, cattle acclimate and adapt to colder or hotter conditions. It should be noted that cattle adapted to −35°C (−31°F) may be uncomfortable (show signs of heat stress) at 10°C (50°F). 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 decrease in feed intake. Primary factors that affect thermal comfort include feed or energy intake, body condition or subcutaneous fat cover, and the animal's ability to express behaviors that reduce the impact of adverse environments.

Thermal Indices

The temperature-humidity index (THI), where 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 for selection of management practices during seasons other than winter (Hahn et al., 2003; Mader, 2003; Amundson et al., 2006; Mader et al., 2006). The THI, first proposed by Thom (1959), has been extensively applied in 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 >70 by 0800 h, it is recommended that managers of confined cattle with 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 is critical (Hagenmaier et al., 2016) and 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 accounting for airflow and radiation heat load in the index (Mader et al., 2006). Eigenberg et al. (2005) developed similar adjustments based on predictions of respiration rates using ambient and dew point temperature, wind speed, 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 wind speed. 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 straightbred Brahman steer is 96. 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). Gaughan et al. (2008) also described accumulated heat load (AHL), which arises from insufficient night cooling and results in animals entering the day with an accumulated heat load. Gaughan et al. (2008) reported that HLI and AHL were highly correlated. Insufficient recovery periods from elevated HLI results in increased AHL. Recovery time is the time needed to bring body temperature back to normal. Recovery periods have been recommended to be 6 h with a THI <70 or can be calculated by the equations provided by Gaughan et al. (2002). Additional information on management of cattle exposed to adverse environmental conditions is presented in the review by Mader (2014), and readers are referred there for additional information.

Limited data exist for assessing environmental effects on reproduction. Amundson et al. (2006) found THI and daily minimum temperature to be equally correlated with pregnancy rate at 42 d into the breeding season. However, the combination of wind speed and THI were strongly correlated (r = 0.79) with pregnancy rate. Paula-Lopes et al. (2013) concluded that high environmental temperature and resulting heat shock can reduce reproductive efficiency by negatively affecting the oocyte and early embryonic stages of development. Additionally, observed effects were more pronounced in *Bos taurus* than in *Bos indicus* genotypes.

Indices for cold stress are not as well defined as they are 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 the effects of wind on domestic livestock (see Chapter 3: Husbandry, Housing, and Biosecurity for discussion). Mitigating the chilling effects of wind during periods of cold stress through the use of windbreaks increases cattle comfort (Mader, 2014; NASEM, 2016). Mader (2014) outlines and discusses several practical approaches to enhancing animal comfort in feedlot pens and other areas during the winter.

From the above discussion, it is evident that beef cattle can be adapted to a wide range of environmental conditions and that zones of cattle comfort vary depending upon many factors. It should be emphasized that UCT and LCT for individual animals are moving targets (NRC, 1981; NASEM, 2016). For beef cattle, care should be taken to match genetics to environment in production systems. Cattle, like other animals that we care for, should not suffer from hypo- or hyperthermia. If they do, management techniques including but not limited to shade, fans, misting, windbreaks, bedding, and dietary adjustments should be provided when practical or unless approved care and use protocols justify and dictate otherwise. Within range and pasture-based production systems, hypo- and hyperthermia should be avoided when and if possible. Beef cattle used for research or teaching may be housed in intensive management systems, either indoors or in open lots, with or without shelter. Facilities should provide cattle with an environment that mitigates hypo- and hyperthermia and presents opportunities for behavioral thermoregulation when needed (e.g., access to a windbreak, sunshade, mound, or roofed shelter).

Range and Pasture Systems

Acceptable systems for grazing beef cattle on pasture and rangeland vary widely. Cow body condition is a measure of degree of fatness (body energy reserves) and is widely used as a performance standard for monitoring the well-being and nutritional status of cattle. The *Nutrient Requirements of Beef Cattle* (8th rev. ed.; NASEM, 2016) discusses body condition score (BCS) in detail, and readers are referred there for additional information. Body condition score naturally fluctuates across season and within normal management paradigms. This is particularly the case in pasture and extensive grazing production scenarios, and NASEM (2016) has modeled and recommended management and feeding approaches to move cattle from thin or obese back to a moderate BCS. Biologically, cattle evolved in grazing environments, and seasonal swings in BCS reflect both forage quantity and quality and seasonal environmental conditions. Dry forage organic matter intake measured in 19 trials within extensive western rangeland grazing conditions has been reported to range from 0.91 to 2.57% of live body weight (BW) and average intake was 1.49 and 2.17% of live BW during forage dormancy and the growing season, respectively (Krysl et al., 1987). These ranges in grazing cattle intake are supported by more recent work by Cline et al. (2009), who reported that dry forage organic matter intakes of grazing cattle ranged from 1.14 to 2.61% of BW. Extremes in body condition can affect calf birth weight. For example, NASEM (2016) states “Calf birth weights are positively related to BCS when cows are below BCS 3.5, remaining constant between BCS 3.5 to 7, and are inversely related to BCS when cows are above BCS 7.” As in cows, BW and BCS of bulls fluctuate throughout the year, with bulls losing considerable weight and condition during the breeding season. Variation in intake and BCS experienced by cattle are natural components of range and pasture management systems, and have and will continue to underpin research programs focused on improving production and care, not only in range and pasture systems but in other production systems as well.

Within range and pasture-based production systems, hypo- and hyperthermia should be avoided. Beef cows decrease grazing time and forage intake as ambient temperature decreases below 0°C or 32°F (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 the benefits of natural or manmade windbreaks vary depending upon the severity of the weather (temperature and wind speed) and effectiveness of the windbreak in decreasing wind exposure (Krysl and Torell, 1988; Mader et al., 1997). Supplementary feed should be provided during periods of heavy snow cover that preclude grazing or during other times when nutrient demand exceeds nutrients supplied by available forage for specified production and health goals. In areas where exposure to extreme cold is likely, provision of shelter for grazing beef cattle may be desirable

When ambient temperature and thermal radiation exceed cattle body surface temperature, then cattle cannot dissipate their body heat by the standard mechanisms of conduction, radiation, or convection; consequently, cattle will gain heat. Some moderate increases in daytime heat gains can normally be dissipated through changes in behavior (seeking shade or water) or through cooling during less warm periods during the day or night (NASEM, 2016). Heat stress is evidenced when respiration rates begin to increase in attempts to dissipate body heat. Respiration rate and panting scores have been used as measures of the degree of heat stress (NRC, 1981; Mader et al., 2006; Hales et al., 2014). Respiration rate can be predicted from temperature, relative humidity, wind speed, and solar radiation (Eigenberg et al., 2005). Prolonged increases in body temperature will result in decreased feed intake, body condition, and weight (Robertshaw, 1987; Hahn, 1995). Initial decreases in intake are likely associated with physiological demands for reduced metabolic heat production resulting from periods of heat stress. Beef cattle managed in grazing conditions may use location, position, or orientation to mitigate excessive heat loads (Caton and Olson, 2016).

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 stocking rate. Guidelines for acceptable amounts of standing forage per unit of BW at given stocking rates (herbage allowance) are available (NRC, 1987). Grazing beef cattle are often supplemented to meet performance goals or when forage quality or quantity becomes limiting to support desired production or stocking rates. Supplementation strategies for grazing livestock vary regionally, by management system, and per performance goals. In almost all grazing environments, range cattle are provided free-choice access to supplemental salt as a source of sodium. Often, salt-based, free-choice mineral supplements will also be fortified with trace minerals.

Observation and monitoring often occur less regularly for range cattle than for other livestock. When supplemental feed is provided, cattle are usually observed at least 2 or 3 times weekly. Nonsupplemented cattle on open range may be observed less frequently; however, it is recommended that, when possible, 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 dedicated to such problems, and efforts should be made to manage or mitigate these adverse conditions.

Water is available to cattle from intake of free water, ingestion of water associated with feedstuffs, and metabolic water. Practically, metabolic water contributes little to overall water demand. Adapted cattle can consume snow and ice in the absence of liquid water in adequate amounts to offset the absence of drinking water in extensive winter grazing systems (CSIRO, 2007; NASEM, 2016). Cattle appear to prefer liquid water, and water availability is critical for the performance and health of grazing beef cattle (NASEM, 2016). 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). Data evaluating distance between water sources in extensive grazing systems are limited; however, Holechek et al. (2011) recommended that the 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 is important, and every animal should have the opportunity to drink ad libitum at least once per day.

Feedlot and Housing Systems

Beef cattle used for research or teaching may be housed in intensive management systems, either indoors or in open lots, with or without shelter. Facilities should provide cattle with an environment that mitigates hypo- and hyperthermia and presents opportunities for behavioral thermoregulation when needed (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 (University of Minnesota Extension, 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 windbreaks 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 is advised when placing cattle in sheltered areas in the summer because of the adverse effects of restricted airflow on cattle in hot environments (Mader et al., 1999).

During potentially stressful heat episodes (nighttime THI $\geq$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 used as an indicator of stress level (Mader et al., 2006; Mader, 2014). 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 competition for cooler areas in a pen or around the water trough increases, even during cooler days when heat alleviation methods (e.g., sprinkling) are not used (Mader et al., 2007). When this occurs, evidence of crowding is observed, which exacerbates heat stress problems. Wetting the ground or floor of holding facilities can be an effective method of cooling cattle managed in outdoor units without shade and where surface vegetation is sparse or nonexistent (Mader, 2003, 2014; Mader and Davis, 2004). Direct wetting of cattle during extreme heat is also an effective practice and is often used as an emergency measure. In these cases, care must be taken to allow cattle to acclimate because applying significant amounts of cold water to hot cattle can cause additional stress. Additionally, actively cooling cattle after maximum ambient temperature occurs is more effective at reducing heat load compared with active cooling during peak ambient temperature (Lees et al., 2019). Benefits of sprinkling are enhanced if sprinkling is started in the morning before cattle experience high heat loads (Davis et al., 2003). A daily application of 0.5 to 1.0 cm of water is sufficient to cool pen surfaces. Applying 1.25 to

1.50 cm every other day is also 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 to be sprinkled would be similar to the shade area recommendations. As a routine protective practice, wetting can be efficiently accomplished by using 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 the respiration rate to increase compared with that in cattle that were not misted. Additionally, Mader (2014) presented potential negative effects of sprinkling in some circumstance, including acclimation of cattle to sprinkler systems and elevated pen humidity in environments with poor air flow or when too large of an area is sprinkled.

Shade for cattle can mitigate hyperthermia for animals that are not conditioned to a sudden heat wave with high solar radiant loads, such as experienced in the central and southern regions of the United States. Mader et al. (1999) found limited performance benefits of shade in the north-central region of the United States, in contrast to the findings of Mitlöhner et al. (2001), which indicated that shade was effective in southern regions. In addition, use of shade may be costly and logistically prohibitive because of snow load requirements (unless shade is taken down after the summer), potential mud problems under shade (low evaporation rates), and the low percentage of time that cattle may actually benefit from using the shade. Mitlöhner et al. (2001, 2002) found favorable results when shade was 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. Although recouping benefits from shade structures through improved performance can be challenging, putting shade structures in sick pens or in pens with cattle prone to heat stress will be helpful. Hagenmaier et al. (2016) indicated that provision of shade for feedlot cattle in Kansas increased feed intake and dressing percentage in feedlot cattle nearing the end of the finishing phase. Shade structures should allow air movement but must be able to withstand strong winds, especially in certain regions. Improperly designed shade structures could risk animal or human injury or harm. Designing shade structures requires careful consideration of location, orientation, and height, as well as repair and maintenance to prevent injury and regular cleaning under the shade to minimize increased pen floor humidity (Eirich et al., 2015). While providing shade alone will likely not completely eliminate the effects of high heat loads, the goal of providing shade is to reduce heat stress and prevent hyperthermia. Cattle subject to environments that could precipitate hyperthermia need to be observed for signs of heat stress, and management action should be taken as needed.

Unheated housing may be provided for beef cattle. Open sides of any cattle building need to face away from the prevailing winds. Such structures are ventilated by natural airflow, and the resultant winter temperatures are typically warmer than outdoor conditions as a result of body heat and wind protection. Totally enclosed housing requires ventilation to maintain the air temperature at acceptable levels and to minimize the accumulation of water vapor, noxious gases, other odorous compounds, and dust in the air. 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. Soil-surfaced pens should be regularly cleaned of animal waste and maintained to minimize accumulation of water. In areas subject to excessive mud, a hard surface apron in front of the feed bunks and around water troughs and shelters should be considered in soil-surfaced pens. When slope and drying conditions are inadequate, mounds should also be provided in soil-surfaced pens for cattle to lie on during wet and muddy soil conditions (Table 6-1). Accumulation of mud in a pen or on the cattle can influence maintenance energy requirements and thermal balance (NASEM, 2016). 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 use 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 eliminate or minimize bruising and injuries and to improve the efficiency of cattle handling (Mader, 2014).

Proper lighting permits inspection of animals in feedlots and other cattle housing systems and provides safer working conditions for animal care personnel. Mainte-

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

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

[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. When considering space allocations, decisions should be based on slope, rainfall, size of cattle, season, and group size, as discussed in the text.

nance 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 published and accepted recommendations (NASEM, 2016). Formulations 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 is often available for a large percentage of the day, even though cattle do not eat continuously and in situations where feed is abundant. Instead, cattle eat in bouts and then ruminate, returning to eat again later. In some management situations, overconsumption of feed can be problematic, resulting in excessive BCS, and negatively affect reproductive performance in both females and males. Limited feeding of diets may be practiced to meet maintenance requirements or targeted production goals or even to return males and females to optimal BCS for breeding. When limit feeding is practiced, feed should be uniformly distributed to allow all cattle to have simultaneous access to the diet. When high-energy diets are fed, increased attentiveness should be given to the possible occurrence of diet-related health problems such as grain overload, lactic acidosis, and bloat. Abrupt changes in diets should be avoided; however, extreme weather conditions can lead to feed deprivation in many production systems. Feed deprivation for more than a day should be avoided unless justified in the animal use protocol.

Cattle can vary considerably in BW and condition during the course of grazing and reproductive cycles (see discussion above on BCS). Feeding programs should allow animals to regain BW that is lost during normal periods of negative energy balance. Modeling normal periods of negative energy balance within experimental protocols is often needed to appropriately address relevant animal performance, welfare, and food production questions. Cattle should have access to a source of water unless the research or animal care protocol requires otherwise. 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, consumption of snow resulted in decreased water intake as shown 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 averaged approximately 10% less.

The quantity and quality of water available will influence water consumption and animal comfort, especially under hot conditions. Evaporation of moisture from the skin surface (sweating) or respiratory tract (panting) are the primary mechanisms used by cattle to lose excess body heat in a hot environment. Estimates of daily water requirements for beef cattle are available in *Nutrient Requirements of Beef Cattle* (8th rev. ed.; NASEM, 2016). During summer months, in particular, waterer space availability and water intake per animal become 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 (3 vs. 1 in) 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).

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 is available in Chapter 7: Dairy Cattle of this guide.

The health of young growing cattle should be assessed regularly before and after weaning. 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. 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 for all treated calves and their treatment should be maintained. For cattle reared in close confinement (e.g., cattle in feedlots), assessments should be conducted 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 by commingling, dehydration, digestive problems, respiratory problems, or interactions of any of these factors with environmental stress. Signs of healthy calves are alert ears and clear eyes, no signs of diarrhea, and, on 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. More details on causes, implications, and management of stress can be found in the "Stress" chapter of the NASEM (2016).

Appropriate medication and vaccination programs should be used to decrease 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 cow herd, 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 by both the cows and their calves (Veissier and Le Neindre, 1989). An alternative to abrupt weaning and permanent separation is a period (approximately 7 d) 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 introduction of the weaned calves to the location and facilitate consumption of feed and water (Gibb et al., 2000). Bailey et al. (2016) investigated 3 different calf weaning strategies, including dry lot weaning with dam separation and concentrate feeding, fenceline weaning with dam contact, and fenceline weaning with supplemental access to concentrate feed. They concluded that weaning strategy yielded differences in calf performance during the weaning and receiving period, but no differences in final BW, days on feed, or harvested carcass characteristics were reported. Regardless of the weaning process selected, it is important that weaned calves be provided access to clean water and a source of feed, forage, or both. To encourage intake, highly palatable forage and feed sources are recommended until calves become accustomed to the separation from their dams. Additional information on best management practices for newly weaned calves for improved health and well-being can be found in Wilson et al. (2017) and Riggs et al. (2019).

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 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 relationship between position in the social order and productive performance (Hafez, 1975; Stricklin and Kautz-Scanavy, 1984; Fraser and Broom, 1990).

Proper animal care includes observation of groups and 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. In addition to the size of cattle being housed, 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 such as soil type and rainfall distribution. Simroth et al. (2017) provides a recent review of current practices used in the High Plains region of the United States (Texas, Oklahoma, New Mexico, Colorado, Kansas, and Nebraska).

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 mats. Keane et al. (2018a) concluded that the equation $y = 0.033w^{0.667}$ (y = space allowance, m^2; w = body weight, kg) is sufficient for estimating the space required by finishing beef cattle housed on concrete slatted floors. Recently, Keane et al. (2018b) reported that flooring type (concrete, slatted, matted, or bedded) had no influence on lying duration, dirt scores, or performance measures. In feedlot steers, the floor surface in stanchions and metabolism stalls may be concrete, expanded metal, wood, rubberized mats, or a combination of materials that provides support for the animals' bodies; it does not damage hooves, feet, legs, and tails; and it 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, using hydraulic and manual chutes for restraint, roping, hoof trimming, routine calving assistance, ultrasonographic 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, but are not limited to, artificial insemination, electro-ejaculation, 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 management tools to minimize injuries or other problems associated with confining horned cattle and commingling of cattle. Additional guidelines outlining veterinary oversight of these practices, other animal health issues, and related institutional policies are covered elsewhere in this publication.

Dystocia Management

Dystocia is more prevalent in primiparous than in multiparous dams and is defined as delayed or difficult parturition. Dystocia can have serious consequences for both the dam and offspring and is typically caused by mismatched fetal–maternal size, abnormal fetal presentation at birth, or other maternal-related causes (Arnott et al., 2012; Holm et al., 2014; Funnell and Hilton, 2016). Breeding management should be structured 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 dams.

Parturition without complication is common in beef cows (Battaglia, 1998). Therefore, before administering assistance to a cow experiencing calving difficulty, personnel should be familiar with the stages associated with approaching parturition and the signs of normal delivery. When the management system allows, females should be examined within 30 to 60 min following presentation of feet, nose, or fetal membranes if delivery of the calf does not seem imminent. However, heifers or cows exhibiting signs of a malpresentation, oversized fetus, fetal anomaly, or other obvious complication should be assisted immediately.

In dystocia cases where fetal presentation appears to be compromised or there seems to be a disparity between the size of the fetus and the diameter of the birth canal, assistance of 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 assist the delivery or perform a caesarean section or fetotomy. Use of excessive force can damage the calf, the dam, or both, and lead to suffering or death. Strict sanitation should be used with all obstetrical procedures.

Vaccinations and Drug Administration

Vaccinations are a key component of 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.

Castration

Cattle are routinely castrated 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 (Battaglia, 1998; Federation of Animal Science Societies, 2010; AVMA, 2014a; Lyles and Calvo-Lorenzo, 2014). Accordingly, castration of young bulls is a necessary management practice in beef production.

Several methods for castrating cattle are acceptable (AVMA, 2014a; Lyles and Calvo-Lorenzo, 2014), 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 using specialized rubber rings or surgical tubing bands (applied with specially designed instruments) are available that cause devitalization and eventual sloughing of the tissues below the ring or band. 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 method of castration is chosen, the procedures should be conducted by, or under the supervision of, a qualified, experienced person and carried out according to the castration equipment manufacturer recommendations and accepted husbandry practices (Battaglia and Mayrose, 1981; Ensminger, 1983; Battaglia, 1998).

Castration is normally a short-term event with a short-term duration of pain-associated responses (Coetzee, 2013; AVMA, 2014a; Lyles and Calvo-Lorenzo, 2014). Procedures associated with castration are normal production practices that cause short-term pain-associated responses. However, these procedures are typically conducted without pain relief because of regulatory access and costs associated with practical application of drugs associated with pain relief (AVMA, 2014a; Lyles and Calvo-Lorenzo, 2014); and because of the lack of effective over-the-counter analgesics and as nonsteroidal anti-inflammatory drugs (NSAIDs). In a large meta-analysis of scientific evidence for the effects of castration in male beef cattle on welfare indicators, cortisol did not differ between no castrated, surgical castration, and nonsurgical castration, and multimodal pain relief did not mitigate the cortisol increase in castrated cattle (Canozzi et al., 2017). In contrast, Nordi et al. (2019) found that knife-castrated calves experienced more acute pain than band-castrated calves, and the combination of flunixin plus lidocaine reduced indicators of pain. Castration is least stressful when performed at or shortly after birth. Marti et al. (2017) reported that indicators of chronic pain were not evident when calves were castrated at less than 2 mo of age, which supports the Farm Animal Welfare Council's (1981) conclusion that castration between 2 and 3 mo of age results in less stress than castration at an older age. Conversely, regardless of the method tested, castration caused acute pain independent of calf age (Meléndez et al., 2017). An increasing body of still-limited literature indicates that it is best to castrate calves as young as possible (Robertson et al., 1994; Bretschneider, 2005; Marti et al., 2017). Any time that castration is performed, regardless of method, the treated animals should be monitored by experienced individuals for behavioral signs of distress. Animals showing behavioral indicators of distress should be treated to reduce their discomfort. In some production settings, such as the rearing of replacement bulls, it is impossible to castrate calves at a young age because their breeding potential has yet to be identified. Consequently, the animal welfare benefits of conducting painful production procedures, like castration, need to be balanced with commercial operation goals, typical management of calves, and research and teaching needs, as documented in approved animal care protocols (Lyles and Calvo-Lorenzo, 2014).

Research investigating the use of anesthesia and analgesia during castration has yielded varying results depending on the metrics being evaluated (AVMA, 2014a; Lyles and Calvo-Lorenzo, 2014). Local anesthetics administered at the time of castration will provide temporary pain relief, whereas analgesics, such NSAIDs, provide a longer course of pain mitigation. Combining the use of local anesthetics and analgesics may provide better control of acute and chronic pain (AVMA, 2014a). It may be desirable to inject a local anesthetic in the scrotum of older calves when surgical methods of castration are used or when the spermatic cords are crushed. 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; Rust et al., 2007). However, all forms of castration appear to cause pain, and the degree of acute and chronic pain increases with calf age and method used (AVMA, 2014a). It should be recognized that the effect of anesthetic agents is short-lived. The need for pain mitigation approaches appear to be more justified in older animals. Castration of post-pubertal bulls should be performed only by skilled individuals. When it is necessary to castrate these bulls, techniques and procedures to control bleeding should also be used. Bloodless procedures for castration of post-pubertal bulls should be accompanied by administration of tetanus antitoxin.

The possibility of infection after castration should be given additional consideration in all calves and especially older animals. 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, the herd health veterinarian should schedule a prophylactic tetanus immunization program.

Disbudding and Dehorning

Disbudding involves procedures that destroy the horn-producing cells found in the horn bud, whereas dehorning is the removal of horns after they have been formed from the horn bud (Stafford and Mellor, 2005; AVMA, 2014b). Procedures associated with disbudding and dehorning are normal production practices that cause pain (Stafford and Mellor, 2005; Stock et al., 2013; AVMA, 2014b; Lyles and Calvo-Lorenzo, 2014). However, these procedures are typically conducted without pain relief because of regulatory access and costs associated with practical application of drugs associated with pain relief (AVMA, 2014b; Lyles and Calvo-Lorenzo, 2014). Horns on cattle can cause bruises and other injury to other animals, especially during transport and handling (AVMA, 2014b). Horns on adult cattle can also be a hazard to humans. These facts alone lead to the recommendation that naturally polled or dehorned cattle be used in teaching and research absent a strong justification for horned cattle.

Disbudding and dehorning cattle in the United States is not currently regulated. The Canadian Veterinary Medical Association recommends that disbudding be performed within the first month of life (CVMA, 2016). 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 of age (LaFontaine and de Witte, 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. Additional disbudding and dehorning information can be found in AVMA (2014b) and in Chapter 10: Domestic Sheep and Goats of this guide.

When horned breeds of cattle are selected, disbudding and dehorning should be performed under the supervision of experienced persons using proper techniques (Ensminger, 1970; Battaglia and Mayrose, 1981; Battaglia, 1998; AVMA, 2014b). The horn buds should be removed by one of several means, such as hot cauterizing irons, cauterizing chemicals, a sharp knife, or commercially available mechanical devices.

Dehorning should be conducted at the earliest age possible, preferably before they are 2 mo old. A recent meta-analysis of 69 trials (Canozzi et al., 2018) found heterogeneity between studies for cortisol ($I^2 = 50.5\%$), average daily gain ($I^2 = 70.5\%$), and vocalization ($I^2 = 91.9\%$). Further, local anesthesia and use of nonsteroidal anti-inflammatory drugs either separately or in combination has been found to produce heterogeneous responses in indicators of pain/stress in disbudded calves that were less than 12 wk of age (Winder et al., 2018). All 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. When it is necessary to remove horns from older cattle, it is recommended that the methods used minimize pain and bleeding and prevent infection. Dehorning may temporarily depress the growth of cattle (Loxton et al., 1982) but does not have long-term effects on production measures (AVMA, 2014b).

Hornless cattle require less space in the feedlot and at the feed bunk; dehorning is a common practice in the beef industry (Battaglia, 1998; Stock et al., 2013), with calves being disbudded or dehorned either before weaning or upon arrival at the feedlot (Lyles and Calvo-Lorenzo, 2014). In the event that bunk and pen space are ample (e.g., 2 times the recommended space requirements), then tipping the horn (removing the tip only; Lyles and Calvo-Lorenzo, 2014) may be considered 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, visual (flap tags) or radio frequency identification (RFID) ear tags, 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 has a long history of use as a means of identification and is still legally required in some localities. However, reduced value of the hide and studies indicating that freeze branding is less painful than hot branding (Lay et al., 1992; Schwartzkopf-Genswein et al., 1997) have led to recommendations to consider alternatives when possible. Skin and hair color, in addition to limited access to liquid nitrogen or dry ice in extensive range operations, may affect the ability to achieve a quality freeze brand. 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. Additional information on branding can be found in the AVMA (2011) and in Lyles and Calvo-Lorenzo (2014).

Implanting

Implanting of cattle is a management practice to administer growth promotants and potentially as a means to deliver 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 should 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 in this publication for information on enrichment of environments for beef cattle.

HANDLING AND TRANSPORT

Refer to the Chapter 5: Animal Handling and Transport in this publication 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, long or short-term infusion studies, 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, come into close contact with humans, or are exposed to unfamiliar conditions or laboratory/teaching settings should have calm dispositions and be adapted to frequent contact with animal care personnel and to 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 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 variations in light intensity and provide for a normal light/dark cycle.

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.

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, particular attention should be given to the alertness of the animal; appetite; fecal and urinary outputs; and condition of the feet, legs, and hock joints. Rubber mats or suitable alternatives may be used to increase the comfort of cattle maintained for lengthy periods on hard surfaces.

Transgenics and Cloning

Refer to Chapter 1: Institutional Policies for information on transgenesis and cloning as they relate to animal care and use.

SLAUGHTER AND EUTHANASIA

Floors of livestock pens, ramps, and driveways of harvest facilities shall be constructed and maintained so as to provide good footing for livestock (USDA-FSIS, 2006). Animals shall have access to water in all holding pens and, if held longer than 24 h, access to feed. Additionally, for animals held overnight there shall be sufficient room in the holding pens for the animals to lie down (USDA-FSIS, 2006). Protocols for slaughter should follow the AVMA *Guidelines for the Humane Slaughter of Animals* (AVMA, 2016, or current).

The AVMA *Guidelines on Euthanasia* (AVMA, 2020, or current) 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 followed by exsanguination 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 US 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. 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 (2020) recommended procedures. Their disposal should be accomplished promptly by a commercial rendering service or other means (e.g., burial/landfill, composting, or incineration) according to applicable ordinances and regulations. More information on slaughter and euthanasia is found in Chapter 2: Agricultural Animal Health Care of this publication.

In the United States, all procedures used to slaughter research and teaching animals that will enter the food chain must comply with US Code of Federal Regulations, Title 7, Chapter 48, Humane Slaughter of Livestock (https://www.govinfo.gov/content/pkg/USCODE-2011-title7/pdf/USCODE-2011-title7-chap48.pdf). The North American Meat Institute (NAMI) has embraced guidelines (https://animalhandling.org/producers/guidelines_audits) that exceed the regulatory requirements (Grandin, 2017) and the NAMI guidelines (NAMI, 2019) are incorporated here by reference.

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CHAPTER 7: DAIRY CATTLE

INTRODUCTION

The aim of this chapter is to provide specific guidelines regarding the housing, care, and management of dairy cattle, including bull calves, replacement heifers, veal calves, lactating and dry cows, and bulls. The focus is to provide the necessary information required for those responsible for the design, maintenance, and management of dairy cattle research facilities and those who are responsible for serving on an institutional animal care and use committee (IACUC) and charged with ensuring that animals kept in such facilities are well cared for, so that the highest standards of animal welfare are met and maintained.

Specific recommendations are required within a framework that provide housing and management flexibility but that specifically address key welfare concerns. We will therefore take the approach of providing recommendations within each section, based upon the lifecycle of the cow, beginning with the milk-fed calf, the growing heifer stages, through lactating, dry, maternity, and special needs cattle housing and added considerations for dairy bulls. We will provide outcome-based measures for evaluating key elements, when possible.

FACILITIES AND ENVIRONMENT

Milk-Fed Calf

Whatever the end use of the calf, whether it be for veal production, heifer replacement, or otherwise, the standards for care discussed herein are best practices.

Calves should be kept in full social contact with at least one other calf for the majority of the milk-feeding period. In the United States, milk-fed calves are typically housed individually (on 75% of operations), but group housing is becoming increasingly common (USDA, 2016), and providing social contact (tactile, auditory, visual) is supported by many scientific studies. Individually reared milk-fed calves exhibit deficient social skills, poor learning abilities, and difficulties in coping with new situations, all of which may reduce the animal's ability to adapt effectively to the variable environments experienced as an adult (see review by Costa et al., 2016). Calves housed individually or with only limited auditory or visual contact were more fearful than pair-housed calves (Jensen and Larsen, 2014). Calves have also been shown to work to gain access to full social contact with a known calf even when already provided limited social contact across a barrier (Holm et al., 2002; Estevez et al., 2007), indicating that they are motivated to be with other cattle. Providing full social contact with peers during the milk-feeding period has been shown to provide numerous benefits, including reduced fearfulness (Bøe and Faerevik, 2003), reduced food neophobia (Costa et al., 2015), increased starter intake, reduced weaning distress, and reduced growth check during regrouping (de Paula Vieira et al., 2010). The results of this latter study also illustrated longer-term costs to housing calves individually. When weaned, calves that had previously been housed individually took 50 h to begin feeding, on average, compared with just 9 h for pair-reared calves.

While calves are being fed milk or milk replacer, all housing should provide a spatial allowance of at least 2.8 m^2 (30 ft^2) or more of bedded space per calf (not including service alleys) to minimize the risk of respiratory disease (Lago et al., 2006). This space allowance should allow the calf to turn around and select a comfortable resting space based upon preference for different microenvironments within the pen. Calves groom diverse parts of the body beginning at a very young age (Chua et al., 2002) and restriction of movement, especially the ability to turn around, decreases their ability to perform natural behaviors when space allowance is compromised (Le Neindre, 1993). Based on the need for socialization and the ability to groom and turn around, tethers that restrict these behaviors should not be used for calves.

Dairy calves should be provided a clean, dry, soft place to lie down. Dairy calves show aversion to lying on concrete surfaces and a clear preference for drier sawdust bedding (Camiloti et al., 2012). Calves benefit from deep bedding, especially in temperatures less than 10°C (50°F), for example, with deep, dry clean straw (Lago et al., 2006; Hill et al., 2011). A drainage system installed below the bedding is beneficial to remove moisture and minimize the need for fresh bedding. In warmer climates, shavings, sand, or other materials can be an acceptable bedding alternative. Wooden or metal slats, tenderfoot flooring, rocks, and bare concrete should not be used as the only resting area.

Multiple, smaller group pens that allow for "all-in, all-out" groupings, which enable complete cleaning and downtime between uses, are recommended.

Calves should be provided adequate ventilation and protection from inclement weather. Provision of adequate ventilation minimizes the risk of respiratory disease, and control of the thermal environment is required to prevent chilling in newborn calves and heat stress during hot weather. The use of a calf jacket does not preclude other measures necessary to ensure thermal comfort in cold weather (such as heating and increased feeding rate), in part because only a single study has evaluated this option (Earley et al., 2004). Provision of a heat lamp has been reported to provide benefits during the first day of life (Uystepruyst et al., 2002), and milk-fed calves show a preference for heated areas, regardless of milk-feeding level, and tend to be closest to the heat lamp in colder temperatures than in warmer temperatures (Borderas et al., 2009). Care is needed to ensure that heat lamps do not impose a fire risk when used.

Calves should be provided protection from heat, and should be provided shade. Heat stress can be monitored by evaluating respiration rates and panting. Although hutches have long been considered a gold standard in calf rearing, attention to heat stress should be provided in hot weather because temperatures within the hutch can exceed ambient conditions and air quality can be poor (Hill et al., 2011). Indeed, Hill et al. (2011) found that a well-ventilated nursery barn with straw bedding resulted in improved average daily gains (ADG) over hutches. Positive pressure tube ventilation systems can ensure a minimum of 4 air changes per hour (ACH) year round and have been reported to be associated with benefits to calf health (Jorgensen et al., 2017). In hot weather, shade and supplementary cooling with additional fans can lower respiratory rates and improve ADG (Hill et al., 2011).

Growing Heifers

Growing heifers fall in an age category that covers the period after milk feeding ends but before lactation begins. Heifers should be provided a clean, dry, soft lying area of sufficient size (see Table 7-1 later in the chapter for recommended dimensions). After weaning, heifers are often housed on bedded packs or pasture or moved to freestall housing. In the days following introduction into the freestall, many heifers also lie in the alley (von Keyserlingk et al., 2011), leading to an increased risk of developing intramammary infections (Breen et al., 2009). Monitoring animal hygiene is a way to assess the dryness and cleanliness of the lying area, regardless of the housing type used. Heifers should be scored for hygiene as part of routine management. For descriptions of hygiene scoring systems, please visit http://www.paacodairywelfareauditortraining.com/.

Lactating and Dry Dairy Cows

Housing should provide protection from the weather (extremes of temperature and precipitation), while giving cows the freedom to eat, drink, and rest to maintain health and productivity with minimal risk for injury. Lactating and dry adult dairy cattle may be managed at pasture or on dry lots, or be housed in tiestall barns, freestalls, or in loose housing or bedded pack facilities.

Primary Housing

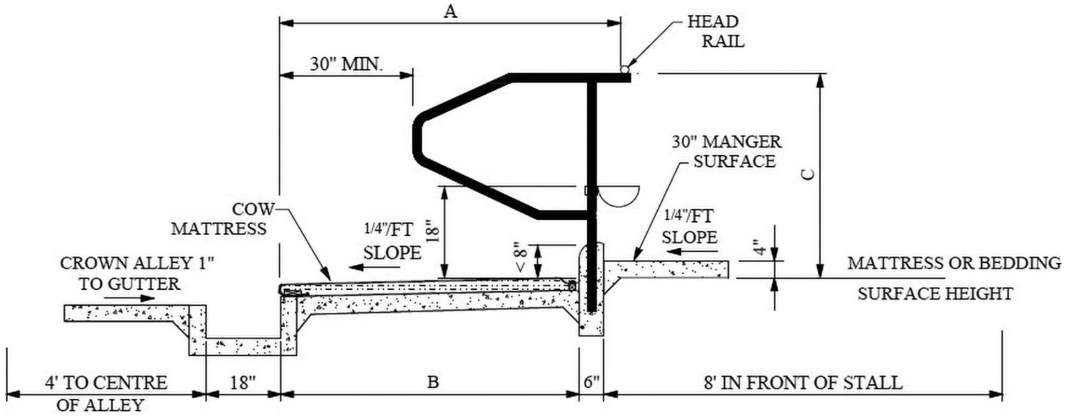
Stanchions, the yoke that confines the cow to a stall and limits her movement, should not be used for housing. The lack of freedom of the animal to rest with its head pulled back alongside its flank ("the closed position"), the compromised ability to lunge forward when rising to a standing position ("lunge space") caused by the yoke, a limited ability to groom the back of its body, and the associated risk for injury to the scapula anecdotally associated with stanchions mean that they should not be used for daily housing of adult dairy cattle (Tie-stall Task Force, National Milk Producers Federation, 2018). Indeed, there are negative consequences of limited opportunities to rest and sleep with the head supported (Kull et al., 2019; Ternman et al., 2019).

Tiestall housing should be designed to provide sufficient space for the resting imprint of cows of different sizes and room for the milker to attach the milking unit if the cow is milked in the stall (see Table 7-2). A tether

Table 7-1. Resting space area for bedded packs based on approximate body weight (BW) estimates (based on industry best practice)

Bedded space requirement	Estimate of BW, kg (lb)								
	<181 (400)	181–272 (400–600)	273–363 (601–800)	364–453 (801–1,000)	454–544 (1,001–1,200)	545–635 (1,201–1,400)	636–725 (1,401–1,600)	726–816 (1,601–1,800)	817–907 (1,801–2,000)
m^2	2.8–3.0	3.7	4.6	5.6	6.5	7.4	9.3	11.1	13.0
ft^2	(30–32)	(40)	(50)	(60)	(70)	(80)	(100)	(120)	(140)

Table 7-2. Recommended design and dimensions for tiestalls for adult cattle milked in the stall (from OMAFRA; http://www.omafra.gov.on.ca/english/livestock/dairy/facts/tiestalldim.htm)



	Dimensions,[1] cm (in)				
Holstein cows	A	B	C	Width	Chain length
Primiparous	213 (84)	178 (70)	112 (44)	127 (50)	91 (36)
Multiparous	218 (86)	183 (72)	122 (48)	137 (54)	102 (40)
Dry cow	218 (86)	183 (72)	122 (48)	152 (60)	102 (40)

[1]Note: The dimensions A, B, and C are shown in the diagram for reference. Other dimensions shown in the diagram are for consideration only.

should allow for normal lunge as the cow rises, and the chain should be long enough to allow the cow to groom her flank and lie in the closed position. Access to the water cup should be unencumbered within 61 cm (24 in) of the top lip of the cup.

Although tiestall housing carries with it some benefits to the cow, including less competition for a place to rest, feed, and drink; provision of a controlled thermal environment; and improved detection of the sick, there is growing concern regarding the negative effect of a lack of behavioral freedom associated with tethering (Spooner et al., 2014) and use of electric cow trainers to position the cow.

Electric cow trainers should not touch the cow while she stands in a normal position. There is evidence that cattle find electric shock aversive (Pajor et al., 2000). The purpose of electric cow trainers is to reduce the amount of manure in the last one-third of the stall (Bergsten and Pettersson, 1992). Some work has identified the use of electric cow trainers as a risk factor for hock (Zurbrigg et al., 2005) and soft tissue injuries (Busato et al., 2000).

Tied cattle should be provided a period of daily untethered exercise. This approach has support from the scientific literature with benefits including less risk of lameness (Popescu et al., 2013), less risk of hock injury (Gustafson et al., 1993; Keil et al., 2006), reduced risk of illness (Gustafson et al., 1993), improved ability to groom (Krohn, 1994; Loberg et al., 2004), and improved socialization and movement (Veissier et al., 2008).

Freestall facilities are rapidly becoming the dominant form of adult cattle housing globally. These barns consist of multiple pens of stalls connected to a holding area and milking parlor or an automated milking system (AMS), with a feed bunk along which feed is delivered and to which cows have direct access. Cows are free to move between the resting, feeding, and drinking areas of the pen and, in some facilities, cows have access to outside lots (Brotzman et al., 2015).

Freestall pens can be designed with between 1 and 4 rows of stalls per feed bunk, with 2- or 3-row pens being the most common. Feed space per cow depends on the pen stocking rate and the pen layout, with feed space being typically ~75 cm (30 in) per cow in 2-row pens and ~45 cm (18 in) per cow in 3-row pens. To reduce feeding competition and optimize feed access, 2-row pens are preferred (see review by Cook, 2019). There is also evidence that the use of headlocks or dividers where cows place their heads through a structure that they can enter and leave freely or that can be locked to restrain them, rather than a post-and-rail feed bunk, reduces competition and displacements from the bunk (Endres et al., 2005). Headlocks facilitate management tasks involving handling of cattle within the pen, such as the administration of vaccinations.

It is recommended that heifers be trained to use headlocks to access feed, necessitating prior exposure before moving cattle into pens with this type of feed access at critical periods, such as the close-up pen before calving. It is also recommended that adult dairy cattle have access to at least 1 headgate/cow or 61 cm (24 in) of bunk space/cow; during the transition period, cows may benefit from greater space allowance. Whether headlocks or a post-and-rail bunk design are used, the recommended industry standard for effective throat height (the distance from the standing surface to the point where the cow's throat would be when eating) for adult Holstein dairy cattle is 53 to 58 cm (21 to 23 in) and for Jerseys 46 to 48 cm (18 to 19 in). Ideally, the headlocks are angled forward slightly to improve access to feed.

Because waterers in freestall barns are typically provided in the areas ("crossovers") between the stall alley and feed alley, the number of stalls between crossovers is limited to a maximum of 25 in best practice, with accessible water trough perimeter recommended to be 8 to 9 cm (3 to 3.5 in) per cow and a minimum of 2 waterers per group for group sizes larger than ~10 cows. A minimum of 3.7 m (12 ft) of space around the waterers allows for one or more cows to drink, with room for cows to pass through the crossover without disturbance. Placement of water troughs in the return lanes from the milking parlor can also provide additional sources for cows to meet their requirements for daily water intake. This information is based on industry best practice, as no scientific evidence exists that evaluates water allocation and placement.

Dairy cattle freestalls should be stocked at 1:1 animal:stall or less. An abundance of research has shown a reduction in lying time when cows compete for access to a lying space (Fregonesi et al., 2007a; Krawczel et al., 2008, 2012; Hill et al., 2009; Winckler et al., 2015).

The time out of the pen each day for milking should not exceed 3 h/d. Pen group sizes can affect time out of the pen milking. Freestall cow time budgets demonstrate that increased time milking leads to reduced lying times (Gomez and Cook, 2010), a risk factor for lameness.

Freestalls should be sized to accommodate the resting imprint of the cow and provide for sufficient lunge space to ensure normal rising and lying movements. Recommendations based on estimated body weight (BW) are provided in Table 7-3 based on The Dairyland Initiative (https://thedairylandinitiative.vetmed.wisc.edu).

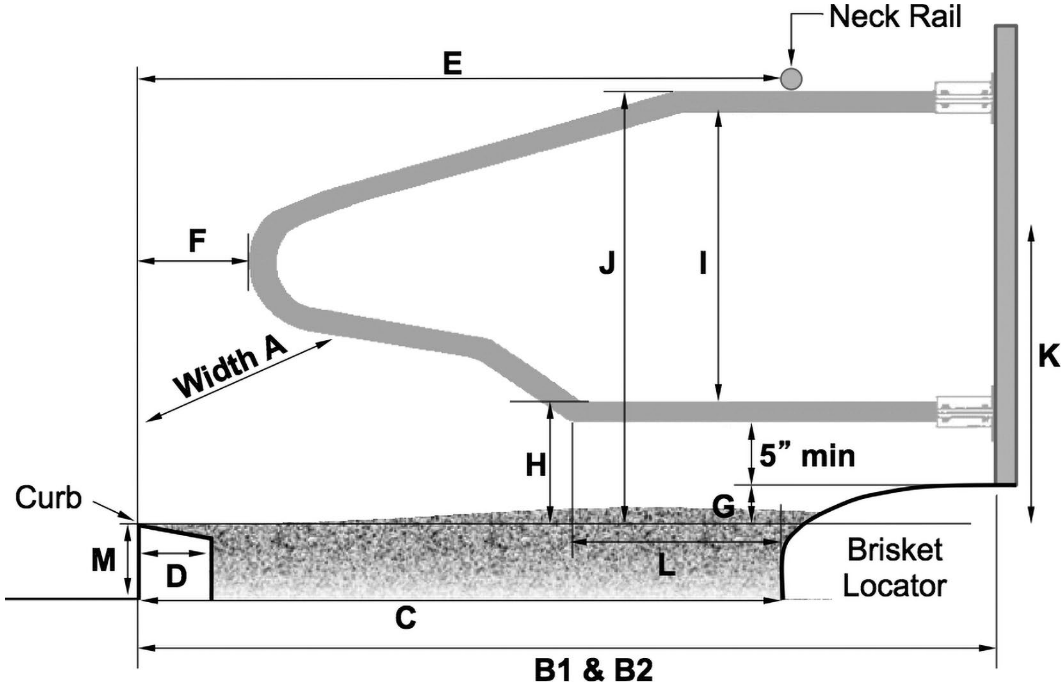
Cows should be provided a clean, dry, soft lying area of appropriate size. Mats, mattresses, waterbeds, or concrete, even when supplemented with less than 8 cm (3 in) of bedding, should not be used. Injuries, swelling, and hair loss on the legs of lactating and dry cows should be evaluated regularly to evaluate the softness of the lying area. Common scoring systems are described at http://www.paacodairywelfareauditor-training.com/. The prevalence of severe hock and knee injuries should be ≤1% (Barrientos et al., 2013; Cook et al., 2016; Cook, 2018). The hygiene of the animals should be assessed regularly to evaluate the dryness of the lying area.

An essential element of tiestall and freestall design to ensure optimal lying times is the stall surface. Cattle show clear preferences for soft and dry lying areas (Tucker et al., 2003; Fregonesi et al., 2007b; Reich et al., 2010), and lying time is reduced on concrete (Haley et al., 2000) and wet surfaces (Fregonesi et al., 2007b). Unyielding and poorly bedded lying surfaces, such as mattresses or mats, are a key risk factor for leg injuries; namely swelling, open wounds, and hair loss on the hock and knees (Barrientos et al., 2013; Zaffino Heyerhoff et al., 2014). Mattresses are associated with higher rates of lameness compared with deep-bedded sand (Espejo and Endres, 2007), whereas deep bedding is a protective factor for lameness in geographical regions with high levels of lameness (Chapinal et al., 2013, 2014). Mattresses covered in enough bedding may function in a manner similar to deep sand or other soft materials, but maintaining coverage and depth is key. For example, lying times are compromised on lightly bedded mattresses compared with deeply bedded ones (Tucker and Weary, 2004), and cattle show a strong preference for deep-bedded lying areas over mattresses (Tucker et al., 2003). Poor stall design, either freestalls or tiestalls, can be detected by leg health. Stalls that are too small result in hair loss, abrasions, and swelling on the legs (reviewed by Kester et al., 2014).

Whatever surface or bedding material is used, contaminated bedding should be removed from the stall each milking or at least once per day and fresh dry bedding should be applied at a frequency to keep the beds level, comfortable, and clean.

Loose housing or bedded packs are commonly used to house sub-groups of adult cows or entire herds. Bedded packs may be managed aerobically or anaerobically, but the key requirement for animal welfare is that cows should be provided enough space per animal (Table 7-1) and that the bedding should be soft and dry. In some systems, anaerobic beds use straw added daily to a bed, which accumulates in layers over a period of 4 to 6 wk before removal and replacement. The layers compact, become moist, and decompose, removing oxygen from the bed and leading to an anaerobic fermentation. Aerobic beds or "compost beds" use fine bedding material such as dry wood sawdust and are composted by stirring twice a day to a depth of 20 to 30 cm (8 to 12 in), with the aim of generating a minimum temperature of 60°C (140°F), which is sufficient to inactivate bacterial pathogens, weed seeds, and fly larvae. Moisture levels are maintained between 40 and 65% in best practice. Typically, a concrete feed alley or an area where trucks drive and deliver feed that cows access through a feed barrier (see headlocks and post-and-rail above) is 3.7 to 4.3 m (12 to 14 ft) wide and is connected to a bedded area no deeper than 9 to 11 m (30 to 35 ft) with sufficient area to accommodate cows of different sizes. Space allocation for bedded areas has received little attention in adult dairy cows. A single study investigating the effects of space allowance found that cows spent more time lying when more space was

Table 7-3. Recommended design and dimensions for freestalls for cattle of various weights (https://thedairylandinitiative.vetmed.wisc.edu)



Stall dimension, cm (in)	Body weight estimate, kg (lb) 270 (600)	360 (800)	450 (1,000)	550 (1,200)	640 (1,400)	730 (1,600)	820 (1,800)	910 (2,000)
Center-to-center stall divider placement (stall width) (**A**)	86 (34)	96 (38)	107 (42)	114 (45)	122 (48)	127 (50)	137 (54)	145 (57)
Total stall length facing a wall (**B1**)	203 (80)	224 (88)	244 (96)	274 (108)	274 (108)	305 (120)	305 (120)	320 (126)
Outside curb to outside curb distance for head-to-head platform (**B2**)	396 (156)	427 (168)	457 (180)	488 (192)	488 (192)	518 (204)	518 (204)	549 (216)
Distance from rear curb to rear of brisket locator (**C**)	No brisket locator recommended		163 (64)	168 (66)	173 (68)	178 (70)	183 (72)	191 (75)
Width of rear curb (**D**)	15–20 (6–8)	15–20 (6–8)	15–20 (6–8)	15–20 (6–8)	15–20 (6–8)	15–20 (6–8)	15–20 (6–8)	15–20 (6–8)
Horizontal distance between rear edge of neck rail and rear edge of curb for mattress stalls (**E**)	117 (46)	140 (55)	163 (64)	168 (66)	173 (68)	178 (70)	183 (72)	191 (75)
Horizontal distance between rear edge of neck rail and rear edge of curb for deep-bedded stalls (**E**)	102 (40)	125 (49)	147 (58)	152 (60)	157 (62)	163 (64)	168 (66)	175 (69)
Distance from rear edge of divider loop to point of curb (**F**)	23 (9)	23 (9)	23 (9)	23 (9)	23 (9)	23 (9)	23 (9)	23 (9)
Height of brisket locator above top of curb (loose-bedded stall or mat/mattress surface) (**G**)	No brisket locator recommended		8 (3)	8 (3)	10 (4)	10 (4)	10 (4)	10 (4)
Height of upper edge of bottom stall divider rail above top of curb (loose bedded stall or mat/mattress surface) (**H**)	20 (8)	20 (8)	25 (10)	25 (10)	31 (12)	31 (12)	33 (13)	36 (14)
Interior diameter of the stall divider loop (**I**)	61 (24)	71 (28)	76 (30)	84 (33)	84 (33)	91 (36)	91 (36)	91 (36)
Height of neck rail above top of curb (loose-bedded stall or mat/mattress surface) (**J**)	86 (34)	97 (38)	107 (42)	114 (45)	122 (48)	127 (50)	132 (52)	137 (54)
Obstruction height (**K**)	13–89 (5–35)	13–89 (5–35)	13–89 (5–35)	13–89 (5–35)	13–89 (5–35)	13–89 (5–35)	13–89 (5–35)	13–89 (5–35)
Horizontal distance from brisket locator to loop angle (**L**)	No brisket locator recommended		51–56 (20–22)	51–56 (20–22)	51–56 (20–22)	51–56 (20–22)	51–56 (20–22)	51–56 (20–22)
Rear curb height (**M**)	15 (6)		20 (8)	20 (8)	20 (8)	20 (8)	20 (8)	20 (8)

provided (Schütz et al., 2015). Aggressive behavior and interruptions of lying behavior decline when more space is provided (Schütz et al., 2015).

Pasture and dry-lot systems are also used to house lactating cows. The animal-based measures recommended throughout this chapter (body condition, hygiene, locomotion, leg injuries, respiration rate) serve as outcome-based indicators of welfare, and in combination with the facility-based measures for all lactating cows (space allocation, lying area requirements, shade, heat abatement, protection from inclement weather), cover the key recommendations for these 2 housing systems.

Thermal Environment

The thermoneutral zone of mature dairy cattle ranges from 5 to 25°C (40–77°F) (depending on humidity), and within these temperatures cattle generate basal levels of metabolic heat (Kadzere et al., 2002). The thermoneutral zone of cattle depends on breed, dry matter intake (DMI), ration composition, milk production, housing and management, body condition, and behavior. Therefore, although adult cattle are relatively tolerant of cold temperatures, they are susceptible to heat stress and show early signs of this even within the upper range of the thermoneutral zone. When dairy cows accumulate heat load, production, health and welfare problems result, including increased body temperature, decreased milk yield (Wheelock et al., 2010) and fertility (de Rensis and Scaramuzzi, 2003), and, in extreme cases, mortality (Stull et al., 2008; Morignat et al., 2014).

Cows under increased heat load alter their behavior in an attempt to improve cooling. They spend more time standing and less time lying (Cook et al., 2007; Allen et al., 2015). Several studies examining the lying time of cows in freestalls report a range of 11 to 14 h (Cook et al., 2004; Jensen et al., 2005; Ito et al., 2010) under thermoneutral conditions, with a 30% reduction when ambient temperatures increase (Cook et al., 2007). Extended periods of prolonged standing are a major risk factor for lameness (Cook and Nordlund, 2009; Allen et al., 2015), which may also be associated with painful experiences (Flower et al., 2008). Similar risks from heat stress are present for the growing heifer. Although research to evaluate their response is lacking, it is expected that they will respond in a similar manner to adult cattle.

Cattle should be provided shade and other forms of heat abatement (soakers, fans) in warm conditions. The effectiveness of heat abatement should be evaluated during afternoons of summer months on a regular basis. During these evaluations, when the temperature exceeds 23°C (73°F; temperature-humidity index = 68), no cattle should be panting, and respiration rates should be below 70 to 80 breaths/min (Tresoldi et al., 2017).

Additional cooling may be provided, most commonly through the use of fans to create localized areas of fast-moving air and through the use of water, either to mist and cool the air before it reaches the cow or to soak the cow directly. Fans improve heat loss and are often provided in combination with soakers (West, 2003). Compared with shade alone, soakers reduce body temperature, respiration rate, and localized air temperature (Kendall et al., 2007; Chen et al., 2013). Cows show a clear preference to feed from bunks with soakers and increase feeding time when fed from bunks with soakers compared with those without in summer (Chen et al., 2013). Providing cows access to soakers in hot conditions and having a nutritionist balance rations is associated with a lower percentage of thin cows (Adams et al., 2017).

Cattle should be provided protection in cold weather. In cold weather, cattle will use artificial windbreaks (Olson and Wallander, 2002) and shelters that provide protection from rain (Vandenheede et al., 1995). Cattle will use conspecifics for protection (Graunke et al., 2011) and will position themselves toward the sun in cold weather (Gonyou and Stricklin, 1981). Although most of the evidence about the use of windbreaks and response to cold weather comes from research in beef cattle, similar benefits of protection likely also apply to dairy animals, with housing typically being provided for protection from the elements. In cold weather, facilities ventilate enough to ensure that noxious gases such as ammonia are removed from the barn, and the provision of fresh air minimizes the risk for pneumonia while air exchange is controlled to prevent freezing. As the temperature increases, increasing the ventilation rate removes moisture and heat until a maximum ventilation rate is achieved either using natural ventilation principles or mechanical assistance. Minimal air exchange rates of 4 ACH are suggested for cold weather, increasing to 40 to 60 ACH in hot weather (Yeck and Stewart, 1959).

Holding Areas

Holding areas have been identified as a particular area for heat stress control in lactating cow facilities (Collier et al., 2006) as cows are commingled closely in a small area. Supplementary fans and soaking are recommended to provide additional cooling in this area and have been widely adopted in freestall herds (Cook et al., 2016). Space allowance in the holding area is also important, but recommendations have not received scientific scrutiny. Currently, 1.86 m^2 (20 ft^2) per cow is proposed as a minimum space allocation.

Specific Considerations: Transition Period

The transition period, typically defined from 21 d before to 21 d after calving is a particularly challenging period for the cow, marking the end of gestation, birth of the calf, and commencement of lactation. For management and feeding purposes, it is typical to create 1 or 2 separate groups of dry (nonlactating) cows before cows are moved to a maternity pen to calve. This allows specific diets to be fed during this period.

After calving, the parturient cow is normally segregated from the main herd while colostrum is collected and antibiotic withholding periods are observed, after which the cow is moved either to a lactating cow pen with herd-mates or to a dedicated fresh cow pen, typically for 14 to 30 d, where cows may be easily surveyed for signs of ill health and a specific diet may be fed.

Although moving cows between different groups aids management for the delivery of different diets, it can negatively affect behavior. Regrouping groups of cows triggers a period of unrest for approximately 72 h, during which regrouped cows are subjected to 2.5 times as many aggressive interactions compared with before regrouping, which also negatively affected milk production (von Keyserlingk et al., 2008). Schirmann et al. (2011) demonstrated a 9% decrease in DMI in cows moved into the pen during the transition period. Moreover, cows that were moved also reduced their intake and number of lying bouts and were more aggressive at the feeder (Schirmann et al., 2011). The latter study also showed that cows already present in the pen into which new cows are mixed also had decreased feeding rate and rumination time.

It is recommended that efforts be made to minimize regrouping stress during the period 21 d before calving as reduced DMI during the prefresh period has been shown to foreshadow metabolic and other periparturient diseases in early lactation (Huzzey et al., 2007; DeVries, 2019). Talebi et al. (2014) showed that the effects of regrouping can be lessened by avoiding overstocking, emphasizing the importance of ensuring sufficient space for cows to rest without competition and enough bunk space for all of the cows to eat at the same time during this critical transition period [75 cm (30 in) per cow] to ensure optimal DMI (Huzzey et al., 2006). The negative effects associated with aggressive interactions can be mitigated through the use of headlocks (Huzzey et al., 2006) or feed stalls (DeVries and von Keyserlingk, 2006).

Historically, little scientific work has focused on the special needs of cows on and around the day of calving. In the hours before and during labor, cows become restless, which is often characterized by a dramatic increase in position changes between standing and lying (Huzzey et al., 2005; Miedema et al., 2011; Jensen, 2012), thus the type of flooring in the maternity pen is important. Some recent work investigated the effects of different standing and lying surfaces (rubber, deep sand, and concrete, all covered with a fresh layer of straw) in the calving pen. Cows demonstrated a preference for a softer bed and avoided rubber flooring in the maternity pen (Campler et al., 2014). A series of recent studies found that, in addition to seeking an appropriate surface, cows also seek some visual isolation from pen-mates at the time of calving; cows preferred to calve in an area within the maternity pen that allowed for visual isolation, particularly during the nighttime hours (Proudfoot et al., 2014).

Maternity pens may be designed as either group or individual pens and should provide a minimum of 9.3 m^2 (100 ft^2) of bedded area/cow. Group or individual pens should be positioned to emphasize a quiet, stress-free calving location away from high traffic areas on the farm (Proudfoot, 2019). It is recommended that individual pens have a catch gate to hold the cow and be large enough to allow space behind her if she needs calving assistance. Dimensions of 3.7 m × 3.7 m (12 ft × 12 ft) or 3.7 m × 4.3 m (12 ft × 14 ft) are common.

Specific Considerations: Housing for Sick Animals

Hospital and sick pens should be in quiet areas that provide some opportunity for cows to hide from others if they choose. Sick cows are potential sources of infectious agents (e.g., *Salmonella*, *Mycoplasma*, *Staphylococcus aureus*) to naive herd-mates, and treated cows may have antibiotic residues in meat and milk, requiring segregation of the milk from the bulk tank. It is therefore common to group cows with milk residues separate from healthy untreated cows and it is prudent to attempt isolation of the sick cow from the rest of the herd. Interestingly, cows will seek isolation (e.g., lying in a secluded corner of a pen) if given the opportunity when ill (Proudfoot et al., 2014). In addition to their motivation to avoid other cows during this vulnerable time, dedicated sick pens provide the opportunity for caregivers to frequently monitor at-risk animals and those undergoing treatment. Sick cows are also less likely to compete well for access to the feeding area (Huzzey et al., 2007; Goldhawk et al., 2009), making a separate pen located away from the main herd a recommended strategy.

Lame cows benefit from being segregated to a separate bedded pack pen close to the milking center, with ready access to feed and water and reduced competition from sound cows (Thomsen et al., 2019).

Bulls

For space requirements, use body weight, as appropriate, as shown in Table 7-3. See also Chapter 6: Beef Cattle for guidelines about facilities for bulls.

FEED AND WATER

All cattle must be provided access to clean water from birth. Water requirements are affected by many factors, including environmental temperature, diet (particularly ration dry matter and sodium content), milk production level, and age (National Research Council, 2001). For example, a healthy high-producing lactating cow 2 to 3 wk into her lactation can consume in excess of 75 L (20 gal) of water per day (Huzzey et al., 2007). Water should be clean, fresh, and potable. Willms et al. (2002) reported that when cattle were provided a choice of freshwater or water contaminated with even 0.005% fresh manure by weight, they avoided the contaminated water. If water contains compounds that diminish palatability, cattle will reduce their water consumption (Grout et al., 2006) or seek alternative sources (Digesti and Weeth, 1976). For calves and non-ambulatory animals, water may be offered at several points throughout the day if freezing weather or cows knocking waterers over is a problem.

Milk-Fed Calf

Colostrum. Bull and heifer calves should be provided colostrum. Colostrum management is one of the most critical areas of calf care and it has an important effect on the health and welfare of calves (Beam et al., 2009; Vogels et al., 2013). Despite its importance, surveys continue to report that large numbers of dairy calves in the United States still receive either inadequate or marginal levels of colostrum; 15% of farms tested colostrum quality and only 6% routinely screened for failure of passive transfer (FPT; USDA, 2016). Colostrum contains antibodies known as immunoglobulins, large glycoprotein molecules that constitute the main protection against diseases during the milk-fed period. The immunoglobulins contained in colostrum are absorbed into the calf's blood (a process called "passive transfer"). The immunoglobulins obtained in this way protect the calf until its own immune system becomes fully functional at around 3 to 6 wk of age (Nagahata et al., 1991). Thus, FPT is a low concentration of circulating immunoglobulin (IgG <10.0 g/L) in the blood of the calf as a result of inadequate colostrum intake (McGuirk and Collins, 2004) and it is a welfare concern.

The ability of the calf to defend itself against infectious diseases is directly related to the amount (volume), quality (immunoglobulin level and hygiene), and timing of colostrum intake. Several studies have documented the close association between inadequate colostrum intake, FPT, and increased mortality or morbidity of calves (Rea et al., 1996; Filteau et al., 2003; Dewell et al., 2006). According to Wells et al. (1996), 31% of calf deaths during the first 3 wk of life could have been prevented if colostrum feeding had been adequate. Even when death is avoided, there can be long-term effects of inadequate colostrum intake; calves with FPT have been reported to have lower BW 6 mo later (Dewell et al., 2006).

Recommended best practices to prevent FPT include feeding a minimum of 4 L (4.2 qt) of high-quality colostrum within 6 h of calving (Godden, 2008) by voluntary or assisted means. Passive transfer of immunity following colostrum feeding can be assessed using the radial immunodiffusion technique, considered the gold standard for assessing blood serum IgG concentrations. However, a more practical method is the quantification of serum total protein using a refractometer that has been shown to be highly correlated with IgG concentrations (Deelen et al., 2014; Elsohaby and Keefe, 2015). Suggested cut-off values for FPT using a refractometer are <5.2 g/dL serum total protein in calves (equivalent to 1 g/dL serum IgG; Tyler et al., 1996; Windeyer et al., 2014), although Godden et al. (2019) has a more detailed list of proposed recommendations to consider ranging from excellent (>6.2 g of serum total protein dL) to poor (<5.1 g of serum total protein/dL). Recent work suggests that calves may be reliably tested for passive transfer of immunity using IgG or serum total protein concentrations up to 9 d of age (Wilm et al., 2018).

Milk Feeding. Calves should be fed to maintain a growth rate of 0.82 kg/d (1.8 lb/d) on average (excellent growth; Shivley et al., 2018). If it is not feasible to measure growth rate, body condition score can serve as a proxy and, in this case, calves should be in good condition, not thin or emaciated. For descriptions of body condition scoring systems, please visit http://www.paacodairywelfareauditortraining.com/.

Calves are highly motivated to suck and should be fed through a teat or nipple during the milk-feeding period. During the early life period, solid feed intake is very low in calves, regardless of the amount of milk or starter provided (see review by Khan et al., 2011b). Calves benefit especially from higher intakes of milk or milk replacer during the first 4 wk of life when their ability to digest solid feed is limited. Benefits of improved growth and reduced hunger can be achieved by feeding calves higher rates of milk or milk replacer equivalent (reviewed by Khan et al., 2011b). Calves are motivated to consume large amounts of milk or milk replacer equivalent. For example, Holstein calves will drink in excess of 9.5 L/d (10 qt/d; Rosenberger et al., 2017). Feeding higher milk allowances results in weight gain advantages before and after weaning and reduces the numbers of unrewarded visits to automated milk feeders, an indication of persistent hunger (Rosenberger et al., 2017). Moreover, limit feeding (10% of BW equivalent or approximately 3.7 L/d or 3.9 qt/d of milk or milk replacer) does not allow the calf to meet its nutritional requirements for maintenance, growth, and development, and there is strong evidence that limit feeding causes hunger (De Paula Vieira et al., 2008). There are no known negative side effects of feeding more milk or milk replacer; indeed, there are long-term benefits such as an earlier breeding age and higher milk yield later in life (Soberon et al., 2012; Soberon and Van Amburgh, 2013). If given the opportunity, calves will spend on average 45 min/d suckling; thus, delivering larger amounts of milk [7.6 L/d (8 qt/d) or more in 2 or more feedings per day] via nipple feeding is more natural and results in higher concentrations of digestive hormones such as cholecystokinin and insulin (Appleby et al., 2001). Moreover, nipple-feeding higher volumes of milk (that prevent hunger) is associated with a lower incidence of the abnormal behavior of cross sucking (de

Passillé et al., 2010; Costa et al., 2016). Higher milk intakes are not associated with increased diarrhea or other health problems (Borderas et al., 2009).

Calves should be provided access to forage, such as hay, from birth in addition to starter (Khan et al., 2016). This reduces nonnutritive sucking and promotes both species-typical feeding patterns and rumen development (Webb et al., 2013). Providing forage to calves during the milk-feeding period has historically been discouraged, because forage is less energy dense and believed to displace concentrate intake, thereby shifting rumen fermentation in favor of acetate and potentially delaying differentiation of the rumen papillae (Tamate et al., 1962). Indeed, inclusion of forage in the diet during the milk-fed period results in poorer BW gains in calves fed restricted and low quantities of milk (e.g., 3.7 L/d or 3.9 qt/d; Kertz et al., 1979). However, recent work suggests that forage may play a role during the transition from milk to solid feed intake in calves provided higher milk rations (e.g., 8 L/d or 8.4 qt/d) (see review by Khan et al., 2016). For instance, providing chopped hay to calves fed 7.6 L or 8 qt/d resulted in higher solid feed intake and improved rumen development without negatively affecting BW gain (Khan et al., 2011a).

Cross sucking is an undesirable behavior performed in group-housed calves. A combination of slower milk flow, feeding hay, and access to a nonnutritive artificial teat are 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., 1997).

Weaning. Calves should be weaned gradually. At weaning, the dairy calf transitions from milk to solid feed. Under natural conditions, the weaning process normally involves a gradual reduction in milk intake, accompanied by decline in social dependence from the dam and increasing intake of solid food (Weary et al., 2008).

It is commonly thought that feeding less milk will encourage solid feed intake and thus facilitate weaning. Indeed, feeding calves less milk does increase starter consumption, but this practice also severely limits weight gains (reviewed by Khan et al., 2011b). To date, little information is available on how best to wean rapidly growing calves fed high milk rations. There is some evidence that slowly reducing milk intake in the days before weaning can be helpful (Khan et al., 2007a,b; Rosenberger et al., 2017). Diluting the milk with water or slowly restricting the amount of milk can successfully achieve gradual weaning; this will increase starter intake and minimize the growth check at weaning (Khan et al., 2011b). Gradual weaning has been shown to minimize the effects of weaning distress (Weary et al., 2008).

Growing Heifers

Growing replacement heifers are normally fed a high-forage, moderate-energy diet formulated to meet their nutrient requirements and control ADG (National Research Council, 2001; DeVries, 2010).

Heifers should not be limit fed. Some have argued that feeding growing heifers a nutrient-dense diet reduces feeding time (Hoffman et al., 2007) and is an effective strategy to reduce feed costs, decrease fecal excretion, and increase feed efficiency (Lascano et al., 2009; Kitts et al., 2011). However, this feeding management regimen has also been linked to certain behavioral concerns; limit feeding reduces feeding and lying time and increases idle standing time (Hoffman et al., 2007; Greter et al., 2011; Kitts et al., 2011), both of which are known risk factors for lameness in older animals. Limit feeding also increases vocalization levels (Hoffman et al., 2007) and has been associated with increased levels of tongue rolling, head nodding, and bar biting (Redbo et al., 1996; Lindström and Redbo, 2000). Oral stereotypies associated with limit feeding may be a consequence of frustration or hunger due to a lack of satiety resulting from feed being available for a short duration and in a limited amount (Lindström and Redbo, 2000). Oral stereotypies have been overwhelmingly associated with barren and poor environments that cause a myriad of welfare concerns (Mason and Latham, 2004).

Lactating Dairy Cows

Cows should not be emaciated (BCS $\leq$2; Edmonson et al., 1989). Body condition can be used as an outcome-based measure to evaluate the welfare implications of the nutrition program and should be evaluated on a regular basis. Except as necessary for a particular research or teaching protocol, dairy cattle should be fed diets formulated to meet their needs for maintenance, growth, production, and reproduction, see Chapter 2: Agricultural Animal Health Care. Beyond the guidelines provided in the NRC (2001), physically effective fiber, or the fiber that stimulates chewing, is required to maintain rumen function and health (Zebeli et al., 2012). In best practice, feed ingredients and finished feeds are wholesome, carefully mixed, and stored and delivered to cattle to minimize contamination or spoilage of feeds. To ensure freshness, under best practice, feeds that are not consumed are removed daily from feeders and mangers, especially high-moisture feeds such as silage.

HUSBANDRY

Use of Outcome-Based Measures to Monitor Welfare

Within the dairy industry, outcome-based measures are increasingly used to assess and monitor welfare.

This approach is particularly valuable in sectors with diverse management and facilities that can achieve good animal care in several ways. Rather than providing prescriptive instructions about how to house and manage animals, we can rely instead on how cattle respond to evaluate quality of care. Common animal-based measures include dairy cattle hygiene, locomotion, body condition, and injuries. Injuries include hair loss, swelling, and abrasions on the hocks, knees, and neck and broken tails. Less common in industry-wide on-farm assessments, but also valuable, are respiration rate and panting, both measures of heat load. Bedding type and stall configuration are known risk factors for hock and knee injuries, and neck injuries are associated with feedbunk and neck rail design. Locomotion scores are often divided into moderate and severe lameness, and it is widely understood that both are painful (Whay et al., 1997). Body condition is often evaluated in terms of animals being too thin or too fat, as both ends of the extremes are associated with animal welfare concerns. Hygiene scoring systems vary but, in general, the goal is to identify dirty animals. There are 2 concerns here: wet or soiled bedding compromises comfort, and udder cleanliness corresponds with measures of mammary health. Incorporating such measures into the day-to-day management of a dairy farm is increasingly common nationwide and provides valuable feedback about the care provided.

Restraint

Cattle should not be restrained for more than 1 h at a time. Lying time is a critical component of a dairy cow's time budget, and management practices that cause lying deprivation are problematic. Periods of 2 or 4 h of lying deprivation were shown to cause detrimental behavioral changes that were evident up to 72 h afterward (Cooper et al., 2007). Similarly, behavioral indicators of restlessness increased during 4 h of restraint at the feed barrier, regardless of the floor type on which the cows were housed (rubber vs. concrete; Krebs et al., 2011). After 3 h of deprivation, cows prioritized lying over feeding (Metz, 1985). As little as 1 h of restraint was sufficient for cows to display increased behavioral indicators of restlessness, such as weight shifting and increased steps. Stanchions, head gates, and squeeze chutes can be utilized, but acclimation and positive reinforcement by individuals trained in low-stress handling can minimize the need for additional restraint by halters, rope, and tail hold. In best practice, hobbles and casting ropes are used selectively and only when necessary for the health of the cow, not as a corrective device for problematic behaviors.

Maternity Pen Management

Movement of cows into the maternity pen is often based upon calving signs; cows are moved when calving is imminent. However, the duration of labor can be affected depending on what stage of labor the cow is in when moved. For instance, Proudfoot et al. (2013) showed that cows moved during late stage 1 experienced a delay in the second stage of labor, which was likely driven by altered lying behavior. Delays at this stage may lead to an elevated risk for calving complications.

Estimates suggest that between 2 and 23% of dairy cows within a herd experience dystocia that requires farmer or veterinarian assistance (Mee, 2004, 2008). Dystocia is painful (Huxley and Whay, 2006) and associated with reduced milk yield; it increases the risk of health disorders, reproductive complications for the cow (Oltenacu et al., 1988), and risk of death for the calf (Tenhagen et al., 2007).

Management of the cow at calving time has been reviewed extensively by Mee (2004), who emphasized that the vast majority of multiparous cows calve successfully without intervention, whereas a greater proportion of primiparous cows may need assistance. If calving progress in stage 2 of labor appears interrupted, an examination informs the decision of whether or not assistance needs to be given, or whether veterinary involvement is needed.

Sick Cows

Sick cows should be monitored daily for changes in clinical signs and treatments administered according to predetermined protocols.

Injections

Dairy cattle are routinely administered medicines, vaccines, and anesthesia via injection. Despite evidence that injections are painful in humans (Gidudu et al., 2012), few studies have evaluated needle-related pain in other species. Ede et al. (2018) recently demonstrated that dairy calves find intramuscular injections in the rump aversive, but to date, no studies have evaluated methods to alleviate injection pain in cattle. However, it is recommended that the number of injections be minimized, while still maintaining animal health. This applies, for example, when considering injections given to synchronize estrous cycles or using exogenous bovine somatotropin.

Hoof Care

It is recommended that hoof trimming be practiced to a high standard. Each cow should be trimmed at around dry off and again 2-4 months after calving, and an effective footbath program implemented to control infectious hoof disease (Griffiths et al., 2018). Locomotion should be routinely scored in lactating and dry cows. Best practice suggests that severe lameness (almost unable to bear weight on the affected limb) should be ≤1% and moderate lameness (asymmetric gait with noticeable weight transfer off the affected limb) should be ≤15% in lactating cows (Cook, 2018).

Lameness is a significant animal welfare concern and affects the ability of the cow to eat, rest, reproduce, and remain in the herd. Prevention strategies are essential, especially considering that, globally, ~24% of cows are lame (reviewed by Cook, 2016).

The etiopathogenesis of a variety of hoof lesions has been researched and reviewed extensively (e.g., Cook and Nordlund, 2009; Bicalho and Oikonomou, 2013), centering on genetic, nutritional, hormonal, mechanical, infectious, and environmental factors. Herd-level risk factors for lameness have been studied in a variety of production systems in recent years, and several consistent findings have emerged from these studies. Factors that appear to be associated with lower lameness risk include less time standing on concrete (Bell et al., 2009); use of deep-bedded comfortable stalls designed to accommodate the size of the cow using them (Cook, 2003; Chapinal et al., 2013; Solano et al., 2015) (see Tables 7-1 and 7-2), with less restrictive neck rail locations and absence of stall lunge obstructions (Chapinal et al., 2013; Westin et al., 2016); access to pasture or an outside exercise lot (Chapinal et al., 2013); use of nonslip, nontraumatic flooring scraped of manure when the cows are outside the pen (Barker et al., 2009); use of a divided feed barrier and wider feed alleys (Westin et al., 2016); prompt recognition and treatment of lameness (Barker et al., 2009); preventive hoof-trimming; and frequent footbathing (Griffiths et al., 2018).

STANDARD AGRICULTURAL PRACTICES

Tail Docking

Cattle must not be routinely tail docked. Tail docking is the removal of the tail below the vulva by cutting with a hot iron or banding and removing necrotic tissue after 1 to 2 wk. It was initially performed to improve udder cleanliness and worker comfort. There is no scientific evidence that this practice improves animal welfare; instead, it impairs the ability of the cow to deal with flies and may cause some pain (see review by Sutherland and Tucker, 2011). This practice should be used only to treat injury and is not standard practice.

Removal of Extra Teats

Some cattle are born with more than 4 teats, and the additional teats can interfere with the milking process later in life. Distress associated with extra teat removal has not been studied, and there is no information available regarding pain associated with the process. Tissue damage associated with surgical procedures is thought to be minimized when procedures are done during the preweaning period with pain mitigation.

Disbudding and Dehorning

Pain relief, including a local nerve block, should be used for disbudding and dehorning. The horns of dairy cattle are typically removed if animals are not polled. The horn buds are thought to attach to the frontal bone of the skull at approximately 8 wk of age; therefore, performing the procedure before this time point is recommended to minimize pain and damage. The 2 primary methods are cautery and caustic paste. For cautery, ample evidence indicates that both a local nerve block and administration of a nonsteroidal anti-inflammatory drug (NSAID) reduce the behavioral and physiological signs of pain (Stafford and Mellor, 2011). Use of paste to chemically destroy horn tissue is less common but is also painful (Stafford and Mellor, 2011), and a combination of a local nerve block and NSAID is effective in reducing the immediate pain associated with its application (Winder et al., 2017, 2018).

Castration

Pain relief, including a local nerve block, should be used for castration. Bull calves are typically castrated. Banding (restriction of blood flow to the testes) and surgical castration are the most common methods in the United States. However, castration by banding is known to cause lasting pain (Thüer et al., 2007; Marti et al., 2010; Becker et al., 2012), more so than surgical removal of the testicles. This pattern of chronic pain is apparent in older animals, but also those castrated with bands or rings at 5 to 7 d of age (up to at least 48 d afterward; Molony et al., 1995). Bands should not be used. In addition to bands or rings causing pain over a longer period than other methods, this pain is not easily controlled by local anesthetic or NSAIDs. In contrast, both local anesthesia and NSAIDs provide immediate benefit, when provided in combination, in young dairy calves that have been surgically castrated (Webster et al., 2013). Regardless of method, it is advisable to administer tetanus antitoxin at the time of castration.

Branding

Cattle should not be branded. Hot-iron and freeze branding are painful at the time of the procedure (e.g., Lay et al., 1992; Schwartzkopf-Genswein et al., 1998). Hot-iron brands remain more sensitive than unbranded tissue throughout the healing process (Tucker et al., 2014). Little is known about how to control either the immediate or long-term pain associated with this procedure.

Cow/Calf Separation

Dairy calves are typically removed from the dam within hours of birth. The available evidence on distress associated with separation is limited to a few studies that have focused on the acute behavioral effects associated with separation; fewer vocalizations by the dam when separation takes place earlier compared with later (reviewed by Flower and Weary, 2003, Jensen, 2018; Meagher et al., 2019). There is little evidence that early separation provides any general benefit to the health of either cow or calf (see review by Beaver et al., 2019).

Nose Rings

Nose rings are used for the handling of show animals and bulls. Nose rings are also used to prevent cross sucking or milk "stealing" in dairy cows. These rings either penetrate the nasal septum or are tightened on either side of it. There is no evidence evaluating how these rings affect the animals, but it is assumed to be painful, and pain mitigation at insertion is recommended if used to facilitate bull handling. It is recommended that alternative devices that do not penetrate the nasal septum are used to prevent milk stealing and for other reasons.

Reproductive Management

Approximately 90% of dairy cows on commercial dairy farms in the United States are bred by artificial insemination (AI) following a synchronization protocol, which was described in detail in a recent review (Colazo and Mapletoft, 2014; USDA, 2018), or when observed in estrus. Estrus detection is done either by direct observation for associated behaviors or through the use of technologies designed for this purpose (Dolecheck et al., 2016). If using a synchronization protocol, the risks and challenges for the cows will be the same as outlined in the previous section on "Injections." Cows find rectal and vaginal examination aversive (Kovács et al., 2014; Pilz et al., 2014). It is recommended that the number of repeated exams is minimized. The remaining 20% of dairy cows are naturally bred by a bull (see other sections for requirements on the housing, husbandry, and management of bulls).

Claw Amputation

Claw amputation should not be done. Claw removal is used, in some cases, to treat severe hoof disorders. Rizk et al. (2012) found that intravenous regional anesthesia alone or in combination with preoperative xylazine did not abolish the elevation in cortisol concentrations in dairy cows undergoing claw surgery, suggesting that pain persists, and Bicalho et al. (2006) found that cows undergoing claw amputation were much more likely to be culled and that they produced less milk than controls. Based on these findings, the practice of claw amputation to resolve lameness cannot be justified because it causes pain and does not benefit the animal.

Electroejaculation

Electroejaculation is used to collect semen from bulls for breeding soundness evaluation or AI. Electroejaculation is considered painful for the bull (Palmer, 2005) and results in significant increases in cortisol compared with nonelectrified controls (Whitlock et al., 2012). Compared with bulls electroejaculated without pain relief, caudal epidural anesthesia lowered the frequency of struggling, escape attempts, and vocalizations (Pagliosa et al., 2015). It also tended to reduce cortisol levels (Falk et al., 2001) and heart rate (Mosure et al., 1998). There are potentially less painful alternatives (e.g., transrectal massage, artificial vagina). However, transrectal massage increased progesterone in bulls (Falk et al., 2001) and cardiac responses during rectal palpation in cows (Kovács et al., 2014), leaving use of an artificial vagina as a less painful alternative that is recommended.

ENVIRONMENTAL ENRICHMENT

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

HANDLING AND TRANSPORT

Handling

Cattle should not be handled roughly. Electric prods should not be used, except under certain very specific conditions (outlined in Chapter 5: Animal Handling and Transport. Cattle recognize individual people and become frightened of those who handle them aggressively (Rushen et al., 1999). Shouting, hitting, and using cattle prods are frightening when used aggressively or inappropriately (Pajor et al., 2000, 2003). Cattle will show more vigilance behavior when exposed to a human who has handled them roughly than when exposed to a gentle or unfamiliar handler (Welp et al., 2004). This research also indicates that humans may serve as a substitute for conspecific contact, if social contact is not possible. There are benefits associated with gentle and confident handlers, including 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). Low-stress handling of dairy cattle has received relatively little attention from the scientific community, but appropriate movement of people, well-designed facilities, optimal lighting, nonslip flooring, and smooth, quiet restraint are all thought to be beneficial (see review by Kammel et al., 2019). Further information about best practice is covered in Chapter 5: Animal Handling and Transport.

Transport of the Milk-Fed Calf from the Farm

Neonatal dairy calves should be supported by the body in both arms or placed in a wheelbarrow or special cart when being moved. They must never be dragged by the legs, head, tail, or other body part nor thrown.

Departure from the farm at a young age can be problematic for dairy calves. Calves, 5 to 9 d of age, transported between 6 and 12 h in conjunction with a 30-h feed withdrawal, had reduced concentrations of glucose (Fisher et al., 2014). These calves spent approximately 20 to 30% of their transport time lying, which indicates that feed withdrawal might be the more negative aspect of departure from the farm. These results were inconsistent with responses of 5- to 10-d-old calves exposed to a 12-h transport combined with a 30-h feed withdrawal (Todd et al., 2000). Within that study, calves transported at a low stocking density were able to rest during transport, which resulted in them being metabolically indistinguishable from untransported calves. Careful planning of feed management and duration of transport can be used to mitigate this effect. Use of umbilical cord dryness to establish a suitable age to transport calves off the farm is problematic. Umbilical cords were determined to be dry between 1 and 8 d of age (Hides and Hannah, 2005). Although empirical evidence is lacking to support the establishment of the appropriate age for the transportation of calves from the facility, calves were easier to manage at 9 to 11 d of age than at 5 or 7 d of age (Jongman and Butler, 2013). Older calves required less time and fewer interventions to complete a walking course (Jongman and Butler, 2013). Although this does not establish the effect of age on a calf's ability to cope with transport stress, it does indicate that they will be easier to handle if moved when they are older.

Transport of All Other Age Classes

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

SPECIAL CONSIDERATIONS

Milking Machine Maintenance and Udder Sanitation

Proper husbandry of lactating dairy cows requires correctly functioning milking machines and routines. Facilities should be designed and operated to standards meeting or exceeding those of Grade A dairies, as defined in the Pasteurized Milk Ordinance (FDA, 2017). This can be accomplished by regular maintenance and following the recommended mastitis control program of the National Mastitis Council (https://www.nmconline.org/) and evaluated by looking at both somatic cell counts and rates of clinical mastitis. 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 and Ruegg, 2005).

Stray Voltage

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 (reviewed in Reinemann, 2012). The only way to determine whether stray voltage is a potential cause of abnormal behaviors or poor performance is by performing a thorough investigation of the facility to determine the presence of stray voltage and rule out other explanations for issues. For confirmation of stray voltage, a potential of 2 to 4 V (60 Hz, rms) is to be measured between 2 points that an animal might contact (or animal contact measurement), and some animals should exhibit signs of avoidance behavior. The animal contact voltage measurement with an appropriate shunt resistor value provides the only reliable indication of exposure levels. Voltage readings at cow contact points are to be made with a 500- or 1000-Ω resistor across the 2 measuring leads to the cow contact points in addition to open circuit measurements (Lefcourt, 1991; Reinemann, 2012). If suspected, it is advisable to have a qualified electrician or the local power supplier evaluate the situation.

Automated Milking Systems

The use of AMS to milk cows is becoming increasingly common in North America. Although the technology successfully harvests milk from the individual cow, AMS present some management and design challenges to optimize health and production. Management decisions within this system include allowing cows to freely visit the robot or to be forced to visit by using access to resources and stocking density/unit and within the pen. Recent studies suggest that increased milk per cow is associated with free rather than forced traffic (Tremblay et al., 2016) and with increased bunk space per cow (Deming et al., 2013), whereas higher milk per AMS unit may be achieved in pens with 2 units rather than 1 unit (Tremblay et al., 2016). Management incorporates a check for cows with abnormally long milking intervals so that they can be fetched and allowed access to the unit via a fetch pen, while avoiding overly prolonged stays in the pen.

Dry Cows

Common industry practice today is that milking typically ends approximately 40 to 60 d before calving. With the introduction of blanket dry-cow antibiotic therapies, abrupt cessation of milking is now thought to be the most common method of achieving dry-off. However, improved genetics and management have resulted in many cows still producing 25 to 30 kg/d of milk at the time of dry-off, which may pose risks for udder health (e.g., increased intramammary infections due to delayed teat-canal plug formation and milk leakage; Schukken et al., 1993; Dingwell et al., 2004) and pain (O'Driscoll et al., 2011). Zobel et al. (2013) showed that abruptly dried off cows had increased amounts and duration of milk leakage, especially when milk production was high at dry-off compared with gradual dry-off or gradual cessation achieved through intermittent milking over a period of days. Some studies have raised concerns regarding some of the procedures used to achieve cessation of milk production (reviewed by Zobel et al., 2015). Others have shown that abrupt cessation of milking may also induce hunger due to the need to reduce milk production through limit feeding; this causes distress (e.g., increased vocalizations) compared with gradual cessation of milking (Valizaheh et al., 2008; Tucker et al., 2009). Gradual reduction in milking frequency at dry-off resulted in fewer new intramammary infections at calving (Natzke et al., 1975). Best practice is to perform gradual dry off. Cows should be dried off before being culled from the farm (Stojkov et al., 2020).

Nonambulatory Animals (Downer Cows)

The care of nonambulatory cows is one of the greatest animal welfare challenges facing the dairy industry. Cows that are unable or unwilling to stand and remain recumbent for more than 12 h are typically defined as nonambulatory or "downer" cows (Stojkov et al., 2016). The condition typically begins with a primary cause such as hypocalcemia (milk fever), injury, or trauma during parturition. Lack of movement in the hours that follow can then cause additional problems, including ischemic damage to the pelvic muscles and nerves that make it impossible for the cow to rise. This secondary damage can be fatal, and producers rightly recognize that helping the cow stand can prevent this damage and assist recovery.

If the animal needs be moved to a safe area, this should be done as soon as possible by properly trained employees in a manner that minimizes stress and trauma while providing assisted support for the weight of the animal (e.g., bucket, sled, or sling) over the shortest distance possible. It must never involve dragging by the head, leg, or tail.

Recent evidence shows that nonambulatory cows benefit from high levels of care while recumbent when this care is administered within 24 h; recovery is unlikely after 48 h (Stojkov et al., 2016). Moreover, these authors showed that cows that were recumbent for just 12 h before flotation treatment, where cows are placed in a float tank filled with water to allow them to be upright, while limiting weight bearing, were 4.37 times more likely to recover. Cows that had been recumbent for 48 h or more had low odds for recovery. The same study reported that nonambulatory animals should be provided a clean pen with shade and shelter from poor weather with continual access to fresh feed and water throughout the day; such animals were significantly more likely to recover than cows provided poor care.

Bulls

The safety of humans and animals is the chief concern underlying bull management practices. Breeding dairy bulls are known to be aggressive towards humans. As a best practice, staff are trained in safety issues for this class of animal. In consultation with the veterinarian, bulls are managed in such a way that they have appropriate rest and that their health issues, such as lameness, body condition and infectious disease, are given appropriate attention.

Cloning, Editing and Transgenics

Refer to Chapter 1: Institutional Policies for information on cloning, editing, and transgenesis as they relate to the care and use of dairy cattle.

EUTHANASIA AND SLAUGHTER

Acceptable methods for euthanasia are outlined in the *AVMA Guidelines on Euthanasia* (AVMA, 2020) and must be used. Approved methods for cattle are further discussed in Chapter 2: Agricultural Animal Health Care. Disposal involves a commercial rendering service or other means (e.g., burial, composting, or incineration) according to applicable ordinances and regulations.

In the United States, all procedures used to slaughter research and teaching animals that will enter the food chain must comply with US Code of Federal Regulations, Title 7, Chapter 48, Humane Slaughter of Livestock (https://www.govinfo.gov/content/pkg/USCODE-2011-title7/pdf/USCODE-2011-title7-chap48.pdf). The North American Meat Institute (NAMI) has embraced guidelines (https://animalhandling.org/producers/guidelines_audits) that exceed the regulatory requirements (Grandin, 2017), and the NAMI guidelines (NAMI, 2019) are incorporated here by reference.

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CHAPTER 8: HORSES

INTRODUCTION

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, to produce 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, arthritis, and human respiratory diseases such as asthma (Malinowski et al., 2006; Gordon et al., 2007; Kirschvink and Reinhold, 2008). 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 horses to make normal postural adjustments at will, unless the approved protocol requires otherwise. A reasonable area allowance 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. Larger indoor areas allow for longer periods of recumbency in stalled horses (Raabymagle and Ladewig, 2006).

Box stalls should be large enough to permit the horse to lie down, stand up, turn around, and roll (Chung et al., 2018). Table 8-1 provides suggested dimensions for housing of equids used in research and teaching. A 3.7- × 3.7-m (12- × 12-ft) box stall should accommodate most light horse breeds. Tie-stalls are recommended for limited daily use, because they do not allow for the horse to move freely. Horses housed in tie-stalls should have access to free or forced exercise daily. General

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

	Area	
Indoor facilities	m	ft
Box stall (1.8 m2/100 kg of BW)	3.7 × 3.7	12 × 12
Straight stall2 (0.82 m2/100 kg of BW)	1.5 × 3.7	5 × 12
Alleys, width		
Between rows of stalls	2.4–4.3	7.8–14
Behind rows of tie stalls	1.8	6
In front of rows of tie stalls	1.2	4
Outdoor facilities		
Run-in shed (per 450 kg horse, up to 2 horses)	3.3 × 3.3	11 × 11
Outdoor pen (single horse)	3.7 × 3.7	12 × 12
Pasture (per horse)	≥0.4 ha	≥1 acre
Fencing height		
Ponies	1.1–1.5	3.5–5
Horses	1.4–1.8	4.5–6

[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.

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 and to facilitate visual and auditory contact with conspecifics. Stall doors should be either solid or made of material that cannot injure or entangle the horse. 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 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 can 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 because it will allow water to drain through the concrete and does not require an exposed drain. Pervious concrete does require specialized installation.

Stall design should allow for proper ventilation, which may assist in decreasing moisture or humidity levels and odors in the stall. 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, if needed. 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 minimal 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, the 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.

Windows or openings are recommended but not essential if adequate lighting and ventilation are supplied by other means. However, windows may also 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). Windows also allow the caretaker to see the horse from outside the stall. 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 for allowing 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 that face each other that allows room for horses to pass, to handle feed and bedding, and to manage manure; an alley located behind a single row of stalls or in front of a row of stalls allows for feeding horses and 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 to avoid unnecessary contact with passing horses or people.

Horse facilities in tropical and subtropical climates may 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, 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; thus, it is recommended that these beddings not be used. 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. Regular cleaning and replacement of bedding materials will minimize the presence of ammonia and provide the horse with a clean, dry place for rest.

Temperature and Ventilation. Horses can acclimate to subzero air temperatures (to approximately 0°F without a windbreak or shelter) but will benefit from the availability of simple structures such as a windbreak or a run-in stall to protect them from wind and precipitation during winter months and from the sun during hot summer months. Newborn foals require more protection because of their relatively high lower critical temperature and their reduced ability to regulate body temperature. Any building enclosed on all sides that houses horses should have a properly designed and maintained ventilation system (Webster et al., 1987). 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 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. Some evidence indicates 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. If accessible by the horse, 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. Horses evolved to exist on rangeland, where shelter, water, and food can be sparse. Horse pastures, paddocks, and corrals used to house domesticated horses 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 must provide for the biological needs of the animal (e.g., feed and water, exercise, reproduction if appropriate, and freedom to avoid contact with excreta). An exception to the provision of sunshade and windbreak is those animals on extensive rangeland where shelter is absent or sparse, and water and forage can be long distances away. Horses are known to thrive in these environments; however, domesticated horses should be monitored to ensure they are not suffering from hyper- or hypothermia or dehydration.

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 an option to lie on dry ground. Providing an opportunity to forage decreases antagonistic behavior between horses that are housed on dry lots (Benhajali et al., 2009). Tight spaces and sharp corners or projections should be avoided in pens to reduce injury and the chance of dominant animals trapping subordinates. 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 when possible, as provision may not be feasible for horses on rangeland. Shelter providing shade can mitigate some of the effects of heat and insect-avoidance behaviors (Holcomb et al., 2014; Hartmann et al., 2015; Holcomb and Stull, 2016). The determination of whether horses have adequate shelter should be based on the absence of hypo- and hyperthermia. If the horse is experiencing these conditions, measures must be taken to alleviate them. The thermoneutral zone of horses has been estimated to have a lower critical temperature at 5°C (41°F) and an 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 size of 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 when 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 bottoms 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 (https://ul.org/) or other accepted testing organization. Highly visible, conductive plastic tape 0.75 to 1.25 in wide is an effective fence material to cross fence pastures or paddocks. Other electric fence materials can 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 a gate should be similar to that of the adjoining fence to discourage animals from attempting to jump over at the lower point. The width of a gate should span the opening completely and not leave a space where an animal may be caught between the fence and gate. The bottom of a gate, like the bottom of fences, should either extend to the ground or be high enough above the ground to prevent injuries.

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. Research into the motivation of horses show that they have a strong motivation to work for hay (high-fiber diet) when fed a low-fiber diet (Elia et al., 2010), will work for the opportunity to exercise, and even more if placed with conspecifics (Lee et al., 2011) while avoiding exercise on a treadmill, and that horses have a high motivation for physical contact, even if it is just muzzle to muzzle (Søndergaard et al., 2011). 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 frequently keep horses indoors in individual stalls or small outdoor paddocks. These horses have little opportunity to exercise freely and are often fed a diet that is nutrient-dense, requiring dietary limitation in feed intake. To help mitigate this situation, it is recommended to supplement with concentrates only when the available forage does not provide sufficient nutrients to maintain an appropriate body condition for the horse. 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 commonly eats 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 community 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. Breakdown of indigestible carbohydrates and other substrates not absorbed in the small intestine 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 maintenance requirement.

The microbes of the large intestine perform optimally in a consistent internal environment. Intermittent meals or bolus feeding, when improperly managed, can disrupt the microbial population in the hindgut of the horse. This may result in large fluctuations in nutrients and by-products in the circulation 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. Specifically, the absolute minimum recommendation for fiber is 12.5 g (0.44 oz) of dry matter per kg (2.2 lb) of body weight (12.5 lb of dry matter for a 1,000-lb horse). In addition, the amount offered that provides species-specific feed intake behavior of a minimum of 8 h is recommended (Harris et al., 2017). Although a fiber requirement for the horse has not been determined by the National Research Council, 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 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. To increase BW, forage quantity and quality 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 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 National Research Council recommendations, the 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 a rate of 1% or more of BW for mature horses. Although no minimum amount of forage intake has been set for horses under various conditions with existing data (NRC, 2007), low-roughage diets are associated with increased incidence of gastric ulcers, and stereotypical behaviors such as wood chewing, cribbing, and weaving (Willard et al., 1977; McGreevy et al., 1995; Andrews and Nadeau, 1999; Parker et al., 2008). Legume hays, usually alfalfa or clover, are generally higher in protein, energy, and calcium than 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. However, horses can gain too much weight on any type of forage,and attention to body condition is important. When no pasture is available, providing foraging opportunities via hay consumption may satisfy the strong motivation of horses to participate in feed intake behavior (i.e., grazing; Ellis, 2010).

Concentrates are used to supply energy, protein, vitamins, and minerals to the ration and are typically characterized as high-energy, high-protein diets meant to supplement forage diets. 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 have been implicated as causative for laminitis and other metabolic disorders in horses (Kronfeld et al., 2004). Overweight horses or those prone to metabolic diseases may benefit from a low-starch diet. 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 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. Growing horses and late-pregnant and lactating mares have greater energy, protein, vitamin, and mineral requirements than adult horses in maintenance condition. The primary requirement of performance or athletic horses above maintenance is for increased energy. Often, somewhat higher needs for other nutrients are satisfied when the energy requirement is met, although in some cases, supplementation of additional minerals and vitamins may be appropriate. Geriatric horses may do better on rations with higher nutrient levels, similar to those for growing horses, perhaps because of diminished metabolic efficiencies or confounding conditions. Details of nutrient requirements are presented in NRC (2007). Feed analysis of concentrates and forage materials can be used to ensure that the diet meets the nutrient requirements of the horse. 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 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 appease the desire to chew. 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 and Rangelands for Horses

Nutrient needs of horses on pasture or rangeland may be provided from available forages or by a combination of 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, fenceline mangers, buckets, or boxes may be used to allow feeding from the fenceline. 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 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 or rangeland, care must be taken to ensure that the resource 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). For smaller pastures, good management is required to optimize utilization of the limited space. Care may include regular fertilization and clipping (mowing) of excess growth to increase the nutrient value and palatability, the control of parasites through manure removal or pasture dragging to break up the manure piles, and the use of a rotational grazing system. Horses housed on rangeland should be moved to fresh range when available forage becomes limited. Pastures should be inspected routinely for growth of unusual or poisonous plants (Kingsbury, 1964; Oehme, 1986), especially when pastures are overgrazed.

Another consideration specific for pregnant mares is that, in many parts of the world, horse pastures contain a high percentage of fescue and other grasses that may be infected with endophyte. Ball et al. (1991) noted that 90% of fescue samples (4,500 from 30 states) tested at Auburn University had some level of endophyte infection. Consumption of endophyte-infected tall fescue during late gestation can result in fescue toxicosis in broodmares, presenting as prolonged gestation, foaling difficulties, thickened placentas, and a decrease or absence of milk at delivery. Broodmares should be removed from fescue pastures at least 90 d before the estimated foaling date. If broodmares cannot be removed from fescue pastures, they may be supplemented with domperidone.

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 can also 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. Alternatively, individual amounts of feed can be spaced far away from each other such that a horse cannot control access without leaving an available pile. 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 slip 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

It is recommended that clean water be freely accessible or provided free access at least twice daily if continuous availability is not possible. 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 qt per 220 lb) of BW 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, tacky saliva, skin that tents (remains compressed when pinched), and increased capillary refill time at the gums. Horses should not be dehydrated unless the teaching or research requires so. Also, lack of adequate water may be a cause of colic.

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.

Waterers may vary from simple buckets to troughs or automatic drinking devices. Continuous flow systems may also be acceptable to prevent freezing and moderate temperature of drinking water. Waterers should be free of sharp edges. Automatic waterers must be functional, clean, and able to be operated by the horses. Some waterers can be operated by a pressure plate pressed by the horse; it may require several days for most horses to learn to operate this type of waterer, and foals or horses with very small muzzles may not be able to operate them. Also, the noise of some waterers refilling may frighten some horses initially. A water bucket should be provided 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 or rangeland 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 fenceline pacing (McGreevy et al., 1995; Cooper et al., 2000; Bachmann et al., 2003). Careful selection of the horse's social environment must be considered so as to not interfere with 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; stallions are often 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; Briefer Freymond et al., 2013).

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 horse or 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. Total isolation, even for a few hours, of 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 elderly or pregnant. Behavioral problems such as stall walking, weaving, and cribbing also 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). The need for controlled exercise or free time (turnout) is recognized. However, requirements for its frequency and duration have not been established by scientific studies for confined horses (McDonnell et al., 1998; Houpt and Houpt, 2000). It is recommended that horses confined to box stalls receive 30 min of free time (turnout) or 15 min of controlled exercise per day; horses in tie-stalls should be provided with more time for exercise.

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 premolars 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 depends on age, diet, housing, and environment. It is recommended that a veterinarian check teeth yearly or as needed. 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), Venezuelan equine encephalitis (VEE), West Nile virus, rabies, and tetanus. In certain areas of the United States, equine herpesvirus myeloencephalopathy, 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. Pregnant mares require a specific vaccination program, which should be reviewed by a veterinarian. Additionally, when indicated or required by state or federal regulations, disease monitoring and surveillance programs should 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 stocking density, 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 (e.g., *Strongylus vulgaris*), small strongyles (40 species), ascarids (e.g., *Parascaris equorum*), bots (e.g., *Gasterophilus intestinalis*), and pinworms (e.g., *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 the 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 they can be easily detected and controlled with an appropriate drug, in consultation with a veterinarian. The incidence of tick-borne diseases, such as Lyme disease, is increasing across the United States. Proper pasture management may help decrease the exposure to ticks, but no vaccine is currently available for horses (Divers et al., 2018).

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 they 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-borne diseases such as equine infectious anemia and West Nile virus.

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 the 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 larvicides 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.

Breeding Procedures. Pasture breeding, live cover (in-hand), and artificial insemination (AI) are all appropriate methods of breeding mares, and 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, breeding horses should not be present in adjacent areas. Live cover (in-hand) and AI 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 AI 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.

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. In extremely cold weather, 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 to 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 indicate 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 their 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 dilute iodine solution (0.1% solution) or chlorhexidine (1:4) 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 after 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 usually ineffective. In cases of a failure of transfer of passive immunity from colostrum, transfusion of plasma from hyperimmunized donors may be advisable.

The mare's placenta should be tied up in a way that she will not step on it after foaling, and it should be passed within the first couple of hours after foaling. After the placenta has been delivered, the foaling attendant should examine the placenta to ensure that it is complete and that no pieces have been retained. Retention of the placenta by the mare more than 3 h postfoaling 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.

Restraint. Proper restraint of horses is an important management skill that is critical to the health and wellbeing 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 or 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 should be constructed of material that is of sufficient strength to contain the horse. Material should have no sharp points or edges. Pipe, smooth cable, PVC fencing, wooden planks, and woven wire are all appropriate materials.

Stalls should be constructed of material that is of sufficient strength to contain the horse. The lower portion should be of solid construction and of sufficient height that the horse's legs cannot become entangled. Wood planking and concrete are examples of appropriate materials.

Halters may be constructed of rope, nylon webbing, other 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 recommended that horses not 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, several factors must be considered: (1) the horse should be tied at wither height or above; (2) a quick-release mechanism should be in place; (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 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.

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 AI. 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. Hobbles 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 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 to 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 are used to immobilize horses for short 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 short-term restraint that can often be used in lieu of chemical restraint. When used incorrectly, twitches are dangerous to both the horse and the handler. Horses may have a violent reaction to twitches when they are improperly used or left in place for too long.

Chemical restraint is necessary for many surgical procedures and may be necessary for some nonsurgical procedures. Chemical restraint should be used when other types of restraint are inappropriate or inadequate because of the duration or stress of the procedure. In these cases, it is recommended that protocols be developed in consultation with 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

Permanent identification of individual horses may be done by insertion of microchips or lip tattoos. Horses should not be branded unless legally required. Proper restraint—physical, chemical, or both—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 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 trained personnel, is essential at all ages. Horses should be carefully monitored post-surgery for infection or herniation of bowel through the castration site. Appropriate analgesia should be used following castration surgery.

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.

Chronic signs of pain or distress in horses can 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, increased horse grimace score (Dalla Costa et al., 2014), 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 and in humane handling and restraint techniques; they must also be 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 controlled by the US Food and Drug Administration; thus, only a US Drug Enforcement Agency license holder or their designee is able to use it for euthanasia. 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 may also 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, 2020).

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 or larger 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 at the intersection of the line from the base of the ear to the outside corner of the opposite eye or, more specifically stated, one-half inch above the intersection of a diagonal line from the base of the ear to the inside corner of the opposite eye (diagram available from the American Veterinary Medical Association online; www.avma.org). 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.

When practical, choose a location for euthanasia procedures where the carcass can be removed easily by equipment, but do not drag animals or cause more pain and distress to move the animal to a convenient place. In these circumstances, the animal should be euthanized in place and dragged after it is dead. Animal carcasses should be disposed of promptly, usually by a commercial rendering company or other appropriate means (burial, landfill, 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: SWINE

INTRODUCTION

Swine adapt readily to a variety of production systems (MWPS, 1983; Baxter, 1984; Whittemore, 1993; US Pork Center of Excellence, 2010). 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, sun exposure, ventilation, vapor pressure, floor condition, area or space per pig, manure management, quantity and quality of feed (i.e., appropriate diet) and water, housing system, disease, and distress.

Predictable daily management allows pigs to develop a routine. 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 those experiencing stress or reduced well-being.

Attention should be given to the environment, age of the animals, and pig dunging and resting areas of preference during both the design phase and the daily operation of facilities. Movement of manure and urine between pens should be minimized. Similarly, animal care personnel should take necessary precautions to decrease transmission of pathogens between pens and between facilities, even at the same location.

PHYSICAL ENVIRONMENT

The microenvironment consists of all factors external to the animal: environment (air temperature, quality, movement, and moisture), physical environment (pens, walls, and floors), social environment (access to other animals), and microbial environment. The thermal environment is probably one of the most difficult components to manage because pigs of different age have different thermal requirements. Hence, it is important that pigs be managed based on their thermal needs during each stage of production (Table 9-1). The lower critical temperature is higher for younger pigs than for older pigs; thus, a higher effective environmental temperature is required. When possible, the thermal environment should be managed so that the microenvironment is maintained close to the zone of thermal neutrality for the age of the pig being housed (Table 9-1). Note that although specific ranges are provided, footnote 1 in Table 9-1 emphasizes the need to base requirements on swine behavior and physiology, not simply within a broad range, because many factors, including radiant heat load, air speed, relative humidity, health, stage of production/gestation, can affect animal comfort.

Ventilation goals differ with season. A properly ventilated building is free of drafts and provides clean, fresh air without chilling the pigs. 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% relative humidity) provides a vehicle for microorganisms, condenses on the pigs, and damages insulation. 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 factors should be considered when controlling ventilation rate (Kephart, 2007). Ventilation rate in the summer should be sufficient to keep air moving to remove animal heat and moisture.

LIGHTING

The domestic pig is less sensitive to its photic environment than are some other species. Changes in photoperiod have not been linked to pig well-being because no consistent or decisive evidence has been presented linking photoperiod to pig performance at any stage of production. Some data indicate that photoperiod can influence productivity and various physiological measures of sows and their offspring (Bruininx et al., 2002; Niekamp et al., 2006, 2007; Hälli et al., 2008). Reiners et al. (2010) found no effect of increased photoperiod on feed disappearance or body weight (BW) of weaned pigs. 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, they prefer some light and some dark every hour of the day and night (Baldwin and Meese, 1977). This

Table 9-1. Recommended thermal conditions for swine used in agricultural research and teaching[1]

Animal	Preferred range[2]	Lower extreme[3]	Upper extreme[4]
Lactating sow and litter: sow	15–26°C (59 to 79°F)	15°C (59°F)	32°C (90°F)
Lactating sow and litter: creep area for piglets	32°C (90°F)	25°C (77°F)	—
Pre-nursery, 3 to 15 kg (7 to 33 lb)	26–32°C (79 to 90°F)	15°C (59°F)	35°C (95°F)
Nursery, 15 to 35 kg (33 to 77 lb)	18–26°C (64 to 79°F)	5°C (41°F)	35°C (95°F)
Growing, 35 to 70 kg (77 to 154 lb)	15–25°C (59 to 77°F)	−5°C (23°F)	35°C (95°F)
Finishing, 70 to 100 kg (154 to 220 lb)	10–25°C (50 to 77°F)	−20°C (4°F)	35°C (95°F)
Sow or boar,[5] >100 kg (>220 lb)	10–25°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 thermoregulatory behaviors are better indicators of the appropriate air temperature than a thermometer. PQA, 2019: https://lms.pork.org/Tools/View/pqa-plus/program-materials. It is important to realize that how the animal feels is based on temperature combined with radiant heat load, air speed, and relative humidity.

[2]Based on values given by NRC (1981), DeShazer and Overhults (1982), Curtis (1985), Hahn (1985), and Shao et al. (1997).

[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. There is no practical upper limit for the creep area for piglets.

[5]With the combination of "sow or boar" into one category, physiological changes (i.e., gestation and lactation) that can impact the preferred temperature range of a sow as metabolic heat production changes have not been considered. For example, metabolic heat production of ad libitum-fed lactating sows at 25°C may differ from early gestation sows fed at maintenance requirement, etc., which can alter thermal preferences. These and other differences should be considered. Therefore, these ranges do not consider the actual preferred range or upper extreme for gestating and/or lactating sows.

apparent light-dark cycle preference is not similar to any natural situation; thus, this type of preference test may not be the best mechanism to determine the light requirements for swine.

Photoperiod manipulation may influence pig immune status (Niekamp et al., 2006, 2007), but data on photoperiodic effects on pig biology are contradictory for growing pigs (Berger et al., 1980). Hälli et al. (2008) found that photoperiod had no effect on changes in luteinizing hormone in prepubertal gilts. However, research by others found that developing breeding animals may benefit from a long-day photoperiod as evidenced by advanced puberty (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 than did those on short days. When photoperiod increased by 1 h, age to estrus decreased by 3 d (albeit a very weak association, $r = -0.03$; Tummaruk, 2012) and age to first mating decreased by 1 d (Iida and Koketsu, 2013). Seasonal infertility has been a longstanding problem in the swine industry. Photoperiod in late gestation can also influence endocrine and performance measures of the gestating sow and her offspring (Niekamp et al., 2006). Auvigne et al. (2010), studying 610,000 sows in France, found a significant role of photoperiod contributing to seasonal infertility with the compounding challenge of heat stress. 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). These effects were not observed in a subsequent study using more replications (McGlone et al., 1988). Light regimens oscillating from 9 to 16 h of light daily had no effect on boar semen quality, 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, 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 once each day. Feeders and waterers must be checked for functionality. Design and position of feeders and waterers should enable easy access while minimizing waste. Feeders or feeding places should be free from manure, urine, and other contaminants. Pigs may be fed on the floor if care is taken to prevent manure build-up and ensure individuals are getting enough feed. Medication under veterinary prescription may be administered through a waterer for management of bacterial pneumonia, enteric, and nonenteric infections and as appropriate for nutrient supplementation.

Care should be taken to minimize dust when delivering feed to buildings that house animals. Pigs should be fed to meet or exceed nutrient requirements, as determined by the NRC (2012), for their particular stage of the life cycle. Pigs should have ad libitum access to water or, at a minimum, adequate scheduled access to water. Quality and quantity of water should be sufficient to limit the incidence of illness and meet the physiological needs of pigs.

HOUSING TYPES

Young pigs and sows are social animals and are usually housed in groups. In nature, wild sows are often found in groups, except before and after parturition when they seek isolation. Older boars should be housed individually to reduce aggression and fighting. Young pigs show behavioral and physiological signs of stress when held in complete isolation from other pigs. Hence, pigs housed individually should be able to see and hear 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 kept in groups from 2 to 1,200 pigs per pen but large numbers of pigs per pen (1,000 to 1,200) have become more common, especially in commercial wean-to-finish systems. When social groups are being established, the level of stress (fighting) increases significantly during the initial 24 to 48 h after the animals are introduced, and productivity may temporarily decline until social status is established. The group often becomes relatively stable if external stressors are managed effectively. Therefore, whenever establishing groups or introducing new animals into an established group, care should be taken to monitor the pigs to promptly identify any individuals that become severely hurt. Methods to reduce aggression are usually short lived but can include mixing groups in the evening, adopting strategies that minimize competition (e.g., grouping pigs of similar size, increasing access to water, providing access to ad libitum feed through a variety of feeding techniques or multiple stations, providing additional space), providing sprinklers and supplemental ventilation to reduce heat load when environmental conditions are warm, and providing other forms of environmental enrichment (e.g., straw, large plastic balls, springs mounted on vertical sections of tubular gates, suspended waterers, toys). By comparison, use of chemical deterrents (e.g., pheromones or odors) and fresh bedding to mask olfactory triggers of aggression has proven unsuccessful (Marchant-Forde and Marchant-Forde, 2005). Adding bedding such as straw is not possible with some types of flooring, especially over pits that collect manure. Movable panels and partial walls that serve as visual barriers and hiding places for animals to escape aggression have been proposed to moderate aggression. However, recent research suggests that even though these structures appear to decrease stress, they do not decrease aggression (Bulens et al., 2017). When mixing sows, parity, size, genetics etc. should be considered. Extremely aggressive or timid sows may need to be culled (National Pork Board, 2018; PQA, 2019). In some cases, adult pigs housed individually may experience less stress than growing pigs because they are not the recipients of overt aggression. As noted above, if the research requires pigs to be housed individually, such as in metabolic studies or gestation stalls, the animals should be able to see and or hear other pigs.

FARROWING SYSTEMS

Sow Management

Before preparturient sows are moved for farrowing, the environment should be cleaned, disinfected, and dried. If farrowing outdoors, it is recommended that the outdoor environmental area be exposed to sunlight for several days before moving a new group of sows into the area for farrowing to allow UV light to assist in disinfecting the area. If parasites are present, sows should be treated appropriately to eliminate transmission of parasites into the farrowing area. Diets fed during lactation differ from those fed during gestation (NRC, 2012), and fresh water should be available at all times. Laxative additives or a specially formulated diet may be fed before or after parturition to minimize constipation.

In high-producing herds, Hoshino et al. (2009) found that increased assistance and supervision during farrowing decreased the incidence of stillbirths. However, Vanderhaeghe et al. (2010b) found that an increased incidence of vaginal palpation increased stillbirths, but this has not been verified with various types of genetics. Housing environment may also affect the number of stillbirths. Numerous studies have been carried out with mixed results; only the research reported by Oliviero et al. (2010) found that sows housed in farrowing crates had more stillbirths than sows in pens (1.0 vs. 0.4).

Behavioral thermoregulation of sows is necessary because they do not perspire and hence may include postural changes. Sows may exhibit extension of their body for contact with a cooler surface, shade seeking, minimizing contact with other animals, or open-mouth breathing (Curtis, 1983; Blackshaw and Blackshaw, 1994). Because sows have a high BW but a low body surface-to-mass ratio, it is difficult for sows to dissipate internal heat (Hansen and Vestergaard, 1984). Sows housed at temperatures >22°C (>72°F) have been found to have a higher incidence of stillbirths (Vanderhaeghe et al., 2010a). During hot weather, especially when humidity is high [daily maximum temperature >29°C (>85°F)], sows may need to be zone cooled with misters, sprinklers, dripping water directly on the sow, ventilation fans (McGlone et al., 1988), or by providing directed currents of air on the nose (Bull et al., 1997). Effective thermoregulatory methods that can be used in extensive or outdoor systems include enabling sows to wet themselves with water or mud, access to shade, or manually misting sows with room-temperature water.

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 behaviors observed in wild, feral, and domestic sows outdoors occur 24 to 48 h before the birth of the first piglet. The sow often leaves the social group and seeks isolation. Therefore, some degree of confinement of the periparturient sow allows her to occupy a space that is precluded to others (Phillips et al., 1991). Even in extensive housing systems, sows may be provided with small houses, huts, or a pen in which they can be confined and excluded from their group.

Housing

A wide variety of options are available for housing sows during farrowing and lactation, ranging from conventional stalls to outdoor pens or paddocks (Collins et al., 1987; Thornton, 1988; McGlone and Morrow-Tesch, 1990; McGlone et al., 1995; McGlone and Hicks, 2000; Johnson and Marchant-Forde, 2008). Farrowing systems should be designed to meet performance standards that include minimizing preweaning piglet mortality, providing thermal comfort for sow and piglets (which may require zone heating/cooling), providing a sanitary environment for sows and piglets, and accommodating normal sow and piglet behaviors where possible. Restricting sow movements in the well-designed farrowing stall will improve piglet survival, and this is a significant consideration when selecting any farrowing system.

Farrowing Stalls

To reduce piglet injury and protect animal care personnel from overly aggressive periparturient sows, indoor sows may be confined in farrowing stalls or freestalls 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 × 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). The length and height of the farrowing stall must be appropriate for the sow's size. A sow must 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 wide enough to allow excreta to pass through, but not allow piglets to get their feet caught in the flooring.

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 can be provided for farrowing crates equipped with solid floors. Flooring materials should meet performance requirements so that (1) animals are supported and slippage is reduced, (2) slatted floors do not trap feet or legs, (3) slats 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 can be sanitized to provide a clean surface.

Good disease management practices dictate 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. 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 and Blackshaw, 1994), and farrowing pens with sloped floors or walls (McGlone and Morrow-Tesch, 1990; Cronin et al., 1996; Marchant-Forde, 2002). Turn-around pens, that allow a sow to turn around, are similar to conventional stalls in that they are made out of tubular metal and the system incorporates a piglet creep area. However, there are increased issues with sows defecating or urinating in their feed. These systems must be installed on a fully slatted floor for hygiene reasons.

Farrowing Houses or Huts

As with indoor farrowing pens, some outdoor farrowing houses or huts allow sows to raise piglets with minimum preweaning mortality. Farrowing huts or houses are enclosures used for outdoor farrowing. A variety of designs are available, often made of plastic, wood or tin. These include housing of different shapes and design, such as A-frame, semicircular, and rectangular designs (Penner et al., 1996; Honeyman and Roush, 1997; Johnson and Marchant-Forde, 2008). It is common to use bedding such as straw, wood shavings, or other materials. Often there is no heated creep area because of concerns about fire, and no water supply for the sow or her litter is provided within the structure due to the portability of the structure. Some farrowing huts/houses 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).

Fences can be fixed onto the front of farrowing huts/houses to help keep piglets close to the farrowing unit, keep bedding inside, and allow unrestricted movement of the sow (Honeyman et al., 1998; Johnson and McGlone, 2003). Fence design may influence the length of time that piglets are confined to the hut/house and safety for the stockperson carrying out routine tasks (i.e., litter processing; Johnson and McGlone, 2003). For instance, fences that are low will eventually be ineffective in keeping the litter in the sow's vicinity.

Sows kept outdoors should be observed daily. A sheltered area or bedding should be provided unless the thermal environment is adequate, and fences should be sturdy and well constructed. Electrified wire may be used to keep animals confined. Proper health care for sows and piglets should be provided, and feces and urine should be removed from the immediate environment as the need arises. Sows and litters kept outdoors can be rotated among pastures to avoid accumulation of pathogens and parasites; if not, increased parasite control measures can help decrease parasitic load. As noted previously, the farrowing houses/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.

Creep Area

An area of safety for the young pigs away from the sow is called the creep area, and it is usually set to the side or front of the farrowing stall, with a heat source to provide a warm lying area. In a pen or house, the creep area may be in one corner, along one of the pen's short sides, or centrally placed in pens that are divided into nesting and dunging areas (Heckt et al., 1988; Johnson and Marchant-Forde, 2008).

Litter Management

Newborn piglets require special attention. They are born with low body reserves of energy, iron, and immunoglobulins. Newborn piglets also thermoregulate poorly and are vulnerable to being crushed. Until weaned, piglets should be provided with an area that is warm, dry, draft-free, and zone heated in cold environments when possible; 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 (Table 9-1). 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, can be provided to meet the differing thermal needs of the sow and piglets.

Any of the following procedures may be performed on piglets within a few days after birth: (1) navel disinfected with iodine (if farrowing was attended); (2) needle teeth trimmed with a disinfected sharp device; (3) tail docked to 1.5 to 2.5 cm (0.5 to 1 in) from the body with a disinfected device (NPB, 2018); (4) supplemental iron injected in neck area muscle; and (5) individual identification (usually ear notches or small ear tags).

NURSERY SYSTEMS

Weaning is a practice that causes distress to the pig because of the sudden change in social and environmental conditions and dietary change. Weaning at night may be less stressful than weaning during the early morning (Ogunbameru et al., 1992); however, the latter 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 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 the need for specialized facilities and care, a higher degree of sanitation, and more costly, high-quality diets (Lecce, 1986; Owen et al., 1995). Typically, in the North American swine industry today, pigs are weaned at 15 to 20 d of age. Segregated early weaning is a production practice used from time to time 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 management practice reduces the transfer of disease microorganisms from sows to nursery pigs by removing piglets from the sow before passive immunity decreases and the sow can infect her offspring. Segregated early weaning is less effective for some diseases but works well for others. However, segregated early weaning is not a routine, ongoing management practice.

The lower critical temperature of a 4-wk-old pig (once it is eating at a rate of approximately 3 to 3.5 times thermoneutral maintenance) is around 26°C (79°F; Table 9-1); therefore, nurseries should be able to meet the ambient temperature needs of the weaned pig, which may (but not always) require supplemental heating equipment such a heat lamps, mats, or bedding for solid floors. If piglets continue nursing the sow beyond 3 wk of age so they derive heat from the sow 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 meets the thermal comfort needs of the pigs.

Ventilation is essential to limit moisture accumulation in the winter and heat in the summer. Hence, it uses the flow of air, to influence the environment and ultimately comfort. Included in this system are the fans, inlets, heaters, and controllers. An example of a ventilation system is shown in Table 9-2. Environmental management is critical to the success of raising pigs in wean-to-finish buildings. Ventilation initially needs

Table 9-2. A 5-stage system utilizing single speed fans (Darrington, 2018)

Fan stage	Set point temperature	Indoor temperature = stage on	Indoor temperature = stage off
1	70°F	Always on	Always on
2	70°F	72°F	70.5°F
3	70°F	74°F	72.5°F
4	70°F	76°F	74.5°F
5	70°F	78°F	76.5°F

to be similar to that of the farrowing facility to allow newly weaned pigs to adjust to the phase of production. As the pig grows, it produces more moisture and heat; hence, ventilation needs change. Zone heating is recommended to meet the needs of the young pig. Pig behavioral thermoregulation will help the stockperson determine if the temperature is too high or too low. Crowding, with pigs lying on top of each other, indicates that pigs are cold. The thermoneutral temperature needs to be determined at the height of the pig, not at the height of the human.

In addition to having supplemental heat, nursery facilities should be maintained at a higher degree of sanitation than is required for older pigs and operated on an all-in, all-out basis. 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 are brought into the building.

Weaned pigs should be fed a nutritionally complete and balanced diet unless the experimental protocol dictates otherwise (NRC, 2012). Feeding space should be provided that allows all pigs to eat to their appetite over a 24-h period. Pigs may share a feeder space if feed intake is not limited. Wet/dry feeders that supply water as a part of the feeder may support more pigs per feeder space. Pigs should be provided ad libitum access to clean water every day in such a way that all pigs can obtain sufficient water throughout the day. At least one watering device (bowl type cups, nipple drinkers, floor pan drinkers with vacuum type valves) should be provided for every 10 to 20 pigs. The height of the waterer should be set so that pigs can readily drink from the watering device, which means it should be raised as the pigs grow. Care should be taken to maintain a clean water system. Loose-type feed pans to hold water or feed are not acceptable on a long-term basis because they are too easily turned over or contaminated with urine or fecal material. Hence, nursery or weaned pigs should have an appropriate feeder and waterer in their pens. When possible, pigs should be allocated to pens based on BW and age to facilitate effective feeding and water management (Patience et al., 2004). Because nutrient needs are influenced by genetics and sex, barrows and gilts have different nutrient needs at the same age and are often penned separately. Pigs grow rapidly, which influences space requirements of individually housed and group-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 available unused or free space increases with an increase in group size, but research has shown that if all the free space is removed, feed intake and BW gain will be reduced (McGlone and Newby, 1994). Space needs for pigs in outdoor lots should be based on local performance standards, not on fixed numbers. Floor area recommendations are given in Table 9-3.

Slatted floors are common in nurseries as well as wean-to-finish buildings. The flooring material may be

Table 9-3. Minimum floor area recommendations for the animal zone for swine used in research and teaching[1]

Stage of production	Individual pigs (per pig)		Groups of pigs[2] (per pig)	
	m^2	ft^2	m^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,[3] 105 to 125 kg (231 to 275 lb) of BW	1.26	14	0.74–0.84	8.0–9.0
Mature adults[4]	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 = $0.33 \times BW^{0.67}$, where body weight (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]A 138-kg finishing pig needs 0.89 m/pig, and a 148-kg finishing pig needs 0.98 m/pig (Johnston et al., 2017).

[4]Minimum stall size of (length × width) 2.1 m (7 ft) × 56 cm (22 in) is recommended. Young adult females may be housed in stalls 2 m (6.5 ft) long. As noted in the text, this differs from sows in groups where the minimum floor space allowance should be 1.49 m^2 (16 ft^2) per sow on partly slatted floors (Salak-Johnson et al., 2007). For large sows (based on BW), floor space allowance should be 1.77 m^2 (19 ft^2) per sow.

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 slotted area for optimal drainage.

GROWING AND FINISHING SYSTEMS

The growing-finishing stage refers to pigs from about 8 or 9 wk of age to market age of about 20 to 25 wk and finished BW 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 acceptable, 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 9-1). Although growing-finishing systems may use a continuous flow of pigs, an all-in, all-out system is recommended. Restricting the number of times pigs are moved or mixed is desirable because mixing pigs causes them distress and generally results in aggression, accompanied by the potential for injury, health problems, and reduced performance.

Typically, growing-finishing pens are rectangular and contain 20 to 1,000 pigs per pen (or more). Animals need to have free access to feed and water, and stocking rate will determine the minimum number and type of access points that are needed. In general, the same feeder space can be shared by up to 10 pigs throughout the day, and up to 20 pigs may share the same waterer during the grow-finish phase. In most circumstances, pigs should have ad libitum access to water. However, other acceptable systems provide water during fixed intervals throughout the day, and some systems provide water only when feed is delivered (wet/dry feeders). 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 eating. The height of the waterer should be adjusted appropriately as pigs grow. Specialized feeding and watering equipment may accommodate different pig densities. Differences in growth potential and nutrient requirements are apparent in the grow/finish stage due to genetics, production goals (e.g., weight gain), environment, and sex, and will influence dietary content.

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 the pig's feet and the manure to fall between the slots. Edges of the slats should be rounded to preclude foot-claw injuries; sharp edges should be avoided. Open flush gutter systems are acceptable, but the risk of contamination between pens is significant.

Ventilation is essential to limit moisture accumulation in the winter and heat in the summer. Hence, it uses the flow of air, to influence the environment and ultimately comfort. Included in this system are the fans, inlets, heaters, and controllers.

Floor-space allowance is a complex issue in swine production. Floor area recommendations are given in Table 9-3. Traditional space requirements were established with relatively small group sizes; hence, in large group sizes, there is a greater amount of shared, unused, or free space. Research suggests that 0.65 m^2 (6 ft^2)/pig is adequate for maintenance of economical pig growth (Brumm and Dahlquist, 1997). Pigs up to 115 kg (250 lb) of BW and in small group sizes (<20) require 0.56 to 0.74 m^2/pig (8.0 ft^2/pig). In larger groups, those up to 136 kg (300 lb) and with over 50 pigs/pen may need only 0.74 m^2/pig (8.0 to 9.0 ft^2/pig), the same amount of space as the smaller pigs. Replacement gilts separated from market animals may need additional floor space to reduce the opportunity for injury. Floor space allowance may be determined using the following equation: $A = k \times BW^{0.667}$, where A = floor space allowance, and k = a space allowance coefficient that converts pig BW into a 2-dimensional concept (Gonyou et al., 2006). A k value of 0.0336 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. Less space is required in outdoor lots in cold weather than in hot and wet weather. In outdoor finishing, several alternative non-environmentally controlled systems are acceptable for grow-finish pigs. A common alternative system is a naturally ventilated, open-air hoop building; these buildings are usually bedded in cold temperatures. Another alternative is indoor-outdoor lots. The floors in these types of structures, which vary in size, 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, especially during cold weather.

BREEDING AND GESTATION SYSTEMS

Sows, if managed properly, may be housed individually or in groups during breeding and gestation (McGlone et al., 2004b; AVMA, 2005). Both field and controlled studies (McGlone et al., 1994, 2004b; McGlone, 1995; AVMA, 2005) support the idea that the individual crate or stall and well-managed sows in group housing promote high reproductive success and do 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. All housing systems have advantages and disadvantages (McGlone et al., 2004b; AVMA, 2005). Several gestation housing systems may be reasonable choices, including individual crates or group pens with outdoor, individual feeders, electronic feeders, floor feeding, or trickle feeding. The tether system is not widely used in the United States and has been banned in European Community member countries since 1997; tether systems should not be used. Some individual states in the United States and Canada have banned or will phase out the use of gestation stalls for sows except immediately after breeding. Teaching and research activities in states where gestation crates have been banned must comply with state regulations unless exempt. According to American Veterinary Medicine Association policy (AVMA, 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 are best managed as a static group, whereas if they are to be housed in large groups, management as a dynamic group is feasible. 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, 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 uniform in 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. Electronic feeding systems can be used to successfully provide the needed feed quantity and reduce competition in group-housed sows.

Building Environment for Breeding and Gestation

The suggested optimum range of air temperatures of the housing environment for gestating gilts and sows [data from sows >100 kg (220 lb), Table 9-1] is 10 to 25°C (50 to 77°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, BW, feed intake, huddling, and number of animals housed together. 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 among farms (McGlone et al., 2004a). Data from a large sample of sows indicate 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 lie down without being forced to have parts of their body 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 lie 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 is 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-housing 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, dry lot or pasture, and use an insulated, mechanically ventilated frame structure or a hoop structure. Floor types may be solid or slatted, with or without bedding.

Sow groups must be managed to reduce social stress that can result in severe injury, especially when initially mixed. 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; without intervention from animal care personnel or a physical system, dominant 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, stall feeding, and electronic sow feeding systems.

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, maintenance as a static group with sows in the same production phase can decrease aggression. In contrast, groups of 80 to 200 sows exhibit minimal aggression when maintained as a dynamic group where sows enter and leave the group every week. Minimizing social stress by keeping sows in individual stalls for the first 25 to 35 d after breeding or grouping all sows at one time helps to decrease fetal loss. Knox et al. (2014) found that productivity is maximized when sows are not mixed; however, when mixing did occur, mixing at d 3 created the poorest welfare and productivity compared with mixing at d 13 or 35 of gestation.

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 with modern and ever-changing genetics. Inputs from managers, proper habituation, and selection of appropriate genetic stock appear to be the 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 and opportunity to avoid or escape from potential aggressors are essential for the well-being of low-ranking sows in group housing. Space should be adequate to avoid physical injury. The minimum floor space allowance should be 1.49 m^2 (16 ft^2) per sow on partly slatted floors (Salak-Johnson et al., 2007). For large sows (based on BW), floor space allowance should be 1.77 m^2 (19 ft^2) per sow; thus, as BW 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 (13 ft^2) per sow compared with housing 5, 10, 20, or 40 sows per pen at 1.49 m^2 (21 ft^2) per sow (Taylor et al., 1997).

Mating Facilities

Recommended areas for breeding sows and boars of different types and sizes are listed in Table 9-3. Sexual development of gilts 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 direct contact with mature boars for at least 30 min/d. Individual housing of mature boars is recommended to preclude fighting. In systems in which boars reside in small groups, boars should be of comparable 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. Hence, 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. If semen is not purchased and shipped to the site, artificial insemination areas will need to include boar semen collection and sow insemination areas and 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 of pens with an area of solid concrete 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 that lack good footing and are used for hand mating, absorbent substances or rubber mats may be placed on the floor.

Natural service mating options are pen mating, where the boar is placed with sows unattended, and hand mating, with personnel attending the mating. 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.

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. Selection of animals with good conformation provides the opportunity for animals to wear off their toes on rough surfaces such as concrete.

Metabolism Stalls

Metabolism stalls are used to pen individual pigs for certain nutrition and physiology investigations with the approval of the institutional animal care and use committee. Feed is usually provided in meals and not ad libitum to meet the objectives of the research. Researchers are able to calculate the amount to be fed based on objectives of the research and known consumption data for the size and age of the animals involved in the project. The metabolism stall usually (but not always) keeps pigs in a manner that precludes them from turning around and defecating or urinating in their feed. 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 9-2), 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, animal care staff must check on the pigs at least twice a day. 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 a BW of approximately 100 kg (220 lb) or more. In view of the demand by US packers for heavier market hogs, almost all male pigs in the United States are castrated a few days after birth and hence are barrows at 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 obvious 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 nursing or feeding time, increased vocalization (apart from that induced by handling), inflammation and swelling at the castration site, and hormonal responses. It is important to note that although all researchers reported some evidence of pain and discomfort in pigs, results have not been consistent across experiments. To minimize stress on the pig, castration should be performed early, preferably between 1 and 14 d of age. Pigs should be checked for cryptorchidism or evidence of scrotal hernia before being castrated. Cryptorchids may require a second castration event to remove the remaining testis once it descends (hence, there is little value in castrating when only one testis is present in the scrotum) and a scrotal hernia can complicate the pig's recovery process. Pigs with evidence of scrotal hernia can be castrated, but the technician needs to be prepared to treat the situation to optimize the pig's likelihood of recovery. 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 precastration 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. Although a great deal of research into methods for pain mitigation has been conducted, no painless alternatives have emerged. Growing intact animals or use of immuno-castration have potential but also provide significant limitations (see Rault et al., 2011 for review).

Nose Rings

Outdoor swine production systems may have undesirable environmental consequences due to pig rooting behavior. Nose rings reduce rooting behavior by making it a painful experience (Horrell et al., 2001; Eriksen et al., 2006); however, pigs only experience pain when fitted with nose rings. This presents an issue of environment versus welfare (McGlone, 2001). Nose rings should not be used as they 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).

Other Standard Practices

Several other standard agricultural practices that cause pain or distress but prevent more serious distress or injury later in the pig's life may also be performed. As noted earlier, needle teeth of pigs may be clipped at 1 to 3 d of age to reduce damage to littermates and to the sow. However, if a smooth surface does not result, clipping needle teeth may not be a good practice (Michigan State University Extension, 2019). 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; this is an important and acceptable practice used in commercial production. Alternatives exist for each procedure performed; thus, Marchant-Forde et al. (2009) compared each method with an alternative: teeth grinding versus clipping; cut castration versus tear castration; cold tail docking versus hot tail docking; ear notching versus ear tagging; and iron injection versus oral iron. In general, tasks that took longer were more stressful. However, they also found that grinding teeth was more stressful than clipping. They created the "best" and "worst" combinations of procedures (Marchant-Forde et al., 2014); again, the longer the tasks took to perform, the more distressing the procedures were. Painful processing procedures are thought to have only acute effects. However, Zhou et al. (2013) found that pigs that were tail docked and had their teeth clipped had decreased exploratory behavior through the grower phase and a reduced average daily gain and BW up to 70 d of age compared with undocked, unclipped pigs. This difference disappeared by 160 d of age. Tail docking at a young age is used to reduce or prevent tail biting, which affects the health of the pig that is abused. Tusks of boars may be cut at the gum line to prevent them from harming humans or other pigs. Several methods of cutting the tusk of boars exist, including using bolt cutters, embryotomy wire, or a hack saw. To date, no comparison of the methods relative to pain have been conducted. If excessive hoof growth occurs because of the pig's poor structure and lack of rough walking surface such as cement, sows and boars may need to have their hooves trimmed to allow them to walk with greater ease and to avoid injuries.

Because some procedures are known to be painful, a great deal of research has been performed recently to test the efficacy and practicality of several anesthetics and analgesics. O'Connor et al. (2014) performed a meta-analysis of the current literature on pain management for neonatal pigs. They concluded that limited evidence exists to make strong recommendations; however, they did recommend strongly against carbon dioxide/oxygen anesthesia, weakly for the use of nonsteroidal anti-inflammatory drugs, and weakly against lidocaine for castration.

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

Pigs with Small Mature Body Size

Some breeds 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 are seldom 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

Refer to Chapter 1: Institutional Policies for information on transgenesis, gene editing, and cloning as they relate to animal care and use. Information on the additional regulatory oversight of transgenic animals and those researchers or institutions working with transgenic animals is available in *Guidance for Industry: Regulation of Intentionally Altered Genomic DNA in Animals* (FDA, 2018).

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 is available online (http://www.aasv.org/aasv/documents/SwineEuthanasia.pdf) and describes 6 acceptable methods of euthanasia and clearly notes which methods are most appropriate. Human safety risks associated with administering each method of euthanasia are addressed. All methods should only be performed by trained individuals. Blunt force trauma is acceptable for pigs weighing <5.5 kg. Carbon dioxide is a suitable method for euthanizing pigs less than 10 wk of age and less than 14 kg (30 lb), providing that residual O_2 is removed quickly from the CO_2 chamber. Carbon monoxide is not recommended because it is a potential human health hazard. Electrocution is acceptable for pigs over 4.5 kg (10 lb). An overdose of anesthetic or injection with a euthanasia solution is suitable for pigs of all ages; both 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 >5.5 kg. These recommendations are in line with the AVMA *Guidelines on Euthanasia* (AVMA, 2020; Sources: PQA, 2019: https://lms.pork.org/Tools/View/pqa-plus/program-materials; https://www.aasv.org/documents/2016EuthRec-EN.pdf; https://www.avma.org/KB/Policies/Documents/euthanasia.pdf), which is another guide to follow. Incurably ill or severely injured animals in pain or distress must be humanely euthanized as soon as possible after they are diagnosed, according to approved described methods.

In the United States, all procedures used to slaughter research and teaching animals that will enter the food chain must comply with US Code of Federal Regulations, Title 7, Chapter 48, Humane Slaughter of Livestock (https://www.govinfo.gov/content/pkg/USCODE-2011-title7/pdf/USCODE-2011-title7-chap48.pdf). The North American Meat Institute (NAMI) has embraced guidelines (https://animalhandling.org/producers/guidelines_audits) that exceed the regulatory requirements (Grandin, 2017) and the NAMI guidelines (NAMI, 2019) are incorporated here by reference.

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CHAPTER 10: DOMESTIC SHEEP AND GOATS

INTRODUCTION

Domestic sheep (*Ovis aries*) and goats (*Capra hircus*) are small ruminants that may produce meat, milk, and (or) fiber. There is a common perception that needs of sheep and goats are similar. However, differences in behavior, foraging, diet, uses, and various physiological characteristics mean that general care, management, and facilities may need to be tailored to each species. People who care for these animals should be appropriately trained, understand the species requirements, and have good observational and communications skills to ensure that the animals are cared for in a manner that is consistent with their wellbeing.

In many countries, and jurisdictions within countries, various laws and regulations govern animal management 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 management practices, and they should be certain that animals are cared for as specified in IACUC protocols.

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 setting, the management system should be appropriate for the research or teaching objectives and should 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 always be necessary. Goats are more tolerant to heat stress than sheep, and both are superior to cows in this respect, due to the morphological and physiological differences between these species related to heat dissipation (Bernabucci et al., 2010). Observation of increased respiratory rate can provide a reliable and practical indication of heat stress (Silanikove, 2000). However, goats are more sensitive to precipitation, cold, and inclement weather than sheep, and they modify their behavior by seeking shelter (Bøe and Ehrlenbruch, 2013). Shivering with an arched posture is indicative of cold stress in goats (Battini et al., 2016). Sheep will try to maintain their body temperature by reducing their rate of respiration, shivering, seeking shelter, and huddling together. During extreme weather conditions, it may be necessary to mitigate hypo- or hyperthermia. Site-specific needs for artificial shelter should consider the geography, local environment and climate, recency of shearing, 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).

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

Newborn lambs (Pollard, 2006; Dwyer et al., 2016) and kids (Dwyer et al., 2016) are susceptible to hypothermia, as well as hyperthermia and sunburn. At birth, ambient temperature can drop from 39°C in utero to 10°C or lower and maintaining body temperature depends on balancing heat loss and heat production. Frequency of neonatal observations should be increased to ensure adequate bonding between dam and offspring, and appropriate shelter should be provided if natural conditions do not offer sufficient protection from the weather.

When barns or sheds are provided, adequate ventilation and clean, dry surroundings are necessary to maintain air quality, minimize the incidence of disease, and promote animal health and wellbeing. Poor ventilation reduces production by dairy sheep, and recommendations for adequate ventilation have been published (Sevi et al., 2002, 2003a,b, 2006; Albenzio et al., 2005). No difference in reproductive performance or mortality of liveborn lambs was found between warm and cold housing (Simensen et al., 2014). Guidelines for facility layout and housing can be found in *Management*

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

Area	Floor type	Rams 65–90 kg, (180–300 lb)		Dry ewes, 65–90 kg (150–200 lb)		Ewes and lambs (additional creep area required[3])		Lamb creep, 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	1.9–2.8	20–30	1.1–1.5	12–16	1.4–1.9	15–20	0.14–0.19	1.5–2.0	0.74–0.93	8–10
	Slotted	1.3–1.9	14–20	0.7–0.9	8–10	0.9–1.1	10–12	0.14–0.19	1.5–2.0	0.37–0.46	4–5
	Dirt	2.3–3.7	25–40	2.3–3.7	25–40	2.8–4.7	30–50	—	—	1.86–2.79	20–30
Lot area	Paved	1.5	16	1.5	16	1.9	20	—	—	0.93	10
		cm	in	cm	in	cm	in	cm	in	cm	in
Feeder space											
Limit-fed		30.5	12	40.6–50.8	16–20	40.6–50.8	16–20	22.9–30.5	9–12	22.9–30.5	9–12
Self-fed		15.2	6	10.2–15.2	4–6	15.2–20.3	6–8	2.5–5.1	1–2	2.5–5.1	1–2

[1]Adapted from MWPS (1994).

[2]Space requirements should be increased for fully fleeced or horned sheep and during hot weather. Smaller resource allocations reflect minimum requirements for animals at the lower end of the weight range and larger resource allocations reflect minimum requirements for animals at the upper end of the weight range. Linear interpolation may provide reasonable allocations for animals of intermediate sizes.

[3]Increase space if lambing rate is >170%.

and Diseases of Dairy Goats (Guss, 1977), *Goat Production* (Gall, 1981), *Goat Farming* (Mowlen, 1992), *Goat Management* (Mackenzie, 1993), *Sheep Housing and Equipment Handbook* (MWPS, 1994), *Sheep Production Handbook* (ASIA, 2015), *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) discusses sheep housing and welfare.

In confinement, the space required per animal depends on the intent of the research and teaching, type and slope of floor or ground surface, and weather conditions. 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. Requirements vary considerably among locations and type of management. Estimated minimum area recommendations for confined sheep taken from the *Sheep Housing and Equipment Handbook* (MWPS, 1994) are reiterated in Table 10-1. Stocking density is a factor to be considered in dairy sheep housing, and a space allocation <2 m^2/animal may adversely affect performance and health of the lactating ewe (Sevi et al., 1999).

Because goats naturally gravitate toward hard surfaces, managing their housing to include different options can improve both cleaning and animal welfare (e.g., lying on dry hard surfaces and defecating on soft material; Sutherland et al., 2017). 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). Goats in confinement barns require approximately 1.5 m^2 (15–16 ft^2) per animal if in pens or individual stalls (similar to tie stalls for dairy cattle; see Chapter 7: Dairy Cattle) should be at least 0.56 m^2 (6 ft^2) and equipped with feeders and water (Kilgour and Dalton, 1984; UMass, 2019), and recent recommendations suggest that 2.5 to 3.0 m^2/goat (27 to 32 ft^2/goat) may be appropriate (MPI, 2018; UMass, 2019). Access to objects for climbing increases feed consumption and reduces aggression among goats (Flint and Murray, 2001).

Prolonged exposure to wet surfaces compromises hoof health of sheep and goats. Animals should have adequate access to well-drained, dry surfaces. Crushed stone or stone dust is a suitable surface for heavily trafficked areas. However, experience suggests that dusty pens may cause lung damage that is a precursor to pneumonia. Dust control in pens may reduce respiratory and other health problems as well as improve fleece quality.

The surfaces of floors, pens, pastures, and other enclosures can affect hoof wear and health. Goats are adapted for rocky, mountainous terrains (e.g., Shi et al., 2005) and have fast-growing hooves. Without the opportunity to wear their hooves naturally, goats require frequent hoof trimming. Thus, an effective hoof care program is an important component of sheep and goat management and welfare.

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 cooler times of the day. Opportunities for acclimatization should be considered when using sheep and goats for research and teaching, particularly when animals are moved between housing environments of disparate temperature (for discussions of environmental, heat, and cold stress, see Ames et al., 1971; Morrison, 1983; Webster, 1983; and Young, 1983).

FENCING

Fences allow managers to keep their animals together and isolated from other 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. Appropriate fencing varies (Miller, 1984) but a few general recommendations for fencing should be noted:

(1) It is important to understand the behavior of sheep and goats and how they respond to, or cope with, fences. The agility and inquisitive nature of goats can make some difficult to contain. 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. Sheep and goats frequently attempt to eat forage that is beyond the perimeter of the fence. They can trap their heads (especially if horns are present) or legs in an inappropriate fence. During the breeding season, rams and buck goats often attempt to escape enclosures 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) Fences should be designed, constructed, and maintained so that they do not endanger the animals being enclosed and should offer the greatest opportunity to accomplish the objectives for the fence at an affordable cost.
(3) Fences should keep sheep and goats protected from unwanted animals such as domestic, feral, or wild predators or other wildlife.
(4) Fence design should be consistent with institutional, local, state, and federal requirements; some of these may be legal requirements, which must be followed. Those requirements vary among states, and they are likely to evolve and may become more stringent (Centner, 2000).
(5) A fence should be constructed according to the appropriate design. It should be maintained properly, remain effective, and not endanger the animals being enclosed.
(6) 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 can 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), donkeys, and llamas may be used for the management 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). Due to their continuous motivation to herd, herding dogs should be used for management requirements only, and must not be left with sheep and goats as can be allowed with guardian animals.

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). General illumination of 220 lx is recommended (MWPS, 1994). This recommendation may be met with daylight through windows, which may also provide ventilation in warm weather (Colby, 1972). Supplemental light of 170 lx is recommended during hours of darkness for ease of observation during lambing or kidding. In outdoor pens, lighting may deter predators, but it can 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 or management system has special light or photoperiod requirements, illumination in all animal rooms should mimic a normal diurnal pattern of intensity and duration. Specified altered diurnal lighting may at times be implemented for certain reproduction research or for accelerated reproductive management systems that include autumn lambing and kidding because sheep and goats are sensitive to, and can be manipulated with, changing photoperiod 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 recommendations for sheep and goats and factors (feedstuffs, environmental, physiological, behavioral, and diseases) affecting nutrient requirements and availability are addressed in *Nutrient Requirements of Small Ruminants: Sheep, Goats, Cervids, and New World Camelids* (NRC, 2007). Comprehensive descriptions and solutions for assessing and managing feed and metabolic-related diseases in sheep are discussed in the *Sheep Production Handbook* (ASIA, 2015).

A variety of feed ingredients may be fed to sheep and goats, but changes in the relative amounts of forages 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 compositions should be determined, 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 so that all animals have access to feed (see Table 10-1) is important for sheep and goats when feeding limited amounts of feedstuffs that are consumed quickly (supplements and concentrates). An alternative is to offer a diet with adequate potentially fermentable neutral detergent fiber in a self-feeder at which groups of animals take turns eating. A minimum dietary concentration of potentially fermentable neutral detergent fiber provides substrates for normal ruminal fermentation and prevents metabolic disturbances (Thonney and Hogue, 2007; Thonney, 2017).

Sheep and goats in some production settings undergo periods of nutrient deficiencies or intake limitations 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 can minimize the negative effects of such changes. Unlike cattle, where visual assessment can be used to accurately determine BCS, manual palpation of the sternum and spinous process is necessary in sheep and goats (Gaden, 2005). 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 of 2 on a scale of 1 to 5, some animals will have lower BCS, perhaps ≤ 1.5, which may be undesirable for an extended period. Animals on limited planes of nutrition with low BCS can be more susceptible to disease under adverse environmental conditions. Thus, they are 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 unless this is part of an approved protocol.

Both sheep and goats consume a variety of plants (grass, legumes, forbs, and shrubs) when foraging on pasture or range. Unlike sheep, which are primarily grazers, goats are naturally browsers and will seek out small woody plants and brush. Their browsing behavior extends to not just what they eat, but how they eat it; when given the option, goats will adopt a variety of stances, including foraging elevated (above their head) and bipedal (Sanon et al., 2007; Tölü et al., 2012). It has been suggested this type of foraging behavior helps decrease parasite load (Hoste et al., 2001). Goats will eat more from elevated feeders (Neave et al., 2018), and offering feed at different levels decreases aggression (Aschwanden et al., 2009).

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. 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. When risks of plant secondary metabolite exposure are expected from pasture or a fed diet, animals should be monitored closely.

Sheep and goats are sometimes used as biological control agents for managing invasive plant species (Lym et al., 1997; Arviv et al., 2016). 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. Animals showing marked signs of nutrient deficiencies or toxicosis should be removed and treated accordingly.

Water

Sheep and goats must have access to an adequate supply of potable water to avoid dehydration, unless dehydration is a component of an approved research protocol. Their water requirements increase during hot and humid weather, and water availability may need to be adjusted. Freezing of the water supply should be addressed in cold environments. Outdoors, even though an adequate supply of liquid water is preferred, nonlactating sheep may 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).

Water requirements of sheep and goats are based on, but not limited to, physiological state, dry matter intake, climatic conditions, and environment (Marai et al., 2007). 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. When sheep or goats are closely confined, water buckets or troughs can easily become contaminated with feces, bedding, or feed. These sources of water should be checked daily and cleaned if necessary.

Sheep and goats satisfy their water requirements from drinking water, food (preformed water such as that found in lush forages), and metabolic processes (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 recommended (NRC, 2007) for liquid water to be available continually to sheep and goats, this is not practiced in some production and research settings. Sheep on range or pasture may satisfy their water requirement from fresh forages as preformed water (Lynch et al., 1972) or snow. However, this has not been validated with breeds and genotypes that have not been adapted to arid environments, breeds that have high genetic potentials for performance, or nonnative forage varieties.

When cold drinking water is consumed in large volumes, the temperature of the rumen may decrease, which reduces the activity of ruminal microorganisms (NRC, 2007). However, when water is available in the form of snow, sheep 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).

Under some circumstances, water availability need not be continuous. For example, research animals in a head-box respiration calorimetry system may be offered water at discrete times, perhaps twice daily, to prevent accumulation of excessive moisture in the calorimeter and thus compromise the integrity of the research.

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 National Research Council publications for dairy cattle (NRC, 2001) and beef cattle (National Academies of Sciences, Engineering, and Medicine, 2016) are excellent sources of information on water contaminants that reduce livestock production. Historical records of water quality can be investigated, or appropriate analyses should be conducted on drinking water sources. Water contaminants, although not necessarily harmful to sheep, may interfere with results of experiments, such as in mineral balance studies.

Manufactured watering receptacles should be inspected and cleaned regularly to ensure that adequate supplies of good-quality water are available as appropriate with the setting. 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 behaviors 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). Waterers should be located in areas that facilitate research and (or) teaching goals and do not compromise the surrounding environment.

MANAGEMENT

People using sheep and goats for research and teaching should be trained and skilled in observation for general wellbeing of the animals and in procedures they will perform. Sheep and goats should be frequently monitored for lameness and other symptoms of ill health. Procedures for which demonstrated proficiency may be required include injections (intramuscular, intravenous, subcutaneous, and intraperitoneal), ear tagging, ear notching, ear tattooing, tail-web tattooing, deworming (drenching), shearing, docking, and hoof care (including detection, treatment, eradication, and prevention of contagious foot rot; and trimming to remove hoof overgrowth; and trimming to mitigate other causes of lameness). Correction of entropion (eyelids turning inward) should be performed as soon as possible after birth. Immunization should be provided against clostridial diseases. The advice of a veterinarian should be obtained about whether vaccination against other diseases, such as caseous lymphadenitis, rabies, and "abortion diseases," including *Campylobacter jejuni* or *Campylobacter fetus* is necessary. Ewes and does should be boostered against *Clostridium perfringens* types C and D and *Clostridium tetani* about 2 wk before the start of lambing or kidding to provide protection against enterotoxemia via colostrum (de la Rosa et al., 1997). Care should be taken when handling late-gestation animals because extensive handling can be extremely stressful.

It is preferable that lambs and kids nurse their dams (or a foster dam) within 6 h of birth to obtain colostrum. Otherwise, colostrum should be provided in the period from immediately after birth to 6 h of age as a source of antibodies to avoid disease during the neonatal period. Suckling is preferred because it triggers the esophageal groove reflex necessary for best immunoglobulin absorption. However, it is recognized that the experimental protocol may require administration of colostrum via an esophageal feeder. To eliminate a possible route of transfer of disease into research and teaching settings, the practice of using raw colostrum from sources outside the flock to supplement or replace colostrum from a lamb's or kid's dam is not recommended. Cow colostrum may be a source of *Mycobacterium avium* ssp. *paratuberculosis* that causes Johne's disease. In addition, viral diseases, such as lentivirus diseases (caprine arthritis encephalitis and ovine progressive pneumonia), can be transferred through raw ewe and doe colostrum and milk (Herrmann-Hoesing et al., 2007). Heat treating colostrum may reduce the likelihood of transferring pathogenic bacteria and viruses, but it also may denature antibodies unless a specific protocol is followed (Loste et al., 2008). Detailed information on management procedures of sheep and goats is described in the *Sheep Production Handbook* (ASIA, 2015), the *Sheep Care Guide* (Shulaw, 2005), *Goat Medicine* (Smith and Sherman, 2009), *Small Ruminant Production Medicine and Management: Sheep and Goats* (Faerber, 2004), *Management and Diseases of Dairy Goats* (Guss, 1977), *Goat Production* (Gall, 1981), *Goat Management* (Mackenzie, 1993), *Goat Farming* (Mowlen, 1992), and *Meat Goat Production Handbook* (American Institute for Goat Research, 2007). In addition, a web-based training and certification program for meat goat producers is available at http://certification.goats.langston.edu/.

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 near 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. If housing with familiar animals is not feasible, then consideration should be given as to how the teaching or research outcomes are affected. 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 should be monitored frequently to reduce the possibility of injury or distress after separation.

Care must be taken when introducing new animals into sheep and goat flocks. Regrouping goats is particularly stressful and may create elevated levels of aggression (Andersen et al., 2008; Miranda-de la Lama and Mattiello, 2010). Unacquainted rams or buck goats may fight and severely injure or even kill each other. Although fighting cannot be entirely prevented, several methods can be used to try to decrease its severity. Injuries among newly grouped males can be reduced by severely restricting pen space 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 can be increased. 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, provision of extra feeders and space can be used to decrease aggression or social dominance when new animals, especially those having horns, are introduced to a flock or herd.

In intensive management, 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). If claiming pens do not provide sufficient space for animals to move about freely during labor and parturition, then ewes or does should not lamb or kid in them. Claiming pens can become wet and very difficult to keep clean and become sources of disease. Restricting the periparturient female's movements may increase the chances that dams will step on or lie on offspring. Ewes and does should lamb or kid in a relatively open area that can be observed easily; however, opportunity for self-segregation should also be provided. If possible, they can then be moved with their offspring into claiming pens to ensure bonding. Except in special cases, lambs and ewes should normally be removed from claiming pens within 24 to 48 h.

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 location with the recognition that programs that work for sheep may not be effective for goats at the same location, and vice versa. Most available anthelminthics are no longer adequately effective against *Haemonchus 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 anthelminthics, combined with new diagnostic procedures such as the FAMACHA eye color chart system (Vatta et al., 2001; Kaplan et al., 2004; Yilmaz et al., 2016), 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 website (http://www.wormx.info). *Small Ruminant Production Medicine and Management: Sheep and Goats* (Faerber, 2004) contains descriptions and images of how to administer dewormers (drench) to sheep and goats. There is limited evidence to suggest breed differences in resistance to worms (Dominik et al., 2010; Silva et al., 2012; Romero-Escobedo et al., 2018). However, comprehensive characterization of breeds for resistance or resilience to parasites is lacking. Studies involving natural or artificial parasite infection must have appropriate protocols for monitoring disease symptoms and for removal and treatment of severely diseased animals.

In feedlot or laboratory environments, where pasture is not a potential route for parasite lifecycle maintenance, parasites such as *H. contortus* may not be a concern. However, in these same environments, parasites that are not primarily pasture driven, such as 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 condition, which may include pastures of various sizes (Whittier et al., 2003). Provision of adequate clean bedding and ensuring clean feeders can help limit the parasite challenge.

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 more desirable if weather and housing conditions are appropriate.

Hair-breed sheep and short-haired goats do not require shearing. Wool-breed × hair-breed crossbred sheep may occasionally require shearing 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 with the goal of ensuring the health and well-being of the animals.

The shearing facility should be clean and dry. Information on design is given in the *Sheep Production Handbook* (ASIA, 2015) and in Barber and Freeman (2007). To minimize the spread of infectious disease (e.g., caseous lymphadenitis, which is caused by infection with *Corynebacterium pseudotuberculosis*), 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, 2015). Electroimmobilization must not be used to restrain sheep for shearing. Ewes in the 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 digestible dry matter concentration of the diet for a period before and after shearing. In hot, sunny weather, shade may be necessary to prevent sunburn on recently shorn white-skinned animals. Windbreaks, which may also provide shade, are beneficial under many environmental conditions.

STANDARD AGRICULTURAL PRACTICES

Other management 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, 2015), *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* has information that may enhance training programs for people who manage and care for sheep and goats for research and teaching (Hoffman et al., 2013).

Tail Docking

Tail docking of lambs from wool breeds 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. There are several acceptable methods for tail docking. These include rubber rings, hot-iron cautery, surgical removal, and surgical removal after application of an emasculator, and various combinations of the basic procedures (Battaglia and Mayrose, 1981; Smith et al., 1983; Ross, 1989; Kent et al., 2004; ASIA, 2015). The length of tail that remains after docking has been implicated in the incidence of prolapse in sheep. However, vaginal and uterine prolapse are only occasional problems in sheep and are even rarer in goats (Miesner and Anderson, 2008). Tails should be docked when lambs are as young as possible, preferably before 2 wk of age. Thomas et al. (2003) evaluated data from several locations with differing genetics to determine whether docking length was related to rectal prolapse. Thomas et al. (2003) implicated short dock length as a cause of rectal prolapse in lambs finished on high-concentrate diets. They suggest that docking lambs at the site of the attachment of the caudal folds to the tail will result in a negligible incidence of rectal prolapse. Goodwin et al. (2007) recommended that "more research on the issue of rectal prolapse as related to the interrelationships of tail length and the effects of diet, stress, and most important genetics" be carried out. Lewis (2013) placed rubber rings within 24 h of birth just past the distal ends of the caudal folds of the tail of lambs and found that tail length increased from banding to weaning as well as to market weight, and was significantly greater for male lambs that were a black face × white face cross. Hence, breed and sex affected the length of the tail as did breed type. Thus, docking a prescribed length will not result in a uniform tail length at weaning or market weight. However, in an underpowered study, Zanolini et al. (2014) found no difference in the number of animals that prolapsed when (1) tails were docked close to the body, (2) tails were docked midway from the attachment of tail to caudal folds, or (3) tail was removed at the attachment of the tail to the caudal fold. They also did not find sex or muscling (Callipyge phenotype) influenced the number of rectal prolapses. The incidence of vaginal prolapse reportedly occurs more frequently in dairy breeds of goats (Anderson, 2012). Short docking of lamb tails may also increase risk for joint infections compared with lambs having three or more palpable coccygeal vertebrae remaining in the tail stump (Lloyd et al., 2016). The AVMA (2014) recommended length for docking is variously expressed as visibility of 0.7 in of tail, docking at the third or fourth coccygeal vertebrae, or docking at the end of the caudal fold/hairless under-tail area. When practiced, it is recommended that lambs have their tails docked at the site of the attachment of the caudal folds to the tail. Goat kids have an erect tail that should not be docked.

Castration

Castrated males (wethers) may be preferable to intact rams due to reduced agonistic behavior (Fahmy et al., 1999); undesirable odors and flavor of meat from rams (Seideman et al., 1982), and improved meat tenderness of meat from wethers (Seideman et al., 1982; Sales, 2014). Retention of postpubertal rams and bucks may also pose managerial issues in genetic improvement programs, regulating the time of year of lambing and controlling the minimum age of first parturition and lactation. There are 3 commonly accepted methods for castrating rams and bucks: (1) application of rubber rings, (2) crushing the spermatic cord with an emasculator (the Burdizzo method), and (3) surgical removal of the testicles. Various combinations of the 3 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 protocol precludes bilateral castration. Detailed descriptions of castration procedures are available in various publications (e.g., Greiner and Wahlberg, 2003; Faerber, 2004; ASIA, 2015). 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 Molony, 1992). Nevertheless, castrating lambs and kids as early in life as possible, considering weather, nutritional stress, environment, and the presence of complicating disease processes, is prudent. Lambs are typically castrated and docked at the same 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 immunity via colostrum (de la Rosa et al., 1997). Vaccinating dams prepartum will reduce the incidence of tetanus in their offspring 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 (Wood et al., 1991; Sutherland et al., 1999; Price and Nolan, 2001; Kent et al., 2000, 2004). It is recommended that tail docking and castration be done at less than 1 wk of age and that either procedure performed on sheep older than 3 mo should be treated as a major surgical procedure using appropriate analgesia or anesthesia. In young lambs, use of topical anesthesia is recommended following these procedures because it alleviates wound pain, significantly reduces pain-related behaviors, and does not compromise wound healing (Lomax et al., 2010).

Disbudding and Dehorning

Goats without horns are preferred in some situations so as to avoid injury to handlers or animals. Horns on goats (especially non-dairy goats) are common in commercial production. If goats are to be disbudded, the procedure 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 can be used, although surgery, freezing, and an acidic paste are other options. Disbudding and dehorning of young goats is painful (Alvarez et al., 2009, 2015; Alvarez and Gutierrez, 2010). If done incorrectly (e.g., too much pressure, too long application), it can also cause brain injury (Thompson et al., 2005). While local anesthetics (e.g., lidocaine) have proven efficacy with calf disbudding, their use in kids is more problematic. Toxicity (Buttle et al., 1986), causing convulsions and respiratory and potentially cardiac arrest, and general inefficacy to alleviate pain have been reported (e.g., Alvarez et al., 2009, 2015). Analgesia should be provided for postoperative pain mitigation. Horns of adult goats should be removed under general anesthesia or sedation with postoperative administration of analgesics 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 is not completely eliminated, even after a second procedure approximately 1 mo after the first. Dehorned sites are prone to fly strike, and dehorning does 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, or 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. A surgical procedure called "mulesing" was developed to remove wrinkled, wool-bearing skin and reduce fly strike (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. A combination of a local anesthetic and a long-acting nonsteroidal anti-inflammatory drug may reduce the discomfort and pain associated with mulesing (Paull et al., 2007). Nonetheless, mulesing should not be performed.

ENVIRONMENTAL ENRICHMENT

Animals benefit from the opportunity to perform natural behaviors. In particular, goats are known climbers and benefit from environments that allow for this behavior. Refer to Chapter 4: Environmental Enrichment for information on enrichment of sheep and goat environments.

HANDLING AND TRANSPORT

The *Sheep Production Handbook* (ASIA, 2015) and *Sheep Care Guide* (Shulaw, 2005) contain information about handling facilities and transportation. Refer to Chapter 5: Animal Handling and Transport for information on handling and transportation of sheep.

SPECIAL CONSIDERATIONS

Dairy Sheep and Goats

Sheep and goats have been used as dairy animals for centuries in many countries. However, dairy sheep and goat research and teaching activities 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), *Sheep Production Handbook* (ASIA, 2015), and the *New Zealand Code of Welfare: Goats* (MPI, 2018) describe the management and care of dairy sheep and goats. Information in Chapter 7: Dairy Cattle of this guide may also be applicable to sheep and goats, although the details are species-specific and management plans should be developed with this 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. These include the design, sanitation, and maintenance of milking parlors, milk handling and storage equipment, frequent animal movement and handling, udder care, increased risk of mastitis, artificial rearing of offspring (Umberger, 1997; Berger et al., 2004), manipulating nutrition to increase and sustain milk yield and quality, greater water requirements, increased risk of heat stress, and greater metabolic health risks such as ketosis and pregnancy toxemia (Zobel et al., 2015) due to metabolic demands of milk production. 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 known by 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 seasons, sheep and goats need to be protected from predators such as dogs, coyotes, bears, wolves, mountain lions, and some species of birds. Contact between unsupervised domestic dogs and sheep and goats should not be allowed. Nonlethal means of predator control such as guard animals, lights, noise, and fencing are preferable but may be inadequate or infeasible. Special fencing such as electrified netting may be used to exclude most predators from livestock pastures (ASIA, 2015). 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.

Laboratory Environments

Certain laboratory settings do not allow for or utilize any range or pasture. These environments may include traditional outdoor feedlots, indoor/outdoor feedlots, or entirely indoor housing with natural or manufactured surfaces with several bedding possibilities, such as straw, wood shavings, recycled paper products, sand, dirt, and compost. When housed indoors, goats have been noted to select different flooring surfaces for different behaviors; for instance, hard surfaces for lying and wood shavings for defecation and urination (Sutherland et al., 2017). Therefore, these preferences should be considered when intensively housing goats.

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 these 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. If possible, it is recommended that sheep and goats not be housed alone and that they 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 such as metabolic, respiratory, or environmental chambers should such housing be considered for sheep and goats. A common and beneficial practice is to shear sheep and fiber-producing goats before they are moved into intensive laboratory conditions. This improves animal and facility hygiene, often prevents reduced feed consumption, and reduces the size of the animals and thus their requirement for usable space. If sheep and goats are managed under intensive laboratory conditions for extended periods, it may be necessary to increase the frequency of hoof trimming.

Sheep and goats housed in intensive laboratory environments should be kept clean and dry, and excreta should be removed on an appropriate schedule. Pens and stalls should be washed thoroughly before every experimental period and as needed thereafter. Urine and fecal collection vesicles should be kept clean, 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.

When the activity of sheep and goats maintained in intensive laboratory environments is restricted, they should be observed at least daily. In research settings, automatically recorded measures of activity (e.g., via accelerometers) can be useful. These observations can assist in assessing changes in behavior that potentially result from the imposed treatments, and may add robustness to the study by including behavioral measures. 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 evaluate studies carefully that require sheep and goats to be housed in intensive laboratory environments; and 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, attention should be given 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.

Contact of sheep and goats with unwanted animals and vermin, such as birds, rodents, insects, and feral cats should be avoided when possible. Adequate pest-control measures are necessary to prevent bird nests and roosts in barns and sheds. Rodents, which may vector several diseases, should be controlled.

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. Control programs, such as using fly parasites, should be considered when fly strike may be a possibility. Mosquitoes can transmit viral agents such as West Nile virus, and mosquito control programs can be instituted to minimize such exposure.

Transgenics and Cloning

Refer to Chapter 1: Institutional Policies for information on transgenesis and cloning as they relate to animal care and use. Information on the additional regulatory oversight of transgenic animals and those researchers or institutions working with transgenic animals is available in *Guidance for Industry: Regulation of Intentionally Altered Genomic DNA in Animals* (FDA, 2018).

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, 2020) 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. Nonpenetrating captive bolt options exist for neonate kids and lambs (Sutherland et al., 2016; Grist et al., 2018a,b). 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 Slaughter

Lairage 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 (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.

In the United States, all procedures used to slaughter research and teaching animals that will enter the food chain must comply with US Code of Federal Regulations, Title 7, Chapter 48, Humane Slaughter of Livestock (https://www.govinfo.gov/content/pkg/USCODE-2011-title7/pdf/USCODE-2011-title7-chap48.pdf). The North American Meat Institute (NAMI) has embraced guidelines (https://animalhandling.org/producers/guidelines_audits) that exceed the regulatory requirements (Grandin, 2017) and the NAMI guidelines (NAMI, 2019) are incorporated here by reference.

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CHAPTER 11: MEAT-TYPE POULTRY

INTRODUCTION

This chapter addresses the animal care guidelines of meat poultry encompassing meat-type chickens and turkeys, together with other meat avian species, including Japanese quail, emu, and ostriches. In addition, the chapter discusses animal care guidelines for the parent stock for meat-type chickens and turkeys; namely, broiler breeders and turkey breeders.

The welfare of meat-type poultry requires the following:

- housing with heating and cooling systems such that birds are at, or close to, temperatures optimal for their respective ages and with suitable ventilation to ensure a high quality of both air and bedding;
- availability of feed and water to provide adequate nutrition, with feed and water available at such heights to facilitate eating and drinking and with sufficient space (often expressed as linear space in the feeder) to allow all birds to eat sufficient feed for well-being;
- programs (such as sanitation, biosecurity, and appropriate veterinary care) to ensure prevention and treatment of diseases including endo- and ectoparasites;
- facilities designed to minimize the risks of injury to birds and caretakers and to facilitate humane handling;
- freedom from fear and distress (e.g., this is achieved by minimizing exposure to predators or aggressive conspecifics); and
- timely euthanasia.

It is noted that discussion is limited to where unequivocal information is available and is such that proscriptive approaches can be included. Where appropriate, enrichment of the bird's environment is encouraged.

Importance of Observing Bird Behavior

It is important to observe of the behavior of poultry because this provides an indication of their well-being. For example, chicks or poults exhibit behavioral responses to environmental temperatures—huddling when cold or spreading away from the heat source when too warm. Chickens also pant to dissipate excess heat. It is important to compare bird behaviors with norms within the species.

It is useful to observe growing birds, particularly relative to the feeders and waterers, to ensure that all the birds can reach both feed and water. If they cannot, smaller birds are at risk. It is also important to observe social interaction and aggression between birds in the flock and to evaluate any birds that may have a compromised state of health or welfare.

Birds should be inspected at least daily, with increased observation frequency depending on the nature of the research. Good communication among caretakers and the principal investigator is important. Caretakers should be instructed to record their visits to the house (date, time, and name or initials), any problems (including mortality, culling, equipment repair), pertinent observations that were noted during their visit, and any actions taken.

Training of Personnel

All bird handling must be accomplished in such a manner as to minimize stress and avoid injuries. All personnel working with poultry should be trained in all the techniques that they would be expected to perform. Ideally, the principal investigator, project leader, or their designee will already have expertise in the required techniques and can directly teach those to others in the group including students and other people working in the poultry facility. When that is not possible, the principal investigator or project leader should bring in the required expertise from elsewhere in the institution or from outside. Training should, preferably, include one-on-one contact with feedback.

Considerations for Broiler Chickens and Turkeys

Management systems for broiler chickens, broiler breeders, growing turkeys, and turkey breeders should meet the basic needs of the birds but should also, in situations replicating industry conditions, attempt to optimize production performance. To achieve these goals, management must incorporate a plan that includes care, housing, nutrition, ventilation, lighting, and health during pertinent life stages to maximize animal well-being. Researchers and oversight committees may wish to refer to the guidelines from primary breeders available at the breeding company websites; guidelines are updated regularly. These guidelines, in turn, are based on primary literature, when available, such as for photo-stimulation (Renema et al., 2007; Robinson et al., 2007; Zuidhof et al., 2007, 2015), but also on unpublished internal research within a company together with industry experience.

Other Considerations for Turkeys, Ratites, and Quail

There is a relative paucity of published research on turkeys. Caution is expressed about transferring results from broiler chickens to growing turkeys because there can be markedly different responses, for instance, to different photoperiods (Schwean-Lardner et al., 2016; Vermette et al., 2016a,b). The lack of published research is worse for ratites (e.g., ostriches and emus) and quail. In the absence of scientific information, the present recommendations for turkeys, ratites, and quail are based on professional judgment and experience.

FACILITIES AND ENVIRONMENT

Housing and environment (e.g., lighting, feed, water, ventilation) should be planned and implemented for each stage of a bird's life. The housing environment and all equipment utilized in the house should be thoroughly cleaned and sanitized before bird placement. Housing should be secure to limit exposure of chicks to vermin, wild birds, and disease, and to maintain satisfactory temperatures for chicks.

Flooring

Poultry may be kept on solid floors with litter or on slatted floors or in cages or pens with raised wire floors of appropriate gauge and mesh dimension or with solid floors. When poultry are placed on solid floors, litter provides a mechanical cushion during motor activity and resting and absorbs water from droppings. Growing broiler chickens and turkeys are typically raised on litter.

Ammonia and Noxious Gases

Ammonia (NH_3) concentration is a particular issue in broiler chicken and turkey houses because of microbial degradation of excreta. Ammonia can negatively affect the well-being of the birds and compromise worker health (Kristensen and Wathes, 2000; Miles et al., 2004). The ideal NH_3 concentration is less than 10 ppm, whereas a concentration less than 25 ppm is the normal industry standard for ammonia concentration. Adequate ventilation can assist in lowering NH_3 below the threshold concentrations so that bird well-being and worker health are not compromised. It is recommended that ammonia concentrations at both bird and researcher levels are checked on a regular basis (e.g., immediately before placement and during grow-out) and more frequently when ventilation is low.

Litter Management

Litter in a broiler house should provide bird comfort, low dust, biodegradability, and moisture absorption (De Jong and Van Harn, 2012). Litter should be neither too dry and dusty nor too wet. One field test is to squeeze some litter in the hand. If it clumps together but readily breaks apart when prodded, the moisture level is adequate. Poultry will be negatively affected by either excessive dust or wet litter. Footpad dermatitis (FPD) and hock burns (HB) can be indicators of impaired welfare (e.g., Dawkins et al., 2004; Shepherd and Fairchild, 2010). Litter quantity and quality influence both FPD and HB, with lower litter depth associated with increased incidence of FPD and HB (e.g., Haslam et al., 2007). Moreover, the incidence of FPD is higher in winter and related to poor litter conditions (e.g., Dawkins et al., 2004; Haslam et al., 2007; Meluzzi et al., 2008). The increase in FPD in winter is related to reduced rates of ventilation, elevated atmospheric humidity, and greater litter moisture associated with a much higher percentage of birds having dirty food pads (Dawkins et al., 2004). Litter moisture is also related to heater positioning and number of drinkers (Dawkins et al., 2004). In addition, elevated concentrations of NH_3 arising from moist litter can impair broiler health (Dawkins et al., 2004). Maintaining records of the incidence of FPD and HB is encouraged.

Litter

Broiler chicks and turkey poults should be placed and raised on fresh bedding or litter materials such as pine or hardwood shavings or rice hulls. At placement and brooding, ensure the litter is evenly spread to a depth of 7.5 to 10 cm (3 to 4 in). The condition of the litter is very important to the well-being of growing broiler chickens or turkeys. The litter should be as free of contaminants as possible and consistently available from a reliable biosecure source. The preferred litter materials in many areas are pine shavings, sawdust, or rice hulls. However, the use of these may be limited by cost and availability. Alternatives include the following: hardwood shavings and sawdust (disadvantage: a tendency for high moisture and susceptibility to mold growth), pine or hardwood chips (disadvantage: may be associated with the development of breast blisters), chipped pine or hardwood bark, peanut hulls (disadvantages: lack of general availability and susceptibility to mold growth), coconut husks (disadvantage: lack of general availability), sand (disadvantages: requires good management due to susceptibility to retain water and difficulty in ensuring optimal floor temperature; usually requires concrete floors), crushed corn cobs (disadvantages: lack of general availability; may be associated with the development of breast blisters), chopped straw or hay (disadvantage: risk of caking and mold), straw pellets (disadvantage: high water holding and hence wet environment), chemically treated straw pellets (disadvantage: must be used following supplier's instructions), processed paper (disadvantage: risk of caking and difficulty of management in humid areas), peat moss, and flax straw. Recycled (reused) litter may be used to ensure that the research is relevant to industry practices. There are risks of excess moisture or contamination with pathogens (Dumas et al., 2011); these may be reduced by top-dressing with fresh shavings or a new litter substrate (Coufal et al., 2006) and removing wet litter.

Turkey Poult Flooring/Deep Litter

Poults (newly hatched turkeys) should be placed and raised on fresh bedding or litter materials such as pine or hardwood shavings or rice hulls. At placement and brooding, ensure the litter is evenly spread to a depth of 7.5 to 10 cm (3 to 4 in). The condition of the litter is very important to the well-being of growing turkeys. Wet litter can result in FPD (reviewed by Glatz and Rodda, 2013). Litter adjacent to feeders and waterers is likely to become damp due to accumulation of droppings or water spillage and may need to be raked or tilled to facilitate drying. Recycling used litter and covering damp bedding with fresh bedding are also acceptable. The litter should be maintained as friable and dry. The litter (sampled in the middle of the barn) should be friable; that is, loosely compacted in the hand when squeezed. Wet or caked litter may be tilled to dry it. Maintaining records of the incidence of FPD and HB is encouraged.

Lighting

The lighting program is a management technique that consists of light wavelength, photoperiod, and light intensity (Olanrewaju et al., 2006). Light is detected by the eyes and extra-retinal photoreceptors (e.g., Foster et al., 1985; Mobarkey et al., 2010). Endogenous daily rhythms or circadian clocks are located in cells in the hypothalamus and elsewhere, including the pineal gland, and they can be entrained by light. Melatonin is a hormone produced in the pineal gland and is involved in feed and water intake, regulation of body temperature, and immune function (Apeldoorn et al., 1999). It is secreted in a circadian rhythm, with higher concentrations produced during the dark period and lower concentrations during the light period, which suggests that optimum performance requires a diurnal light cycle containing a dark period.

Broiler Chickens. Growth performance, meat yields, leg abnormalities, and behavior of broiler chickens are influenced by lighting programs. In the past, researchers have utilized constant day length to optimize performance objectives. However, Schwean-Lardner and colleagues (2012, 2013, 2016) reported decreased growth performance and meat yields, increases in both mortality and leg abnormalities, and compromised well-being in broilers on very long day lengths (23L:1D; that is, 23 h of continuous lighting, simulating day, and 1 h of darkness, simulating night) compared with birds under day lengths of no more than 20 h of light. Broiler chickens grown at 20L:4D and 23L:1D had higher mortality and cull losses than those grown under longer scotoperiods (the period of darkness; Schwean-Lardner et al., 2016).

Light duration is frequently continuous (24 h of light per day) during the first 2 d of brooding to optimize chick activity levels and facilitate the chicks finding feed and water. Lighting can then be slowly decreased (in intensity and duration) to achieve the expected rearing light program by 2 to 3 wk of age. After broilers reach 7 d of age, the photoperiod should include at least 4 h of darkness per day [<0.5 lx or <0.05 foot candles (fc)]. Subsequently, beginning 1 wk before processing age, the photoperiod may be returned to continuous lighting. A constant light period will not interrupt the feed passage rate in broilers undergoing a feed withdrawal period before processing.

Attention should also be given to light intensity. Providing constant lighting coupled with lighting intensity of 20 to 60 lx (1.8 to 5.6 fc) from 1 to 7 d of age allows birds a good start during brooding. Very low light intensity has been reported to lead to blindness in poultry (Cummings et al., 1986; Buyse et al., 1996). In contrast, Miller et al. (2007) reported no differences in corneal lesion score when broilers were subjected to varying lighting intensities (2.0 vs. 0.20 lx; 0.2 vs. 0.02 fc) from 8 to 36 d of age. It is suggested that the lighting intensity during the photophase from 8 d of age be at least 5.0 lx (0.5 fc) to avoid eye damage or blindness.

Broiler Breeders. Lighting should be controlled during the rearing period for broiler breeders to optimize flock uniformity, promote bird growth and activity, and control sexual maturation. Lighting duration should be 8 h/d, and lighting intensity should be 5 to 10 lx (0.5 to 1.0 fc). Lighting should be tightly controlled during phase 1 (about 21 wk to first egg) of the laying period to optimize flock uniformity, promote sexual maturation, and control the onset of lay. To achieve sexual maturation and egg production, day length is increased from 8 h/d to approximately 15 h/d over several weeks. Increases in hours of light can be achieved via a set program with planned increases over several weeks. Alternatively, increases may be adjusted in accordance with the body weight (BW) and condition of the hens.

In addition, to achieve optimal reproductive performance, lighting intensity is increased from 5 to 10 lx (0.5 to 1.0 fc) to 40 to 60 lx (4 to 6 fc). If open-sided or curtain-sided housing is used during the laying period, artificial daylight must always bracket the hours of natural daylight.

Growing Turkeys. Growing turkeys can thrive in a wide variety of lighting programs. It is common to use long light periods (i.e., 23 h/d) for the first few days to ensure that poults can find food and water. In the early post-hatching period, a period of darkness of at least 4 h should be used (National Turkey Federation, 2016) with up to 8 h per 24-h period commonly used. However, growth rates to 126 d old are maximal under 14L:10D, with a progressive reduction in growth rate as photoperiod increases as follows: 17L:7D > 20L:4D > 23L:1D; the lower growth rate at the longest day length is coupled with much greater mortality and cull losses (Schwean-Lardner et al., 2016). Light intensity can be reduced if necessary to alleviate injurious pecking and other harmful behavior such as excessive mounting.

Breeder Turkeys. Lighting (intensity and duration) is a major factor influencing turkey reproduction. Turkeys are photostimulated; that is, brought into reproductive condition by long day lengths (e.g., Grimes and Siopes, 1999; Siopes, 2010). Photostimulation is the process of increasing day length to cause sexual maturation and maintenance of reproduction. Photorefractoriness is a condition in which birds become insensitive to the stimulatory effect of long day length. Photorefractoriness is terminated when birds are placed on a short daily photoperiod.

Unfortunately, data from the research literature on optimal conditions for raising and breeding turkeys are very limited. It should not be assumed that practices for broiler breeders automatically apply to breeding turkeys. The following synopsis of husbandry is derived from information available from Aviagen turkeys, the primary breeder of both Nicholas and BUT turkeys. Turkey pullets destined to be breeders (0–17 wk old) can be raised in a day length of 10 to 14 h of lighting per day with a light intensity of 80 to 100 lx (8 to 10 fc). The extended photoperiod allows sufficient time for feeding. Subsequently, day length is normally reduced to a short day length (e.g., 6L:18D) with a moderate light intensity of 20 to 100 lx (2 to 10 fc). The short photoperiod prevents both sexual development and photorefractoriness (Siopes, 2010). After a period on short day length and when they are close to the age of puberty, turkeys are photostimulated. It is common to use long light periods (i.e., 23–24 h/d) with minimal light intensity of 86 lx for the first 3 d, followed by 10 to 14 h of light per day. Light intensity can be reduced to minimize injurious pecking (Grashorn, 2011; Schwean-Lardner et al., 2016). It is important not to decrease light once the stimulatory phase before the onset of egg production has been initiated (particularly important in fall and winter; Grimes and Siopes, 1999). Alternatively, at 30 wk old, the pullets can be photostimulated with a long photoperiod (e.g., 14L:10D) and a higher light intensity; for example, 120 lx (11 fc).

Breeding Ratites. The breeding season for ostriches is about 8 mo (217 d) from mid-May to mid-December in the Southern Hemisphere (South Africa; Brand et al., 2015a,b). This is consistent with ostriches being short-day breeders; that is, having their reproductive system develop and function by a stimulatory short-day length or photoperiod. Similarly, emus are short-day breeders, becoming reproductively active in the autumn and winter (Malecki et al., 1998; Blache et al., 2001). To bring emus and ostriches into reproductive condition, a short daily photoperiod of 10L:14D or lower lengths of photophase are required.

Breeding Quail. A photoperiod of 16 h of light and at least 22 lx (2 fc) is required for maximal egg production in breeding quail (Randall and Bolla, 2008; Molino et al., 2015).

Ventilation

Proper ventilation removes dust, moisture, carbon monoxide (CO) and carbon dioxide (CO_2) and provides oxygen (O_2). During brooding, it is important to ensure the absence of drafts. At later ages, when excreta volume is greater, ammonia (NH_3) must also be removed. Adequate ventilation will keep bedding dry and friable. The range of relative humidity (RH) should be 50 to 65%, CO_2 concentration <3,500 ppm, CO concentration <35 ppm, and NH_3 concentration <25 ppm (ideally <10 ppm). It is important to ventilate the house to remove all waste gases (CO_2, NH_3) and bring in fresh air to assure good air quality throughout the birds' living space. Ventilation is also important to control temperature and humidity in accordance with bird needs and comfort (air quality and litter quality). Ventilation systems should be checked daily. The facility should have an emergency ventilation system (i.e., curtain drop, generator, alarm) to provide minimum ventilation when power is lost.

Broiler Chickens. During hot weather, ventilation is particularly important to remove metabolic heat and water vapor from evaporative cooling pads and panting birds. Winter ventilation is needed to remove at least half of the metabolic heat (sensible:latent ratio of 50:50).

Broiler Breeder Chickens. During the laying phase for broiler breeders, it is especially important to provide adequate ventilation during the feeding period because birds will be more active and generate more metabolic heat while eating. The ideal temperature range for a breeder flock is between 15°C and 25°C (59°F and 77°F).

Temperature

Brooding. Supplemental heating should be provided for chicks for the first 2 wk of life. Chicks/poults require supplemental heat for the first few weeks ("brooding"). Without supplemental heating, mortality may be greatly increased. Two common brooding methods are conventional and whole-room brooding. In both cases, temperatures are lowered gradually as the chicks or poults age. Conventional brooder stoves provide heated areas where the chicks/poults can seek their comfort zone. With this system, the chicks/poults are temporarily contained by "brooder rings," which are cardboard or solid flexible fences. The heat source is near the center of the ring, and feed and water are nearby. Whole-room brooding requires a higher room temperature and no drafts. Chicks/poults that are too cold will huddle together so tightly that suffocation can occur, especially if there are corners in the brooding area.

The living space should be preheated before the chicks/poults arrive to ensure the floor or litter is warm and the air is at the goal temperature when the chicks/poults are placed. Minimum ventilation rates should be applied from the day before the chicks arrive. Environmental temperature should always be maintained for bird comfort in accordance with the recommended temperature guide for bird age. In addition to measurement of actual temperature, bird behavior and flock distribution should be evaluated daily to assess bird comfort. If chicks/poults are too cold, they will huddle. If chicks are too hot, they will move away from the heat source and will pant. Chicks/poults that are comfortable should be evenly distributed throughout the brooding space and should exhibit a variety of normal behaviors (e.g., eating, drinking, resting, actively moving) while the lights are on.

Summer Temperatures. Actual temperature can fluctuate beyond the set points in research facilities during the summer months. High temperatures can reduce feed intake, decrease growth rate, and increase the incidence of mortality. Air velocity can lower the effective temperature via heat removal. Even though the target temperature may not be maintained for broilers, an effective temperature with the use of fans and misting systems or cool cell pads may allow for adequate growth and livability objectives during a summer production period.

The effective temperature is that which birds experience when air movement removes heat (sensible heat loss), even though the actual temperature may not meet the target temperature. Evaporation of water through the use of cooling pads or misters can also reduce the effective temperature. Air velocity and cooling pads can reduce the effective temperature by between 9 and 12°C. Relative humidity (RH) affects the optimum temperature for poultry. For instance, the optimal temperature for 27-d-old broiler chickens is 24.8°C (76.6°F) at 40% RH but 19.3°C (66.7°F) at 70% RH (Aviagen, undated). See Chapter 3: Husbandry, Housing, and Biosecurity for a more detailed discussion.

Turkeys. The optimal temperature for growing turkeys decreases during growth. For example, one breeder (Aviagen) recommends a conventional brooding temperature during wk 1 of 30°C (86°F), followed by a gradual decline to 13°C (55°F) in wk 13. Heat stress markedly affects growing turkeys (Glatz and Rodda, 2013). Older turkeys (>10 wk of age) tolerate cool conditions (7.2–15.6°C; 45–60°F) but are susceptible to hot weather (>32.2°C; >90°F). Temperatures exceeding 35°C (95°F) are life threatening if airflow is not adequate.

Growing Quail. Newly hatched chicks should be maintained at 35°C (95°F) for 1 wk; then, the temperature can be reduced by 3.5°C (6.3°F) per week until 4 wk of age (Randall and Bolla, 2008).

Alternative Systems: Outdoor Access or Free Range

Organic production of poultry meat has expanded at more than 15% per year (Crandall et al., 2009; Fanatico et al., 2009). In organic poultry production, access to the outdoors is required (USDA, 2010). No differences in a series of metrics of stress were reported between pasture and conventional poultry production systems (Liles et al., 2015). Moreover, one factor to be considered for studies in which poultry have access to pasture is the presence of *Campylobacter* and possibly other food-borne pathogens. Although the rate of contamination of chickens with *Campylobacter* in Sweden was about 9%, the rate in broiler chickens on pasture was 70 to 100% (Engvall, 2002). Care should also be taken to protect animal caretakers from such food-borne pathogens.

The following are recommended for the outdoor areas for organic production and for pasture-raised or free-range poultry:

- Ranges or pastures free of debris and muddy areas (in the event of areas becoming waterlogged or muddy, slats should be provided).
- Fencing with fine netting to protect from predators. Ideally, fencing is extended into the ground to a minimum depth of 0.25 m (0.82 ft).
- Overhead fine netting to protect poultry from birds of prey.
- Vegetation (including grasses, crops, and bushes) to minimize soil erosion.
- Range rotation is suggested to reduce pathogens.
- Shelter from rain should be available.
- Openings (pop-holes or doors) with baffles should be available to allow birds to move from outdoors to indoors and vice versa.

There is a greater risk of passage of pathogens from wild birds to poultry raised with access to pasture. Ensuring biosecurity is critically important for poultry with access to pasture.

FEED AND WATER

It is again emphasized that researchers should consult with breeder guides for chickens and turkeys for feed and water requirements.

Water

Water should be sourced from a potable water supply if possible. Water from wells or open water sources should be continuously sanitized with an appropriate sanitizer such as free chlorine or chlorine dioxide (Watkins, 2008). Drinking water should not contain excessive amounts of minerals (particularly nitrate) and should not be contaminated with bacteria. Water equipment should be checked daily.

Water should be provided ad libitum each day at least when lights are on. If there are concerns about water spillage and birds playing in water, water can be restricted or turned off when the lights are off, because birds are not generally active during this period. The height of the drinker should be adjusted for bird height to ensure easy access at all times and reduce spillage. When possible, daily water consumption should be recorded as a standard welfare and good management practice. Substantially reduced or limited water intake will negatively affect bird welfare and well-being, growth, and egg production.

Broiler Chickens

Feed form for broilers can consist of mash, crumbles, or pellets. Broilers are typically fed diets in crumble form in the starter period, with subsequent feeds presented as whole pellets. However, mash feed may be used fed in experiments using small amounts of feed or with feed additives that may be heat labile. Feed is provided in either pan or trough feeders located inside floor pens or battery cages.

In battery cages, trough feeders can be attached on the outside of the cage, allowing broilers access to only one side of the trough, which reduces the linear feeder space. Feed space guidelines recommend 1.9, 2.5, and 3.2 cm of linear trough space/bird (0.75, 1.0, and 1.25 in of linear trough space/bird) for broilers <1.5 kg, 1.5 to 3.3 kg, and >3.3 kg, respectively (<3.3 lb, 3.3 to 7.25 lb, and >7.25 lb, respectively). Linear trough space is based on both sides of the trough being available. If only one side of the trough is available, feeder space/bird should be doubled. For commercial housing, manufacturers size the feeder pans to accommodate 50 to 75 birds per pan. The number of birds per pan depends upon bird size and distance between pans. Because floor pens of a research facility have a different dynamic than a commercial broiler house, it is recommended that a pan feeder should not exceed 50 birds per feeder, and pens having broilers with final weights exceeding 3.0 kg (6.6 lb) should be limited to 40 to 45 broilers per pan feeder.

Pan feeder height should be adjusted frequently after 14 d of age so that the lip of the pan is at a height equivalent to about the mid-point of the wing at that age. This will avoid placement of the feeder either too low or too high as the bird advances with age. Feeders at ground level are useful in providing chicks access to feed for the first week of age. Feeder lids or trays placed on the floor to help newly hatched chicks find feed should be filled to only one-quarter to one-half capacity to avoid feed wastage.

A strong relationship exists between water and feed consumption and optimal well-being, growth rate, and feed efficiency in broiler chickens. Broilers should have continuous access to clean drinking water unless otherwise required for experimental or vaccination purposes. However, when water intake is naturally low; for example, during the dark period when birds are inactive, control of the water supply may help reduce unnecessary water leakage (De Jong and Van Harn, 2012). Providing ample drinker space is paramount to achieving adequate water consumption. Water can be provided in troughs, cups, or nipples. Water drinker guidelines for trough waterers consist of 0.5 and 1.3 cm/bird (0.2 and 0.5 in/bird) for 0 to 4 wk of age and 4 to 8 wk of age, respectively. Battery cages are not used widely for broiler chickens. However, when they are, specific issues can arise. In battery cages, trough waterers can be attached from the outside of the cage, allowing broilers access to one side of the trough. This reduces the linear space to which broilers have access; hence, the space requirement should be doubled. Supplemental drinkers (3.78 L or 1 US gal) can be provided to chicks from 1 to 7 d of age to ensure adequate water intake, particularly for pens equipped with trough waterers. Cup and nipple drinkers can supply 28 and 10 birds per device, respectively, during a 9-wk production period. For example, a floor pen containing a drinker line with 5 nipple waterers can provide adequate drinker space for 50 broilers. The water flow rate of nipple drinkers can vary among the types of nipple drinkers and thus it is important to follow the manufacturers' recommendations. It is useful to verify flow rates by determining water flow rates for the nipple type used.

Water During Brooding for Broiler Chicks. Permanent drinkers are subsequently removed by approximately 3 to 4 d of age to transition birds to the primary drinker source. The height of the primary drinker source should be adjusted for bird height to ensure easy access at all times as birds grow and should be high enough to reduce spillage.

Feed and Broiler Chicks. Presentation of food in the form of good quality, small crumbles is necessary to achieve proper feed intake in the first week. Feeding equipment should not be placed directly under or too close to the brooders because this can result in feed being too hot. Feed should be distributed just before the chicks' arrival. During the initial brooding phase, one feeder tray or lid should be provided per 75 chicks. To encourage chick activity and good crop fill, ensure that supplemental feeders remain full and are replenished regularly so chicks do not consume stale feed.

For the first 12 to 24 h after placement, it is recommended that the crops of a random sampling of chicks be palpated to ensure that they are eating and drinking, and thus adjusting to the new equipment and environment. Supplemental feeders (trays or bucket feeders) should be moved in stages toward the permanent feeders and then removed by approximately 12 to 14 d of age to transition birds to the primary feeder source that will be used throughout the rearing period. The height of the primary feeder should start at floor level and then be adjusted for bird height as the birds grow.

Broiler Breeder Chickens. The content of the diet is important during all 3 phases of the rearing period; namely, starter, grower, and finisher. Caloric content is important so that birds never lose weight during the rearing period but must also be monitored so that weight gain and development are controlled. Presentation of the poultry diet in the form of a good quality, small crumble or mash feed during the rearing phase is recommended to ensure good feed intake and adequate distribution of the feed to the entire flock. Insufficient feed amount or feeder space will negatively affect feed intake, BW, and bird uniformity. Chicks should transition to the primary rearing feeding equipment (pans or trough) by d 14. Feed rationing should be designed to achieve target stock-specific BW.

Feeder Space During Rearing of Broiler Breeders. During the ad libitum feeding period, allow 4.0 cm (1.6 in) of trough space per bird. During the controlled feeding period, a minimum trough space of 15.0 cm (5.9 in) per bird or 11.5 cm (4.5 in) per bird for pan feeders should be used so that birds can eat at the same time.

Feed Restriction of Broiler Breeder Pullets During Rearing. Controlled feeding is necessary during the rearing period to control BW and prevent skeletal and other abnormalities that occur with excessive weight (reviewed by Cassy et al., 2004; Tolkamp et al., 2005; de Beer and Coon, 2007; de Beer et al., 2007, 2008; Richards et al., 2010). Controlled feeding may be achieved by restricting the days of feeding (e.g., using skip-a-day feeding) or by restricting the amount of daily feed (e.g., using less feed per period for every-day feeding). The recommendations of industry guides can be used, these being based on published and proprietary research. In both examples, feed should be distributed throughout the house quickly to ensure that all birds have adequate accessibility to the feed because flocks will consume all the feed within 30 to 45 min.

Water for Broiler Breeder Chickens. Ideally, the same drinker equipment used in rearing should be used for birds in the laying phase. Bell drinkers should be installed at the rate of 1 per 60 to 70 birds, and nipple drinkers should be installed at the rate of 6 to 8 birds per nipple. If separate drinker equipment is used for roosters in the scratch area, this drinker may be slightly elevated so that it is primarily and easily used by males and not by females. The goal of this elevated male drinker line is to limit spillage and wet litter in the scratch area, but also to encourage females to use their primary drinker line on the slats and thus be closer to the nests for laying eggs. In such a setup, the recommended distance of the water line to the nest is 60 to 70 cm (23.6 to 27.6 in).

Feed for Broiler Breeder Chickens. Insufficient amounts of feed or feeder space will negatively affect feed intake, BW, egg production, and bird uniformity. For the first 2 to 3 d after transition to the laying housing, it is very helpful to palpate the crop of a random sampling of hens and roosters to ensure that they are eating and drinking, and thus adjusting to the new equipment and housing.

Female birds should be fed according to BW and to the recommended breed standard from the time of transfer to the onset of lay. Feed increases should be planned in advance to reach the desired BW and to stimulate egg production, and should be coordinated with increases in the hours of light per day. Controlled feed increases optimize egg production and will reduce the risk of obese hens and the risk of egg size becoming too large, and will also reduce mortality associated with prolapse, fatty liver syndrome, heart attack, sudden death syndrome, and so on. Initially, in phase 1 (pre-lay to initiation of lay) of the laying period, females are normally given small increases in feed until they reach 5% egg production. After this, they enter phase 2 (from beginning of the laying period through completion of the production cycle) of the laying period and then receive feed increases in relation to egg production. Peak feed consumption should correlate with 60 to 70% hen-day egg production. To exclude males from the female feeder, a restriction grill can be used on trough feeders.

Males should never lose weight during the laying period. However, feed must be controlled to avoid excess BW and excess condition (breast muscle fleshing) because both of these can have a negative effect on fertility, male mating activity, and bird health and welfare. After 16 wk of age, males should receive small increases in feed to maintain BW and allow testes development. If possible, males should be moved to the laying house or pen a few days before the females to enable the males to adapt to their new environment and to facilitate their learning where to find their feed. This is especially important if there is a change in feeder type (e.g., trough to pan) for the roosters.

The following space requirements are recommended: a minimum of 15 cm (6 in) of feeding space per female for one-sided linear feeders or 12 females per pan. Moreover, there should be a minimum of 15 cm (6 in) of feeding space per male or 8 males per pan or as indicated in the latest breeder management guide.

The feeding period during the laying period must be monitored each day to control the BW of broiler breeders. Males and females should be fed daily via separate feeders. Both should be fed early in the morning. Feed for females should be distributed first in such a way to ensure that all hens have adequate access to feed. Females should consume their total feed within 2.5 to 3.0 h. Male feed can be distributed via pan feeders or trough feeder (fixed position, not swinging). Ideally, the male feeder should be elevated and have the daily ration pre-allocated in the feeder before feeding time. After female feed has been distributed, the male feeder can be immediately lowered so the roosters can easily access the feeder. This management procedure will reduce the number of females taking feed from the male feeder, will reduce aggression between roosters at the time of feeding, and will promote better rooster uniformity.

Scratch feed may be distributed on the litter in the afternoon to encourage mating, improve fertility, and to provide the hens with an additional source of calcium. If used, a maximum of 0.50 kg per 100 birds should be distributed via the broadcasting (scattering feed) method.

Nutrition of Broiler Breeder Chickens. The content of the diet is important during all phases of the laying period. Caloric content, protein content, and calcium content are all critical so that the hens have good livability and can produce good-quality hatching eggs. A different diet may be used for the end of phase 2, when hens still require adequate calcium but need fewer calories. Male feed should allow the roosters to maintain BW and condition, but males should not have a high caloric intake because this will result in obesity and decreased fertility.

Turkeys

Growing Turkeys. Feed can be provided ad libitum or in daily portions. Feeding and watering equipment can vary widely. For specific space guidelines and operating instructions, seek advice from the equipment manufacturer. A general guideline for linear feeder space is 2.5 cm (1 in) per poult. Feed should be provided in a texture and size that is age appropriate. A crumble or mash feed should be fed to poults less than 4 wk of age. Pelleted feed (>4 mm; >0.16 in) or mash can be fed to older birds. Drinking water may be provided ad libitum or during the light period.

Turkey Breeders. Feed can be provided ad libitum or in daily portions; in each case, there will be a recommended diet depending on age and breed. For specific requirements, follow the latest breeder specifications of the relevant line. Check the feeders daily and keep them clean and free from shavings, debris, and manure. Equipment for feeding should be checked daily. Either pelleted feed or mash can be used.

Ratites

Ostriches. Ostriches are the largest bird and are herbivorous and grazers. They should not receive chicken feed; rather, their diet should reflect their requirements. Plant materials are subject to grinding by stones in the muscular gizzard. Therefore, ostriches need stones in their diets (Deeming and Bubier, 1999). To utilize plant cellulose, ostriches are post-gastric or hindgut fermenters and have a slow gastric passage rate of about 48 h (Cilliers and Angel, 1999). In the adult ostrich, the ceca are 90 cm (35.5 in) long and the colon is 16 m (52.5 ft) long (Beziudenhout, 1999). Because of this, the metabolizable energy (ME) of feedstuffs in ostriches differs from that of other poultry species. Cilliers and Angel (1999) concluded that "the use of ME values derived from poultry in diet formulation for ostriches results in an underestimation of the true ME content of ingredients for ostriches."

Ostriches are raised on pasture with shelter provided. If the stocking density is between 0.1 and 1.0 birds/ha (0.04 to 0.4 birds/acre) on pasture, damage to the pasture can ensue (Deeming and Bubier, 1999). Research indicates that some pastures are thought not suitable for ostriches; for example, Bermuda grass (*Cynodon dactylon*; Cilliers and Angel, 1999), whereas alfalfa or lucerne (*Medicago sativa*) pastures are highly suitable for raising ostrich (Smith et al., 1995). Ratite pens should to be fenced, with 9-gauge chain-link fencing preferred (Barron, 1995), with fences 1.8 to 2.4 m (6 to 8 ft) high (USDA-FSIS, 2013). Nutritional requirements for lysine and sulfur amino acids peak at 9 and 6.5 g/d at 200 d of age for male ostriches (du Preez, 1991).

There are dietary recommendations for growing ostriches (Cilliers and Angel, 1999) with, for instance, lysine requirements increasing from 2.5 g/d at 30 d of age to 14 g/d from 180 d to maturity (Cilliers and Angel, 1999). The following diets may be used: prestarter (20.5–22% protein) from 0 to 2 mo old, starter (18–20% protein) from 2 to 4 mo old, grower (15.5–17% protein) from 4 to 6 mo old, finisher (13–14% protein) from 6 to 10 mo old, and a maintenance diet (10–12% protein) from 10 mo old (Cilliers and Angel, 1999).

Feed requirements for breeding ostriches include the following (du Preez, 1991): 230 g/d of protein, 14.8 g/d of lysine, and 16.5 g/d of sulfur amino acids.

It is suggested that breeding pairs be fed 3 times a week at a rate of 5.0 kg of dry matter per pair per day (9.2 MJ of ME per kg of feed) with water available ad libitum (Brand et al., 2015a). Feed ingredients can include alfalfa meal, oat bran, corn, wheat bran, and alfalfa hay, with protein from soybean oil cake and sunflower oil cake (Brand et al., 2015a,b). During the breeding season, birds should be fed 2 kg of ration/bird per day (4.4 lb/bird per day) [180 g of crude protein (CP), 10 MJ] supplemented with fresh alfalfa (İpek and Şahan, 2004). Diets should be supplemented with limestone (3.5%) and calcium phosphate (2.1%), to meet the calcium requirement for producing egg shells, and can be pelleted (Brand et al., 2015a,b). A vitamin and micro-mineral premix should be added to the diet for optimal egg production and hatchability (reviewed by Cooper, 2001).

Diets for adults outside the breeding season can be 1.5 kg/bird per day (3.3 lb/bird per day) of pelleted, dried alfalfa (İpek and Şahan, 2004).

The water requirement of ostriches is high. Water intake of the adult ostrich is about 8 L/d (2.1 gal/d) with losses of water including (Skadhauge and Dawson, 1999) 3 L (0.8 gal) in feces, 2.5 L (0.66 gal) in urine, and 3 L (0.8 gal) lost to evaporation.

Emus. Emus can be raised on pasture with a night shelter and, in addition to forages, receive supplements of barley, alfalfa, and canola (Menon et al., 2013).

Breeding Emus. The calcium requirement for ratites should be increased to over 2.0% of the ration when egg laying (reviewed by Cooper, 2001).

Quail

A diet containing 24% CP and 12.1 MJ of ME/kg is recommended by the National Research Council for Japanese quail during the growth period (NRC, 1994); turkey grower diets may be used (Randall and Bolla, 2008). The lysine requirement is estimated to be 1.34% of diet between 3 and 5 wk of age (Mehri et al., 2015). Quail diets should be supplemented with taurine to improve immune functioning (Wang et al., 2009). Feed and water are usually provided ad libitum (e.g., Akbarnejad et al., 2015).

Diets for breeding quail should contain 24% CP, 11.7 MJ of ME/kg, and 3.0% calcium (as limestone or ground oyster shell) when birds consume 16 g of feed/d (Randall and Bolla, 2008).

HUSBANDRY

Chickens and turkeys are social species and should be maintained in groups when possible. However, social environments in which birds exhibit aggression are stressful to poultry and should be avoided. Aggressive behaviors are influenced by group size (Estevez et al., 2003) and genetics, with broiler breeder male chickens exhibiting higher levels of aggression than layer-strain males (Millman et al., 2000). Fighting can lead to injury or worse (death). To avoid aggressive interactions, sexually mature toms are housed separately from hens. Reports on bird condition should include a statement on injuries and overt aggression.

Broiler Chickens

Brooding Broiler Chickens. Brooding is one of the fundamental aspects of broiler management. Maintaining an optimum environment for the young chick is necessary to achieve performance objectives. The problem with not maintaining proper brooding temperatures is that chicks cannot regulate their body temperature until about 2 wk of age. Chicks that are exposed to low brooding temperatures are often found huddling along feed and water lines, which usually results in their consuming inadequate amounts of feed and water. Conversely, chicks that are subjected to high brooding temperatures will pant in an effort to reduce their body temperature.

The research facility (floor pen house or battery room) should be preheated to the desired temperature set point 24 h before chick placement. The desired temperature can be influenced by the heat source used. Primary breeder guides are an excellent resource for temperature guidelines for various ages of chicks.

Forced-air furnaces provide heat in the form of hot air. Hot air will eventually heat the floor, but the floor temperature is usually a few degrees lower than the air temperature. Factors such as house tightness, temperature sensor location, and drafts can affect the difference between the air temperature and the floor temperature. Managing these factors can determine the actual success of using this type of heating system.

Brooders provide heat to chicks in the form of infrared light rather than generating hot air. Infrared light heats the object it strikes. The temperature of the floor will decrease as the distance from the brooder increases. The advantage of this type of heating system is that birds can control the amount of heat they receive, in that they can move close to the brooder to obtain more heat. Air temperature is not as critical because infrared light heats the floor; therefore, bird performance should not be as dramatically affected by a house having drafts compared with heating with forced-air furnaces. Stir fans coupled with regular inspection can minimize temperature stratification in the facility.

Stocking Density During Brooding of Broiler Chicks. To optimize proximity to feed, water, and the heat source, a brooder guard (or ring) may be used to limit the space allowance during brooding. The maximum stocking density for chicks in a surrounded brooding area should be 40 chicks/m^2. If a brooder guard is used to limit chick distribution during brooding, the enclosed area should be gradually increased in size over the first 7 to 10 d until the chicks are given access to the full pen or house. The brooder guard should be removed by 7 to 12 d of age.

Stocking Density and Broiler Chickens. Stocking density can influence the well-being of broilers. Stocking density should take into consideration housing (enclosed vs. open-sided), environmental, and local climat-

Table 11-1. Minimal floor area for meat-type poultry on litter or in group cages

Group and age	Weight, kg (lb)	Space requirement, cm^2 (in^2)
Broiler chickens		
0–2 wk	<0.3 (<0.66)	250 (38.7)
2–4 wk	0.3 to <1.3 (0.66 to <2.9)	500 (77.5)
4–6 wk	1.3 to <2.4 (2.9 to <5.3)	870 (135)
6–8 wk	2.4 to <3.3 (5.3 to <7.3)	1020 (158)
>8 wk	>3.3 (>7.3)	1100 (170)
Broiler breeder females		
0–3 wk	<0.3 (<0.66)	320 (49.6)
3–6 wk	0.3 to <0.6 (0.66 to <1.3)	690 (107)
6–9 wk	0.6 to <0.9 (1.3 to <2.0)	870 (135)
9–12 wk	0.9 to <1.2 (2.0 to <2.6)	1,060 (164)
12–15 wk	1.2 to <1.5 (2.6 to <3.3)	1,240 (192)
15–18 wk	1.5 to <1.8 (3.3 to <4.0)	1,430 (222)
18–20 wk	1.8 to <2.1 (4.0 to <4.6)	1,610 (250)
20–23 wk	2.1 to <2.7 (4.6 to <6.0)	1,860 (288)
Laying		1,860 (288)
Broiler breeder hen individually housed		
>25 wk	~2.4 (~5.3)	1,160 (180)
Broiler breeder males only on 100% litter in multiple bird pens		
0–2 wk	<0.3 (<0.7)	320 (50)
2–4 wk	0.3 to <0.6 (0.7 to <1.3)	690 (107)
4–6 wk	0.6 to <0.9 (1.3 to <2.0)	870 (135)
6–9 wk	0.9 to <1.2 (2.0 to <2.6)	1,058 (164)
9–11 wk	1.2 to <1.5 (2.6 to <3.3)	1,238 (192)
11–13 wk	1.5 to <1.8 (3.3 to <4.0)	1,426 (221)
13–15 wk	1.8 to <2.1 (4.0 to <4.6)	1,612 (250)
15–17 wk	2.1 to <2.4 (4.6 to <5.3)	1,740 (270)
17–20 wk	2.4 to <2.7 (5.3 to <6.0)	1,860 (288)
20–21 wk	2.7 to <3.0 (6.0 to <6.6)	1,974 (306)
21–23 wk	3.0 to <3.3 (6.6 to <7.3)	2,090 (324)
>23 wk	>3.3 (>7.3)	2,195 (340)
Individually caged adult broiler breeder male		
>23 wk	>3.3 (>7.3)	1,393 (216)
Young turkeys on litter or group/individual cages		
	<0.3 (<0.66)	250 (38.7)
	0.3 to <2.0 (0.66 to <4.4)	580 (90)
	2.0 to <3.0 (4.4 to <6.6)	810 (125.5)
	3.0 to <6.0 (6.6 to <13.2)	1,420 (220)
	6.0 to <8.0 (13.2 to <17.6)	1,870 (290)
	8.0 to <12.0 (17.6 to <26.5)	2,740 (425)
	12.0 to <16.0 (26.5 to <35.3)	3,550 (550)
	16.0 to <20.0 (35.3 to <44.1)	3,670 (569)
Turkey breeder hen individually housed		
Laying	<12 (<26.5)	2,700 (419)
Laying	>12 (>26.5)	4,650 (721)
Turkey breeder sexually mature tom individually housed		
	<20 (<44)	4,650 (721)
	>20 (>44)	8,360 (1,296)

ic conditions. High stocking density rates have been reported to adversely affect growth performance, carcass yield, and skin scratches and tears, increase NH_3 production, foot pad lesions, litter moisture, and heat stress, and decrease locomotion and preening (Estevez et al., 2003; Dozier et al., 2005, 2006). Stocking density is often expressed as the number of broilers per meter squared; however, body mass per unit area may affect bird performance more dramatically than the number of birds in the same space. Body mass per floor area, based on final BW at the end of the flock, is a preferable method to express stocking density, particularly for studies emulating industry-type conditions (floor pens). A facility must have adequate ventilation rates and litter conditions to allow the recommended maximum stocking densities.

Stocking density at placement is calculated based on projected final BW at the end of the growout period minus the expected incidence of mortality. Examples of maximum stocking density consistent with industry practices are as follows (National Chicken Council, 2015):

- 32 kg/m^2 for birds between 1.6 and 2.0 kg (6.5 lb/ft^2 for birds between 3.5 and 4.4 lb)
- 37 kg/m^2 for birds between 2.1 and 2.5 kg (7.6 lb/ft^2 for birds between 4.5 and 5.4 lb)
- 42 kg/m^2 for birds between 2.6 and 3.4 kg (8.6 lb/ft^2 for birds between 5.5 and 7.4 lb)
- 44 kg/m^2 for birds between 3.5 and 4.5 kg (9.2 lb/ft^2 for birds between 7.5 and 9.9 lb).

Minimum floor area specifications on a bird basis for multiple-bird pens and cages and individually housed broilers from 1 to 9 wk of age are presented in Table 11-1. In battery cages, it is important to note that broilers should stand comfortably without hitting their heads on the top of the cage. Also, broilers exceeding 2.8 kg (6.2 lb) reared in cages may start to develop lameness possibly because of lack of exercise. If this occurs, broilers should be removed from the study. Broiler colony cage systems represent an alternative for rearing broiler chickens in research and teaching. It is suggested that animal condition reports include gait score, indicating the ability of birds to walk to feeders and drinkers.

Broiler Breeder Chickens

The management of broiler breeders is divided into 2 periods: rearing and lay. The rearing period can be further divided into 3 primary development phases:

(1) From 1 to 6 wk of age: this early growth phase is critically important because this is when the frame size (body size as indicated by skeletal development) and uniformity (similarity of body size) are determined for the flock.
(2) From 6 to 16 wk of age: this is a maintenance phase, when the birds should be maintained under a controlled feeding program designed to prevent them from becoming overweight.
(3) From 16 wk until transition to the laying house: this is the pre-lay, development phase in which growth rate is accelerated to prepare the flock for sexual maturation and to achieve proper uniformity and fat coverage before the lay cycle.

The laying period can be further divided into 2 primary phases:

(1) From about 21 wk to first egg: the pre-lay phase, when hens and roosters are commingled and stimulated with light and feed to become sexually mature.
(2) From first egg to end of production cycle: the laying phase.

During the rearing phase, broiler breeders are normally kept indoors with environmental control to regulate sexual maturation and limit exposure to disease. Breeder management guides provide recommended stocking densities for males and females and suggest that males should be grown separately from females during rearing (until 21 wk). Stocking density should take into consideration specific requirements of different housing types and local climatic conditions.

During the laying phase, males should be commingled with females at a ratio of 7 to 9% males to 91 to 93% females. If fertility is low, more males may be needed to maintain fertility. If roosters are overly aggressive, a lower ratio of roosters to hens may be necessary. The stocking density or space per bird is normally 0.19 to 0.26 m^2/bird (2.0 to 2.8 ft^2/bird), but this can vary depending on the flooring (slatted or litter) and the type of housing (open-sided or enclosed with tunnel ventilation).

The recommended density of hens for nests is 4 to 5 hens/nest for manual nests and 6 hens/nest for rollaway nests. Hatching eggs should be collected from the nest at least 3 times daily. During peak egg production, more frequent egg collection may be necessary to optimize egg quality and egg sanitation. Nests should be monitored for cleanliness, and nest pads or litter should be replaced when soiled. Any floor eggs should be collected as soon as possible and kept separate from clean nest eggs to avoid contamination. If the breeder flock is provided with outdoor access or is an outdoor-only flock, the frequency of egg collection may need to be increased.

Turkeys

Rearing and Maintenance. To raise and manage turkeys reared for meat and turkey breeders with care and success, it is recommended that the latest management instructions of the relevant genetic stock be followed.

Growing Turkeys. Poults can successfully be placed at a stocking density of 0.07 to 0.09 m^2/bird (0.75 to 1.0 ft^2/bird) in the brooder house up to approximately 6 wk of age. For growing and market-aged turkeys, the maximum recommended commercial stocking density is 73 kg/m^2 (15 lb/ft^2) (National Turkey Federation, 2016).

Turkey Breeders. It is recommended that the following checks be performed daily: drinkers, feeders, ventilation, sick or injured birds and mortalities; and the following checks performed weekly: BW and egg production. Nest boxes should be kept clean. Eggs may need to be removed from nest boxes at least once per hour to prevent broodiness.

Hens need time to familiarize themselves with the laying environment. There must be sufficient nest space per hen, typically a maximum of 7 hens per nest box. Management should follow the latest breeding company instructions. Toms should be kept to the target weight (age and breed specific) via tailored feed management; that is, feed with adapted protein level or provision of predetermined amounts of feed.

Ratites

Pairs of ostriches can be maintained in breeder camps or paddocks. Breeding paddocks have been used successfully. These can be between 0.25 and 0.5 ha [0.6 and 1.25 acres] with either little or no pasture (Van Niekerk, 1996; Brand et al., 2015a,b).

Breeding pairs of emu can be held in a fenced pen at least 8 m wide × 20 m long (26 ft wide × 66 ft long; Animal Welfare Advisory Committee, 1998).

Quail

Breeding quail supply eggs both for chicks to be grown for meat and for eggs. These breeding quail are often housed with 1 male and 2 or 3 females, with the group having 145 cm^2 (22.5 in^2) of floor space per bird or 125 cm^2 (19.5 in^2) per bird on wire floors (Randall and Bolla, 2008).

STANDARD AGRICULTURAL PRACTICES

Skilled personnel should carry out handling of birds and all procedures described in this section.

Beak Conditioning in Turkeys

Trimming of the beak tip is done to minimize injury and death due to aggressive and cannibalistic behavior. Pecking at the feathers or head directed at conspecifics can result in injury (Duggan et al., 2014), which can result in mortality or the need to cull. Pecking is reduced by removal of the distal portion of the beak (Glatz and Rodda, 2013), commonly at the hatchery. Beak conditioning is a common practice to reduce harmful pecking and cannibalism. The available evidence, albeit limited, indicates that beak trimming is either painless or of minor effect, with no effects on fearfulness, tameness, or resting behaviors (Noble et al., 1996) and improved growth rates and feed efficiencies (Noble et al., 1994). Moreover, it has been reported that pain receptors are absent in the dermis proximal to the trimmed beak (Gentle et al., 1995). The process may done at the hatchery before birds arrive at a research site. One such technique uses a high-intensity light beam to kill tissue at the tip of the upper beak. The beak sloughs off by 2 wk of age.

Toe Trimming

Because of the size and weight of the broiler breeders and turkeys involved and the sharpness of their toenails, broiler breeder males and market turkeys generally have toes trimmed to prevent them from inflicting serious injuries to hens during natural matings or to pen-mates or to caretakers. Claw (“toenail”) conditioning is sometimes done at the hatchery to reduce skin scratches caused by toenails. A microwave beam is applied to the tip of the toes. The toenails slough off by 2 wk of age. A less common method is the use of a hot-blade device. It is frequently assumed, based on evidence such as the absence of pain receptors or other nerves and by analogy to nail trimming in humans, that toe trimming is painless. However, there is evidence of shifts in behavior and performance after toe trimming. These may be indicative of some impairment of welfare (Proudfoot et al., 1979; Fournier et al., 2014, 2015).

Snood Removal

Turkeys have a frontal process called a snood, which is an ornamental appendage for the adult male. The snood can be a target for pecking by other birds or grasped by other turkeys during fighting and can be torn or damaged (reviewed by Dalton et al., 2011). Snood removal is achieve with small scissors or similar cutting implements. It may be performed at the hatchery, for instance, on poults destined to be breeder toms. It is presumed that this technique is painless, but there is an absence of literature supporting or refuting this.

ENVIRONMENTAL ENRICHMENT

Refer to Chapter 4: Environmental Enrichment for information on enrichment of poultry environments. Environmental enrichment involves adding features to the environment to allow natural behaviors (Leone and Estévez, 2008). Caution is expressed as to whether enriched environments should be mandated for meat-type chickens or turkeys or broiler breeders or breeding turkeys in view of the limited research demonstrating improved well-being with specific enrichments. There is some research, for instance, with platforms with ramps for accessibility (Norring et al., 2016; Bailie et al., 2018). It is suggested that platforms with ramps, perches, or substrates for dust bathing or other enrichment techniques be provided for broiler chickens, adult broiler breeders, and turkeys (growing and adult breeders) where appropriate.

HANDLING AND TRANSPORTATION

Refer to Chapter 5: Animal Handling and Transport for information on handling and transportation of poultry. Additional information on ratites is included below.

Safe Handling of Ratites

Handling of ostriches can cause falls and injury, with greater numbers of injuries reported with handling than with loading and unloading for transportation (Minka and Ayo, 2008). Adult ostriches and emus can be restrained by a V-shaped crush arrangement (Animal Welfare Advisory Committee, 1998). For ostriches, but not emus, hooding the head may be useful with a shepherd’s neck crook facilitating placement of a hood on the head (Animal Welfare Advisory Committee, 1998; Bejaei and Cheng, 2014). Bejaei and Cheng (2014) state that "After being hooded, it [the ostrich] would calm down (in less than 1 min) and could be walked to the sampling pen without resistance." Blood sampling is often more easily conducted in hooded ostriches (Bejaei and Cheng, 2014). It is not clear, however, whether hooding per se is stressful.

Transportation of Ratites

The ostrich anatomy, with a high center of gravity (heavy body) and feet with just 2 toes, makes it difficult for ostriches to maintain balance during transportation (Bejaei and Cheng, 2014). Welfare of ratites can be compromised by transportation (Mitchell, 1999; AHA, 2012).

Transportation has been reported to be followed by increases in 2 indices of stress: plasma concentrations of corticosterone and heterophil to lymphocyte ratios (Menon et al., 2014). Transportation for distances over 500 km results in BW reductions (Bejaei et al., 2014). In addition, body temperature is noted to increase in emus during transportation (Menon et al., 2014). It is recommended that adult ratites be transported in single-decked livestock transportation trailers with a density of 0.5 m^2/bird (5.4 ft^2/bird; AHA, 2012) and at night (Crowther et al., 2003).

INCUBATION AND HATCHING

The sections on incubating broiler breeder eggs and turkey eggs below cover large-scale incubation in industry and represent the state-of-the-art at the time of writing. It is emphasized that the procedures may need to be modified for incubation on a smaller scale and in a research and academic settings.

Broiler Breeder Eggs

Two primary broiler breeder companies—Aviagen (including Ross; http://en.aviagen.com/) and Cobb-Vantress Inc. (https://www.cobb-vantress.com/)—currently produce parent stock for broiler breeder strains. Incubation and hatching are covered in detail in their respective manuals, which are available on the companies' websites.

The following provides a succinct summary of the requirements of incubation and hatching for broiler chickens. Incubation accounts for approximately one-third of the life of broiler chickens. Therefore, the requirements for incubation are critical. Factors that affect the success of incubation requirements include the following: egg characteristics; egg cleanliness; egg storage conditions and duration; and incubation cleanliness, temperature, humidity, and ventilation. Eggs are incubated for the first 18 to 19 d in a setter room or incubator and then transferred to a hatcher room or hatcher. Control of temperature and humidity in the incubator and hatcher is very important to hatching healthy chicks.

Egg Characteristics. Certain eggs should be rejected and not incubated due to the presence of poor quality characteristics that may negatively affect hatchability and chick quality. These characteristics include cracked or damaged eggs (e.g., damaged by toe puncture), misshapen eggs (e.g., round or elongated), excessively small or large eggs, and eggs with poor shell quality (e.g., slab-sided or wrinkled).

Egg Cleanliness. Hatching problems can occur with dirty eggs due to increased bacterial contamination of the hatchery equipment. Nest eggs are preferable over floor eggs because they should have less soiling and will be collected more frequently. Slightly soiled eggs can be incubated, but they should not be wiped clean or washed. Wiping or washing will remove the cuticle that protects the egg from contamination. The egg handling room in the chicken house should be maintained in a clean and tidy manner with an effective insect and vermin control program.

Egg Storage. Once eggs have been collected from the breeder house, they should be placed in incubation trays with the small (pointed) end of the egg facing down and stored in a cooler or cool room until pickup for the hatchery. Primary breeder companies recommend that eggs from modern broiler stocks be stored at temperatures ranging from 15 to 21°C (59 to 69°F), with the cooler temperatures recommended for longer periods of storage (see, for example, Aviagen, 2020; Cobb-Vantress, 2020). These same companies recommend relative humidity (RH) of 50 to 80% for storing eggs. Eggs can be stored for 7 to 8 d before hatchability decreases. After storage for 10 d, there is a marked decrease in hatchability.

Incubation Temperature. Incubation of broiler eggs requires 21 d. Eggs should be prewarmed at 24 to 27°C (75 to 80°F) before incubation. For the first 18 to 19 d of incubation (in the setter), eggs should be maintained at 37.5°C (99.5°F). A temperature of 1° above or below 37.5°C (99.5°F) can reduce overall hatchability. Eggs are transferred from the setter to the hatcher on d 18 and the temperature decreased to 36.7°C (98°F).

Incubation temperature can be measured by monitoring eggshell temperature, which is an indirect measurement of an embryo's temperature. This can be measured with an infrared ear thermometer placed on the shell of the egg below the air cell. The optimal incubation temperature for chicken eggs is an eggshell temperature of 37.8 to 38.2°C (100 to 101°F). Variance in this temperature (higher or lower) can have a negative effect on embryonic mortality, chick weight, and organ development.

Incubation Humidity. The humidity within the incubator is also crucial for a successful hatch. Typically, the humidity in the setter needs to be maintained at 58 to 60% RH. An approximate 11 to 12% loss of egg weight occurs during the first 18 d of incubation due predominantly to loss of water vapor from the egg. When eggs are transferred to the hatcher, RH should be increased to 68 to 70%. Humidity is commonly expressed as a wet bulb temperature. The RH in the setter (58 to 60%) represents a wet bulb temperature of 28.9 to 30°C (84 to 86°F), and RH in the hatcher (68 to 70%) represents a wet bulb temperature of 31.1 to 32.2°C (88 to 90°F).

Incubator Ventilation. The embryo continuously requires O_2 and releases CO_2. It is critical that the CO_2 concentration in the incubator does not exceed 0.4%. To ensure proper gas exchange, fresh air is provided to the growing embryo throughout incubation. Ventilation rates are as follows:

- Setter room: air movement/ventilation of 13.5 m^3/h per 1,000 eggs [8 ft^3/min (cubic feet per minute, CFM) per 1,000 eggs]. The room should have a positive or higher pressure compared with atmospheric.
- Hatcher room: air movement/ventilation of 28.7 m^3/h per 1,000 eggs (17 CFM per 1,000 eggs). The room should have a positive or higher pressure relative to atmospheric pressure.
- Chick holding room: air movement/ventilation of 67.6 m^3/h per 1,000 eggs (40 CFM per 1,000 eggs). The room should have the same pressure as atmospheric pressure.

Egg Turning. During the first 18 to 19 d of incubation, eggs must be turned; that is, rotated through 45° per rotation 3 or more times per day, to prevent the embryo from adhering to the eggshell membranes, to aid in uniform airflow around the egg, and for other critical factors. After egg transfer to the hatcher, eggs should no longer be turned.

Transfer from Setter to Hatcher. The transfer from the setter to the hatcher should be conducted with efficiency and care to avoid unnecessary cooling of the eggs. Problem eggs can be removed at this time. Problem eggs include infertile eggs (as determined by candling) and cracked or rotten eggs (rots and exploders). Transfer is also the time for vaccination if conducted by the *in ovo* approach. After hatch and removal of the chicks and egg residue, hatchers must be cleaned and disinfected before more eggs are placed in the machine.

Chick Holding Room. Chicks can be moved from the hatcher to the chick holding room when their down is dry. The temperature of the holding room should be 23°C (73°F) with RH of 65 to 70%; the room should be free of drafts.

Fertility and Hatchability. Fertility of the eggs can be predicted by candling the eggs at 10 to 12 d of incubation. This can be assessed on individual eggs with a candling light or on a flat of eggs using a candling table. Final fertility assessment should be based on the total number of chicks hatched and include an assessment of hatch residue (nonhatched eggs). Although fertility is highly correlated with the health and management status of the breeder flock, embryonic livability can also be affected by factors such as flock age, egg handling, and incubation management (temperature and humidity). If eggs in the machine have a low rate of fertility or a higher rate of embryonic mortality, the machine (setter or hatcher) will have to compensate for the loss of embryonic heat production.

Turkey Breeder Eggs

Egg Handling. Proper egg handling is important to reduce or eliminate harmful organisms from passing through the eggshell surface as it cools. It is recommended that hens be encouraged not to lay eggs outside nest boxes. Eggs should be collected at least twice per day, sanitized, and then placed in an egg cooler. Nests should be checked weekly for proper operation (e.g., opening, closing, and so on).

Incubation Requirements. Turkey eggs are typically held for 24 to 25 d in an incubator (or setter) and then transferred to a hatcher cabinet for an additional 3 to 4 d until hatching. In the incubator, eggs should be rotated 3 or more times per day to prevent the embryos from adhering to the eggshell. Eggs should not be turned within 3 d of hatching.

Controlling incubator and hatcher temperature and humidity is very important to hatch healthy poults. Proper temperature and humidity settings for hatchery equipment can vary by manufacturer and type (still vs. forced air, single vs. multistage). For specific machine settings and operating instructions, seek advice from the equipment manufacturer. To ensure the correct incubation temperature, eggshell temperature can be monitored, this being an indirect measurement of an embryo's temperature. Eggshell temperature can be measured with an infrared ear thermometer. The thermometer is placed below the air cell of the egg on the outside of the shell. An eggshell temperature of 37.4 to 37.8°C (99.4 to 100°F) is optimal. Humidity can be monitored by weighing a sample of eggs before incubation and then at transfer to the hatchery. Eggs should lose 10 to 12% moisture by d 25 of the incubation process.

Hatching Requirements. For specific machine settings and operating instructions, it is recommended that advice be sought from the equipment manufacturer. If incubator and hatcher conditions are correct, pipping should begin approximately 36 h before scheduled removal ("pull"). Overheating of the poults in the hatchers is a concern and is indicated by a high body temperature. Body temperature is measured by inserting a thermometer probe into the cloaca. Optimal temperatures should be between 39.4 and 40.0°C (103 and 104°F). Body temperatures exceeding 40.6°C (105°F) will result in panting and potentially dehydration.

Ratite Eggs

Ostrich Eggs. Ostrich eggs can be stored at 17°C (63°F) and RH of 35 to 75% after disinfectant treatment (Van Schalkwyk et al., 1998; reviewed by Cooper, 2001). With prolonged storage (>3 wk), hatching rate decreases (Deeming and Ar, 1999). Egg fertility rates are very variable, ranging from <50% to >85% (Deeming and Ar, 1999). The incubation temperature should be 36.5°C (98°F) (Deeming and Ar, 1999), which is lower than that for chicken's eggs. Features of ostrich egg incubation include the following:

- Egg weight: 1.5 kg (range 1.0 to 2.0 kg) [3.3 lb (range 2.2 to 4.4 lb)] (Deeming and Ar, 1999).
- Incubation at 36.0 to 36.5°C (97 to 98°F) (Hassan et al., 2004; İpek and Şahan, 2004; Brand et al., 2015a; reviewed: Deeming, 1997; Cooper, 2001) at 24% (Brand et al., 2015a) or 30% RH (İpek and Şahan, 2004).
- Egg turning:
  - Eggs turned every hour through a 60° or 90° angle (Brand et al., 2015a).
  - Eggs turned through an angle of 45° per hour (İpek and Şahan, 2004).
- Incubator ventilation is important to remove CO_2 and water vapor; 48 m^3/h (1,700 ft^3/h) air replacement per 1,000 eggs is recommended (Deeming and Ar, 1999).
- Time in incubator:
  - After 35 d, the eggs are moved to a hatcher at 36°C and 24% RH (Brand et al., 2015a).
  - At 39 d, the eggs are transferred to a hatcher at 36°C (97°F) and 40% RH until hatching (İpek and Şahan, 2004; Brand et al., 2015a).
- Duration of incubation: 42.8 d (İpek and Şahan, 2004).
- Hatchability of ostrich eggs: 37 to 52% (İpek and Şahan, 2004).
- Weight of 1-d-old ostrich chick: 0.8 kg (1.75 lb; Cilliers and Angel, 1999).

Chicks are allowed to dry off in the hatcher for up to 24 h and can then be transferred into an intensive chick rearing facility (Cloete et al., 2001). Chicks should be initially raised at 30 to 32°C (86 to 90°F) at a density of ≤6 chicks/m^2 (≤6 chicks/10.6 ft^2). Access to the outdoors may be provided (Verwoerd et al., 1999). The density should be decreased by 10% per week and temperature gradually reduced to 26°C (79°F) at 3 wk old (Verwoerd et al., 1999).

High rates of mortality have been reported in the first 90 d of post-hatching growth and development: 47% in the first 28 d and 31% between 28 and 90 d (Cloete et al., 2001). The basis for the high mortality is not well established.

Emu Eggs. Key features of emu egg incubation are as follows:

- Egg storage: 28 to 33% RH;
- Incubation: 34.9 to 36.3°C (94.8 to 97.3°F);
- Time: 54 to 57 d (Brake and Rosseland, 1995).

Quail Eggs

Japanese quail eggs should be stored at 10 to 16°C (50 to 61°F; Cain and Cawley, 1974). Eggs may be fumigated either immediately after collection or before incubation. Japanese quail eggs can be incubated successfully in forced-draft incubators at 37.5°C (99.5°F) and 60% RH or in still-air incubators at 38°C (100.4°F) in wk 1; 39°C (102.2°F) in wk 2; and 39.5°C (103.1°F) in wk 3 (Cain and Cawley, 1974; Randall and Bolla, 2008).

SPECIAL CONSIDERATIONS

Biosecurity

Biosecurity is essential for poultry to minimize risks from pathogens such as *Salmonella*, *Mycoplasma*, avian influenza viruses, or other infectious agents that could harm bird welfare, compromise research or instruction, and represent a threat to commercial and privately owned poultry flocks or public health. Many highly infectious pathogens that infect poultry originate in wild birds. Mechanisms for the spread of pathogens among poultry flocks include movements of personnel, vehicles, equipment, and dead birds contaminated with pathogens; aerosol droplets and dust particles contaminated with pathogens; and vermin such as mites, rats, litter beetles, and flies. Researchers are encouraged to review the 14-point biosecurity standards of the National Poultry Improvement Plan (undated).

Proximity is an important issue in the spread of pathogens. This applies to the physical distance and the shared inputs (e.g., staff, equipment, vehicles) between and among research or teaching poultry units, commercial facilities, and backyard flocks (USDA-APHIS, 2015a). With closer proximity, biosecurity plans must be more rigorous.

Biosecurity can be envisioned under 2 categories: structural and operational biosecurity (USDA-APHIS, 2015a). The following practices are recommended to ensure biosecurity:

- Each research/instruction poultry facility should have a biosecurity officer (institutional veterinarian or equivalent) and provide biosecurity training for all personnel.
- A biosecurity plan should include standard operating procedures encompassing cleaning and disinfection of equipment and buildings; provision of protective clothing for personnel; installation and maintenance of footwear sanitation stations; quarantine procedures; limiting access to the facility; a perimeter buffer area and a line of separation

between buildings; and depopulation measures in the event of a disease outbreak.

- When feasible, biosecurity is best maintained when personnel shower and change into clean clothes and be disinfected before entering a poultry research unit and before moving between such units.
- Biosecurity control measures must be in place to protect poultry from pathogens that can be carried by wild birds, rodents, and insects.
- Equipment must be sanitized thoroughly between uses. The goal should be to restrict sharing of equipment between different research and teaching poultry units.
- External bird sources should be certified flocks and free of primary poultry diseases (*Mycoplasma*, *Salmonella*, avian influenza).
- Birds should be transported in vehicles that have been cleaned and disinfected appropriately.
- Drinking water should be from potable sources where possible.
- Feed and fresh litter must be stored and handled to prevent access by rodents or wild birds and hence contamination with viruses or other infectious agents.
- Informing regulatory and other animal health professionals immediately of possible disease outbreaks as appropriate (based on USDA-APHIS, 2015a,b, 2016a,b).

Biosecurity is particularly important to ostrich raising. Ostriches should not be housed in proximity with other livestock or poultry if possible (Perelman, 1999).

Poultry in Biomedical Research and Other Special Considerations

In some biomedical and other intensive research studies and various teaching programs, poultry may need to be housed in different conditions. These special circumstances include embryonated eggs during hatching in small-scale incubators and metabolic chamber studies.

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. Refer to Chapter 1: Institutional Policies for general information on the care and use of genetically modified animals.

Surgeries

All intrathoracic and intra-abdominal 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.

Artificial Insemination

Modern commercial strains of turkeys are bred by AI. For a review of AI in poultry, see Bakst and Dymond (2013). The major reason for using AI in turkeys is to ensure the safety of the females because the act of copulation can injure the hen. Males are housed separately from females to protect the hens from aggression by tom turkeys. Collection of semen requires careful management and manipulation of the tom. It is recommended that excreta be removed and the tom's abdomen cleaned before collecting semen.

For maximal fertility, the semen should be applied to the female within 30 min of collection. Changes in semen temperature should be avoided during transportation. If semen needs to be stored longer than 30 min, follow semen storage instructions as indicated in professional breeder management guidelines.

EUTHANASIA

Euthanasia recommendations follow those of the American Veterinary Medical Association (AVMA) Panel on Euthanasia (Leary et al., 2020) (also see European Union recommendations; Close et al., 1997). The mechanisms for euthanasia are as follows: (1) depression of cortical neural activity and specifically neurons required for functions critical for life; (2) hypoxia due, for instance, to exsanguination; and (3) physical disruption of the brain or its activity (Leary et al., 2020).

Acceptable Methods for Embryonated Eggs

Embryonated eggs (<80% of incubation) may be destroyed by chilling or freezing at a temperature of 4°C (39°F) for 4 h. Decapitation or anesthetic or CO_2 overdose are suitable methods for older embryos (AVMA, 2020).

Acceptable Methods for Chicks and Pipped Eggs

Only methods of euthanasia approved by the AVMA (AVMA, 2020) can be used. Rapid maceration or displacement of oxygen with N_2, CO_2, or other approved gas are preferred methods of euthanasia for cull chicks and pipped eggs. Personnel must be trained for the method in use.

Acceptable Methods for Growing and Adult Chickens and Turkeys

Methods of euthanasia accepted by the AVMA (AVMA, 2020) can be used. The following methods of euthanasia that, in addition to other AVMA-approved methods, are acceptable:

(1) Rapid decapitation.
(2) Rapid cervical disarticulation, normally between the skull and first cervical vertebra. If a tool is used it should separate, but not crush, the vertebrae.
(3) Displacement of O_2 with CO_2 or another approved gas.
(4) Captive bolt for large birds, including non-penetrating captive bolt.
(5) Intravenous injection administration of overdoses of anesthetics, specifically barbiturates (barbiturate and barbituric acid derivatives). These drugs are controlled substances and "must be administered by personnel who are registered with the US DEA [US Drug Enforcement Administration], and extra-label use requires administration by or under the supervision of a veterinarian" (Leary et al., 2020). Disadvantages of this approach include that the meat cannot be consumed by animals or humans, and any biochemical or artifactual changes may confound experimentation.
(6) Low atmospheric stunning (controlled atmosphere stunning).
(7) Electrocution.
(8) Gunshot (free-range birds only).

Acceptable Methods for Ratites

An accepted method of euthanasia for ratites consists of rendering unconscious by electrical stunning before killing by bleeding (Animal Welfare Advisory Committee, 1998).

SLAUGHTER

In the United States, 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. 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.

Electrical Stunning

Following industry practice (National Chicken Council, 2013), electrical stunning should be used to render poultry unconscious or insensible to pain before slaughter by exsanguination. Exceptions to this practice include when slaughter has to be consistent with Islamic (halal) or Jewish (kosher) dietary practices. Stunned birds may recover consciousness quickly; therefore, exsanguination should be accomplished immediately after stunning to avoid recovery from consciousness. 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. Handheld electrical stunners may be used for shackled birds or for birds that are restrained in a cone. Exsanguination (after stunning) is an effective method of slaughter, particularly if both carotid arteries are completely severed (Gregory and Wotton, 1986, 1988). Alternatively, it is effective to severe both the carotid artery and jugular vein on one side.

Controlled Atmosphere Stunning

Controlled atmosphere stunning is achieved by increasing the CO_2 partial pressure, by very low O_2 partial pressure, or both (Hoen and Lankhaar, 1999). Controlled atmosphere stunning is increasingly being used for commercial slaughter in Europe (reviewed by Berg and Raj, 2015) and, to some extent, in North America (Gregory, 2005). This can entail CO_2 initially at $<40\%$ to achieve unconsciousness and then 80 to 90% CO_2 or CO_2 in combination with either nitrogen or argon (Berg and Raj, 2015).

Single and 2-phase controlled atmospheric systems have been compared (Abeyesinghe et al., 2007; McKeegan et al., 2007a,b). The single-phase system used a hypercapnic anoxic mixture of 60% argon, 30% CO_2, and $<2\%$ O_2. The biphasic hypercapnic hyperoxygenation mixture was initially 30% CO_2, 30% O_2, and 30% N_2 (anesthetic phase), followed by 80% CO_2, 5% O_2, and 15% N_2 (euthanasia phase).

Hypobaric hypoxia stunning (reduced atmospheric pressure stunning) is another method to achieve unconsciousness (Purswell et al., 2007). Stunning is achieved by progressive hypobaric hypoxia with final atmospheric pressures of <26.6 kPa (<199 mm Hg or 0.26 atm) (Purswell et al., 2007). Evidence based on physiological and behavioral metrics indicates that this method is as humane as other methods of controlled atmosphere stunning (Martin et al., 2016). Evidence that hypobaric hypoxia stunning is a humane system comes from the lack of increase in heart rate (McKeegan et al., 2013) or circulating concentrations of the stress hormone corticosterone (Vizzier-Thaxton et al., 2010). The concentrations of corticosterone are lower in meat-type chickens stunned by hypobaric hypoxia than by electrical stunning (Vizzier-Thaxton et al., 2010).

Reduced atmospheric pressure is an irreversible stunning technique when the final atmospheric pressure is 80.6 kPa after 4.67 min (Mackie and McKeegan, 2016). Within 1 min, the following behaviors are observed: mouth opening, head shaking, and open mouth breathing, together with ataxia (loss of control of bodily movements). Between 1 and 2 min, chickens exhibit markers of unconsciousness; namely, loss of posture and convulsions. Birds are motionless after 200 s (Mackie and McKeegan, 2016). As these behaviors were similar to those observed with controlled atmospheric systems, Mackie and McKeegan (2016) suggested that reduced atmospheric pressure stunning is a humane technique.

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CHAPTER 12: EGG-TYPE POULTRY

INTRODUCTION

This chapter will focus on the care and use of egg-type poultry housed in research and teaching facilities. Specifically, commercial egg strains of chickens (white and brown egg layers and breeders) are discussed with reference to housing systems, feeding and watering, husbandry guidelines, standard production practices, and euthanasia. In addition, feeder, water, and floor space guidelines are presented.

The physical environment provided in a poultry research or teaching facility should not put egg-type birds at undue risk of injury or expose them to conditions that would be likely to cause unnecessary distress, disease, or mortality (Tauson, 1985; Bell and Weaver, 2002; Appleby et al., 2004; Anderson et al., 2010). The facility must be maintained in a manner that minimizes stress, allows birds to perform species-specific behaviors (e.g., roosting) and keep themselves clean and safe from predators and parasites, and prevents bird escape and entrapment and unnecessary accumulation of bird waste.

Environmental conditions have major implications for the health, performance, and welfare of poultry (Stamp Dawkins et al., 2004). The thermal environment and air quality should be maintained by ventilation or cooling and heating systems to provide birds with the environmental conditions appropriate for their age and season of the year. In addition to bird well-being, caretaker welfare warrants consideration in evaluation of housing systems (Whyte, 1993), and both are very important concepts to follow during remodeling or development of future designs.

Proper design of all housing systems is important in maintaining clean housing and equipment as well as inspecting birds. Cages with multiple decks must be designed to allow equipment cleaning and inspection of birds without handling, yet the birds should be easily accessible. Adequate lighting is needed for examination of all birds, and a movable platform or other system is necessary for examination of higher tiers if those cannot be readily seen by attendants standing on the floor. Accessibility of feeding and watering equipment is important for easy maintenance.

FACILITIES AND ENVIRONMENT

Advantages and Disadvantages of Conventional and Alternative Housing Systems

Although a variety of systems, including conventional and furnished cages, aviaries, cage-free floor systems (litter or slat floor), and free range, can be used for housing laying hens and layer breeders, no housing system is perfect, with each having its own health and welfare advantages and disadvantages. 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). 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).

Conventional Cages

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 reduced mortality compared with hens in non-cage systems (Flock et al., 2005; LayWel, 2006b; Tauson et al., 2006; Glatz and Hinch, 2008; Arbona et al., 2009; Black and Christensen, 2009; Fossum et al., 2009). Because conventional cages lack perches and do not have access to litter, poor foot health and keel bone deviations and deformities are less of a problem in cages than in non-cage systems or enriched colony cages (Tauson et al., 2006; Regmi et al., 2016b); however, because of lack of exercise, conventionally caged hens are susceptible to osteoporosis (Whitehead and Fleming, 2000; Jendral et al., 2008).

Alternative Housing

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; Pohle and Cheng, 2009; Singh et al., 2009; Tactacan et al., 2009; Golden et al., 2012; Guinebretière et al., 2013; Ali et al., 2016; Blatchford et al., 2016; Campbell et al., 2016a,b; Heerkens et al., 2016a,b; Regmi et al., 2016a,b; Yilmaz Dikmen et al., 2016); enriched colony cages, aviaries, and free-range systems are alternatives to conventional cages for egg-laying strains of chickens.

Enriched Colony Cages. Enriched colony cages can house large (~60 hens), medium (15 to 30 hens), and small (up to 15 hens) group sizes. 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 have been observed in this type of housing, including increased keel bone deformities associated with high perch use (Vits et al., 2005; Tauson et al., 2006) and mortality (Anderson, 2015a).

Floor Systems, Aviaries, and Multi-Tier Systems. Indoor floor systems are sometimes referred to as barn systems or free-roaming systems. The hens have access to litter, slats, or litter and slats, and can roam in the building, pen, or open area, in a poultry house. They have unlimited access to fresh feed and water, while the litter allows for forage behavior. Cage-free systems used for laying hens vary in design, but all systems allow for common handling and care practices. They all provide adequate floor space, nest space, and perches. Depending on the facility, these housing systems may or may not have an automated egg collection system (Anderson, 2018). Aviaries, designed to use vertical space, consist of a ground floor plus one or more tiers having perforated, slatted floors, or platforms with manure belts underneath each elevated level (Appleby et al., 2004; LayWel, 2006a). Providing a littered area allows for dust bathing and reduces the incidence of cannibalism and feather pecking. The scratch area is abrasive, which helps hens maintain a normal claw length. The litter covering the floor area allows for proper mixing of manure, which will help prevent excessive manure and moisture accumulation. The depth of the litter should be sufficient to prevent hens from coming in contact with the floor. In contrast, deep litter is not recommended because 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.

Stratmann et al. (2015b) postulated that falls and collisions by hens housed in aviaries is associated with increased keel bone fractures. In addition, previous findings by Scott et al. (1997) documented that long distances and steep angles between tiers are more likely to result in unsuccessful jumps. Therefore, each tier should be positioned close enough to 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 (Heerkens et al., 2016a). If ramps are used, they are designed to prevent droppings from falling on the birds below. Hens should have access to the entire littered floor area. Additionally, the area under the raised tiers could be closed off to help eliminate the laying of floor eggs. Raised tiers need a belt system for frequent removal of manure.

It is recommended that the vertical distance between tiers, including the floor to the first tier, 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 the design discourages horizontal movement between tiers, the minimum distance between tiers should be 2 m (6.6 ft).

Birds that are to be housed in aviaries as adults adapt better if they are reared as pullets in similar aviaries to facilitate adaptation to perches and nests (Janczak and Riber, 2015). Typically, day-old chicks are housed in a central tier for the first 10 d of age; 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 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.

Since the early 2000s, with the increased interest in alternative housing systems for laying hens, a concerted effort has been made to develop research comparing various housing systems relative to the well-being and health of hens kept in commercial facilities. One study funded by the American Egg Board in 2008 formed a team of scientists to review the sustainability aspects of different hen housing systems. In 2010, the Coalition for a Sustainable Egg Supply (CSES) was formed, which consisted of university and USDA-Agricultural Research Service (ARS) poultry scientists (Swanson et al., 2015). They coordinated a 2-year study of commercial egg production systems (Zhao et al., 2015), examining 5 different sustainability areas, one of which was health and well-being of laying hens. Several research papers have been published documenting the health and well-being responses of laying hens maintained in conventional cages, enriched colony cages, and a cage-free aviary.

The CSES reported that cumulative hen mortality in the aviary system was twice that of hens in the conventional cage and enriched colony cage systems. The enriched colony cage and aviary systems offered hens more behavioral freedom than the conventional cage system. Hens in the enriched colony cages had more keel abnormalities than hens in the conventional cages. During the egg production period, hens in the aviary system had more keel bone damage than those in the conventional cage system (Blatchford et al., 2016). Hens in the enriched colony cages had slightly less feather loss than those in the conventional cages, whereas hens in the aviary had the best feathering (Blatchford et al., 2016). These results suggest that hens in the aviary and enriched colony cages had more freedom of movement than hens in the conventional cages, but at the expense of greater mortality in the aviary system.

Outdoor Access or Free Range. Egg-laying strains of chickens are also raised with access to the outdoors. Hens raised under an organic protocol require outdoor access (USDA Agricultural Marketing Service, 2001), which can be a range (paddock) 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 (paddock) is an outside fenced area. Adequate fence height and fencing material of appropriate mesh size are necessary to retain domesticated poultry and prevent predator entry. Overhead fine netting, as used for game birds, can be used to protect domestic poultry from 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 and environmental contaminants, and they should be designed to prevent muddy areas, to avoid injuries and foot problems, and to promote overall bird health. Vegetation should be used for ranges (paddocks) or sections of the range where soil erosion is problematic. Range rotation is one tool to minimize the risk of disease and parasites and to provide opportunities for land and forages to recover from bird activity. A covered veranda provides shade and outdoor access; it can be connected to the house and made available to hens during 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 the early stages of rearing to facilitate the transition of birds from indoor to outdoor lighting conditions.

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). Free-range birds are leaner with a greater percentage of muscle mass and plumage than caged birds (Hughes and Dun, 1986). However, birds on range are more susceptible to problems caused by inclement weather and have increased risks of bacterial disease, parasites, and cannibalism (Fossum et al., 2009) due to larger group sizes (Appleby et al., 1992), predation (Darre, 2003), environmental contaminants such as dioxin (Schoeters and Hoogenboom, 2006; Kijlstra et al., 2007), increased frequency of old bone fractures (Gregory et al., 1990; Regmi et al., 2016a), and a higher incidence of foot pad lesions (Yilmaz Dikmen et al., 2016).

Free-range birds without access to a permanent building usually have covered shelters that provide shade, protection from inclement weather, litter, food, and water. The sheltered area provides space to allow all ranged birds to rest together without risk of heat stress. Mobile shelters are 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 under the shelter. See the Perches section under Husbandry for more details.

All range, veranda, or any other type of outdoor access is 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 foraging behavior (Anderson, 2014). Egg-laying strains of chickens are allowed access to the range (paddock) at approximately 12 wk of age (Anderson, 2014). Vegetation such as small bushes, crops such as corn, or cover panels (Cornetto and Estévez, 2001a) that provide a sense of protection in the outdoor area can be used to encourage use of the range (Nicol et al., 2003; Hegelund et al., 2005; Zeltner and Hirt, 2008).

When indoor birds are allowed free access to the outdoors, popholes (openings) of sufficient number are installed to facilitate egress of birds 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 allows 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 congregations of birds on either side of the pophole. A roof can be placed over a pophole to provide protection, and baffles can be 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 configurations without individual pens, popholes should be evenly distributed down the length of the building to prevent birds from blocking 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.

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 birds are housed (as is the case for most adult cages), then only one side of

Table 12-1. Minimum feeder space (linear trough space/bird) for commercial egg strains of chickens in floor pens, aviaries, or cages[1,2,3]

	Light breeds				Heavy breeds			
	Female		Male		Female		Male	
Type of housing and age (wk)	(cm)	(in)	(cm)	(in)	(cm)	(in)	(cm)	(in)
Pen[4,5]								
0 to 6[4]	1.27	0.50	1.65	0.65	1.40	0.55	1.82	0.72
6 to 18	2.54	1.00	3.30	1.30	2.92	1.15	3.80	1.50
>18[6]	5.08	2.00	6.61	2.60	5.84	2.30	7.60	3.00
Cage and aviary								
0 to 3[4]	0.51	0.20	0.64	0.25	0.56	0.22	0.70	0.28
3 to 6	1.00	0.40	1.27	0.50	1.12	0.44	1.40	0.55
6 to 12	1.53	0.60	2.03	0.80	1.76	0.69	2.34	0.92
12 to 18	2.54	1.00	3.30	1.30	2.92	1.15	3.80	1.50
>18	3.81	1.50	4.95	1.95	4.38	1.73	5.70	2.25

[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 assumes 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 doubling the linear trough space/bird and multiplying the result by 0.8.

[3]Feeder space for mini-Leghorns (small-bodied, purebred birds) can be reduced by 10%.

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

[5]A pen is considered an enclosure having a litter floor/ground substrate. The arrangement of the feeders and waterers/water line(s) will influence the feeder space allocation.

[6]Feeder space for White Leghorn and Brown Leghorn breeders is the same as that for 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.

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 for egg-laying strains of chickens is shown in Table 12-1. Depending on strain, specifications are for birds housed in multiple-bird pens and cages, individual cages, or aviaries. Feeder space allocation is presented in the table 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.

Feed should be allocated and body weight (BW) routinely monitored to maintain the recommended BW for the particular stock and age. Anderson and Adams (1992, 1994) found that rearing feeder space from 2.7 to 5.4 cm/pullet (1.1 to 2.1 in/pullet) in white egg layers had no effect on growth, fearfulness, or tibia strength at 18 wk of age. There were no carryover effects on production in the laying phase. Anderson et al. (1995) showed that laying-house feeder space had no effect on sexual maturity, feed consumption, or hen-day egg production of the hens. It has been shown that if feeder space is limited, subordinate birds may be inhibited from feeding (Cunningham and van Tienhoven, 1984). In addition, Webster and Hurnik (1994) demonstrated that hens in cages prefer to feed synchronously. When greater feeder space is provided, this may reduce any negative effects of aggressive behaviors and social dominance during feeding. Thogerson et al. (2009a,b) conducted a 12-mo experiment to test the effects of varying feeder space on laying hen productivity, physiology, and behavior. In that study, Hy-Line W-36 hens were maintained at 5.8, 7.1, 8.4, 9.7, 10.9, or 12.2 cm of feeder space per hen. No effects of varying feeder space allowance were found on egg production, bone mineral density, heterophil:lymphocyte ratios, or organ weights. These findings were substantiated by the work of Anderson and Jenkins (2011), which showed that feeder space of 10.2 or 13.6 cm/hen (using one side of the feed trough) independent of population or density resulted in the same productivity. They did find that as feeder space increased, feed consumption also increased. This resulted in poorer feed conversion for hens provided greater feeder space allowance. In addition, almost no aggressive behaviors were observed between hens when feeder space was reduced. These results demonstrated that hens did not aggressively exclude cage mates from the feeder but did desynchronize their feeding behavior. Therefore, the study documented that sufficient feeder space needs to be provided for hens in conventional cages so that they can eat synchronously. If feeder space is reduced, it does not increase aggressive activity or other behavior problems. However, more recent research has shown that feeder space is linked to aggression in other housing systems (enriched cages: Widowski et al., 2017; aviaries: Sirovnik et al., 2018).

Water

Space allocations for waterers vary widely depending on species, type of bird (Siegel, 1974), bird den-

Table 12–2. Minimum drinker space for commercial egg strains of chickens in floor pens, aviaries, or cages[1,2]

	Linear trough space/bird[2]				Cups or nipples[3]	
	Females		Males		(maximum no. birds/device)	
Bird type and age (wk)	(cm)	(in)	(cm)	(in)	Females	Males
Light breeds						
0 to 6[4]	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
Heavy breeds						
0 to 6[4]	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 assumes both sides of the trough are available. If only one side of the trough is available, double the amount of drinker space/bird. Drinker space for mini-Leghorns (small-bodied, purebred birds) can be reduced by 10%. Perimeter space for round drinkers is obtained by doubling the linear drinker space/bird and multiplying the result by 0.8.

[3]Due to different manufacturers the maximum no. of birds/device may be slightly different.

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

sity, and whether water intake is restricted. Anderson et al. (2004) documented that the frequency of drinking behavior of hens housed at 361 and 482 cm^2/bird remained relatively constant throughout a production period, with no negative interactions at the nipple drinkers. Minimum watering space for egg-laying strains of chickens is shown in Table 12-2. Specifications are for multiple-bird pens and cages, individual cages, and aviaries. These space allocations assume moderate ambient temperatures.

Newly hatched birds may have difficulty obtaining water initially unless they can find the waterers easily. Similar difficulties can 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 require operant conditioning. Because individuals may fail to operate the releasing mechanism by spontaneous trial and error, shaping of the behavior may be required, for example, by pressing the individual bird's beak or bill to the trigger to release the water. 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 is regulated carefully with some automatic devices and watering cups. In such cases, pressure regulators and pressure meters are located close to the levels at which water is being delivered. Manufacturer recommendations are 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 are 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 will raise their heads up while standing to activate the trigger pins (Bell and Weaver, 2002). As a general guide, it is recommended that the bottom of the nipple drinker be positioned at the head level of the bird so it can activate the trigger pin to access the water.

Egg-laying strains of chickens must have continuous access to clean drinking water. Water must be provided daily and made available when feed is being consumed. Adequate drinker space is needed to prevent undue competition at the drinkers. Water may also be shut off temporarily in preparation for administration of vaccines or medications in the water.

HUSBANDRY

Social Environment

Egg-laying strains of chickens are highly social and are maintained in stable groups when possible. Some management practices should be avoided. For example, repeated mixing 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, favorably or unfavorably, to the social environment of the animal (Gross and Siegel, 1982; Bryan Jones, 1994). A calm, friendly interaction between familiar 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 Chapter 4: Environmental Enrichment.

Egg-laying strains of chickens are likely to panic when sudden changes in their environment occur (e.g., a wild bird flying overhead, loud noises to which the birds are not habituated, or an abrupt, rapid, or careless human interaction). 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 (Barrett et al., 2014; Gebhardt-Henrich and Stratmann, 2016). Proper husbandry methods are important to prevent injury and death loss caused by smothering. Such sudden changes in management practices should be prevented to the extent possible. Ideally, young birds, which are less reactive to such stimuli, should be habituated to conditions that are likely to be encountered and that could cause panic responses later in life. Producers report that providing grit or feed on litter to encourage foraging behavior, blocking off corners, and walking pens and barns frequently may reduce smothering (Barrett et al., 2014; Rayner et al., 2016).

Excessive fighting may occur in both multiple-bird cages and alternative systems with moderate density (Craig and Polley, 1977) or in mixed-sex flocks. The proportion of mature males in sexually mature breeder flocks should be low enough to prevent injury to females from excessive mounting. Male to female ratios for breeding purposes can vary for different breeds and strains of chickens. The optimal ratio in most layer breeder flocks is 1 male to 12 to 15 females. Some environmental enrichment techniques can be used to control aggression and over-mating in poultry (Estévez, 1999; Cornetto et al., 2002).

Recent research, however, has shown that social dynamics in layers 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., 2003, 2007). Currently, beak trimming is allowed for preventing or reducing injurious pecking and cannibalism (see Beak Trimming section). In addition, according to AVMA policy, beak trimming of poultry should be practiced only when necessary to prevent feather pecking and cannibalism. Intermediate group sizes of around 30 birds have been found to be more problematic than smaller (15) or larger (60 to 120) groups of layers in floor pens (Keeling et al., 2003). More recent research on furnished (enriched) cages indicates no effect of group size in cages housing 8, 10, 20, 40, or 60 hens at 750 cm^2/hen (116.2 in^2/hen) on either production or mortality (Weitzenbürger et al., 2005; Huneau-Salaün et al., 2011; Wall, 2011).

Floor Area and Space Utilization

Egg-laying strains of chickens should have sufficient freedom of movement to be able to turn around, get up, lie down, groom themselves, stretch their wings, wing flap, and express their normal behaviors (Brambell, 1965). Space per bird for key resources including feeders, water drinkers, perches, and nests should be considered specifically. 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 (Guo et al., 2012). They generally use less area during resting and grooming than during more active periods and may seek the protection offered by the walls of the enclosure, although all areas of a pen are typically used (Keeling, 1994; Cornetto and Estévez, 2001b; Campbell et al., 2016a). Hens also tend to cluster around resources, such as feeders, resulting in high density in some areas of a cage or pen (Channing et al., 2001; Collins et al., 2011). Spatial distribution of hens has been observed to vary considerably over time, ranging from 9 to 41 hens/m^2 in groups housed at a constant density of 18.5 birds/m^2 (Channing et al., 2001); these variations in spatial distribution could be greatest for larger flocks (Channing et al., 2001).

The amount of space physically occupied by a hen when performing different behaviors or different postures, is strain-dependent. Ross hybrid hens used 540 to 1,006 cm^2/hen (83.7 to 115.9 in^2/hen) when turning, 653 to 1,118 cm^2/hen (101.2 to 173.3 in^2/hen) when stretching wings, and 540 to 1,005 cm^2/hen (83.7 to 155.8 in^2/hen) when scratching the ground (Stamp Dawkins and Hardie, 1989). White light-hybrids used an average of 563 cm^2/hen (87.3 in^2/hen) for standing, 1,315 cm^2/hen (203.8 in^2/hen) for turning, and 1,378 cm^2/hen (213.6 in^2/hen) for wing flapping; and hens in flocks of 60 individuals or greater are predicted to need approximately 600 cm^2 (93 in^2) of space to perform both static postures and dynamic behaviors (Mench and Blatchford, 2014). Minimum floor areas for multiple-bird pens, conventional and enriched cages, individually housed birds, and aviaries are given in Table 12-3.

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, production measures, and 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 (i.e., higher space allowances). 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.

Table 12-3. Minimum floor area per bird for commercial egg strains of chickens in floor pens, conventional or enriched colony cages, and aviaries[1]

	Light breeds				Heavy breeds			
	Female		Male		Female		Male	
Type of housing and age (wk)	(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	510	79	667	103
6 to 18	929	144	1,206	187	1,068	166	1,387	215
>18 Litter[3]	1,625	252	2,116	328	1,869	290	2,433	377
>18 S&L, W&L[3]	1,393	216	1,812	281	1,602	248	2,084	323
>18 All-S, All W	1,161	180	1,509	234	1,335	207	1,735	269
Cage (conv./enriched)								
0 to 3	97	15	129	20	107	17	142	22
3 to 6	155	24	200	31	171	26	220	34
6 to 12	232	36	303	47	267	41	348	54
12 to 18	310	48	400	62	357	55	460	71
>18	432	67	503	78	485	75	578	90
Aviary								
>18	851	132	—	—	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]Types 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 White Leghorn and Brown Leghorn breeders is the same as for commercial layers up to 18 wk of age. The floor area is defined as being composed of the litter area, raised plastic slats, including elevated areas. After 18 wk of age, provide 1,858 cm^2 (288 in^2) and 2,137 cm^2 (331 in^2) for litter pens with or without raised plastic slats, 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 Brown Leghorn breeders, respectively.

(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 at 310 cm^2/hen (48 in^2) 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 constraints used, 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). 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 housed in cages with vertical bar fronts (Anderson and Adams, 1991); however, a comparison between hens in enriched colony cages and conventional cages with horizontally barred fronts and aviary-housed hens showed feather abrasion in the caged hens (Blatchford et al., 2016). The cage door needs to 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, during cage cleaning (Anderson et al., 2010). 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 than in hens housed in systems where greater freedom of movement is possible (Knowles and Broom, 1990).

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 space allowances are not critical; however, individually caged birds must have ready access to sources of feed and water. Minimum floor areas for birds with outdoor access are presented in Table 12-4.

Table 12-4. Minimum floor area per bird for commercial egg strains of chickens in outdoor access areas

Production system	Outdoor access	Area		Forage cover (%)
		(m^2/bird)	(ft^2/bird)	
Organic	Required[1]	0.20	2.0	0
Free range[2]	Static	8.00	86.0	50
Free range[3]	28-d rotation	2.80	30.0	50
Free range[4]	Static	6.70	72.0	20

[1]In the United States, outdoor access is required; elsewhere, outdoor access is not required but is usually provided.
[2]Anderson (2009).
[3]Anderson (2015b).
[4]Campbell et al. (2017).

Before 12 wk of age, hens are brooded in confinement. If the outdoor space is to be subdivided, the rotation pattern depends on the geographic location of the facilities; however, in most temperate regions, a 28-d rotation program will allow for a 50% forage cover that provides 2.8 m^2/hen (30 ft^2/hen; Anderson, 2015b). 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.

Flooring

Egg-laying strains of chickens may be kept either on 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, litter provides a cushion during motor activity and resting and absorbs water from droppings. The ideal litter can absorb large quantities of water and evaporate 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. When sampled away from drinkers, litter should hold some moisture but not be so moist that it forms into a ball that resists crumbling when compressed in the hands. Litter should not emit excessive dust when disturbed. The poultry house needs to 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 (Stamp Dawkins et al., 2004). Some examples of acceptable materials used for litter, depending on local availability, include rice hulls, peanut hulls, straw, wood sawdust or shavings, cane bagasse, and chopped *Miscanthus giganteus* grass. In some aviary systems with floor litter areas, producers will initially not place litter material on the floor but rely on accumulation of feed, feathers, and manure. Because litter materials differ in their ability to absorb and release water, husbandry practices may be varied to maintain proper litter conditions. Litter material being stored for future use is usually kept dry to retard mold growth. When poultry are kept in cages or on raised floors, accumulated droppings must not reach the birds. Droppings are to be removed at intervals frequent enough to keep ammonia (NH_3) and odors to a minimum. Experimental work has shown that hens will avoid ammonia concentrations of 20 to 25 ppm (Kristensen et al., 2000; Jones et al., 2005).

Perches

Egg-laying strains of chickens housed in cage-free systems instinctively use perches at night (Olsson and Keeling, 2002). An entire flock (100%) will use 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 an opportunity for hens to seek refuge from aggressive birds and thus avoid cannibalistic pecking (Wechsler and Huber-Eicher, 1998). Early exposure to perches during rearing encourages adult perching behavior (Faure and Bryan Jones, 1982a), and the presence of perches leads to a lower incidence of floor eggs (Appleby et al., 1983) and reduces stress in birds (Campo et al., 2005). However, if perches are not designed properly, they can lead to keel bone deformities (Tauson et al., 2006) and a high level of keel bone fractures; more fractures are observed in systems with high perches (86%, Wilkins et al., 2011). Hens reared with perches develop better ability to move around in 3-dimensional space, which could reduce later keel damage (Gunnarsson et al., 2000), and hens that start to perch early in life may use perches more for nighttime roosting as adults (Heikkilä et al., 2006).

Perches are designed to allow hens to wrap their toes around the perch and balance themselves evenly on the perch in a relaxed posture for an extended period. Perches made of or covered with softer materials such as polyurethane can reduce the number of keel bone fractures and deviations (Stratmann et al., 2015a). Perches should also be easy to clean and not provide hiding places for mites (Fiddes et al., 2005). Wooden perches harbor more mites than plastic but may lead to a lower incidence of leg problems (Tauson and Abrahamsson, 1996). There is conflicting information about hens' preferences for different perch materials or the effect of soiling of perches on perch attractiveness or slipping by hens (see Sandilands et al., 2009 for a review).

Perch recommendations usually specify that perches be located high enough above the floor to allow hens to grasp the perch without trapping their claws between the perch and the floor and to allow eggs to roll under, enabling collection of system-laid eggs (EFSA AHAW Panel, 2015). A minimum of 20% of the perch space should be elevated above the adjacent floor. The amount of space between the perch and the cage ceiling should be more than 20 cm (8 in) to improve perch use (Struelens et al., 2008a). The center of the upper surface of the perch should be flat to allow for weight distribution and minimize keel deformities and foot problems (Struelens and Tuyttens, 2009). Perch edges should be smooth and round. The perch is usually made of nonslip material that can be thoroughly cleaned between flocks. The ideal location for perches is over slats or wire to prevent manure accumulation under the perches. Perch placement is important to minimize fecal contamination of birds, drinkers, and feeders below. Perches also need to be placed at a sufficient distance from the wall to allow birds to use the perch. Enough space should be provided to allow a bird to jump down from its perch at an angle no steeper than 45°. Ramps can also be provided between perches of different heights. Perches should be at least 30 cm (12 in) apart (horizontally) to minimize cannibalistic pecking between birds on parallel roosts.

All birds need to be able to roost at the same time; therefore, a minimum of 15 cm (6 in) of usable linear perch space per bird should be provided. However, offering 17 to 26 cm (6.7 to 10.2 in) of perch space per hen can increase the number of hens that perch simultaneously from 71 to 78% to 100% of the group (Duncan et al., 1992; Cook et al., 2011). Perforated floors that have perches incorporated into the floor structure and the rail in front of nest boxes can be counted as perch space. Thus, graspable edges of slatted or grid platforms or tiers that are at least 60 cm (24 in) from the ground could also be considered part of the perching allowance (Schrader and Müller, 2009; EFSA AHAW Panel, 2015). Hens' preference for grasping while perching appears to be weaker than their preference for perch height (Schrader and Müller, 2009; Schrader et al., 2016).

The arrangement of perches within a system can affect hens' ability to perch. Perches should be arranged in parallel configurations and separated as lower and higher perches (Wall and Tauson, 2007). The higher perch should be >60 cm (>24 in) above the ground for nighttime roosting because hens prefer to use higher perches at night. Up to 90% of hens in a flock have been observed roosting on top-level perches and tiers, using lower perches and tiers only as upper levels are filled (Abrahamsson and Tauson, 1995; Odén et al., 2002). The height of the higher perch should not exceed 1 m (3.3 ft) above the floor to minimize skeletal fractures during bird flight from a perch. Hens will use ramps to move between tiers or perches, and provision of these can minimize keel bone injuries to hens from flying up to or jumping down from tall perches (Stratmann et al., 2015b; Heerkens et al., 2016a).

There are differences in perch usage and preference between breeds that need to be considered when placing hens into systems. White Leghorn type hens have been observed to prefer higher perches at night compared with brown hens in some studies, whereas the reverse is true for other strains; in some cases, no differences have been reported (Faure and Bryan Jones, 1982b; Wall and Tauson, 2007; Cook et al., 2011; Ali et al., 2016). A possible explanation for breed-related differences could be differences in wing load, making it more difficult for heavier hens to access higher perches (Moinard et al., 2004) or to control landings onto perches (Scholz et al., 2014).

Nests

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). Hens without prior exposure to nests 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 an electrical hot wire near walls outside the nests may discourage the laying of floor eggs, as may a bright light that eliminates shadows when directed toward the corner.

Nests should be dark inside to lower the risk of cannibalism. Having nests that are properly constructed and maintained is important to protect hens from external parasites and disease organisms. Nests are closed to bird access at night and reopened before lay early in the morning. Regular inspection and cleaning of nests should be performed to ensure that there is no manure accumulation. Nest floors can be sloped to allow eggs to roll onto collection belts, and hens prefer slopes of 12% compared with 18% (Stämpfli et al., 2011). Nests should be provided with a suitable floor substrate (e.g., turf pads or wood shavings) that encourages nesting behavior (Hughes, 1993; Struelens et al., 2008b). It is best to avoid nests with wire floors or plastic-coated wire floors alone. 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, a minimum of 1 nest box per 8 birds should be provided. Nest box size for individual 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). For colony nests, a minimum of 0.8 m^2 (9 ft^2) of nest space per 100 hens should be provided. Hotter climates may require more nest space.

Pullets intended for systems with nests adapt better if they are 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 floor eggs during the laying period (Appleby et al., 1983). However, pullets reared in aviaries and then placed in enriched colony cages may find the nests in cages less attractive than pullets reared in standard cages (Hunniford and Widowski, 2016). Birds transferred to the layer house before sexual maturity need to be allowed sufficient time for exploration of the house and to find the nests before onset of lay.

Crowding in nests may increase the risk of heat stress and smothering (Riber, 2010), or scratches, wounds, and feather loss from birds climbing on top of each other (Appleby and Smith, 1991). Several factors may result in overcrowding of nest areas, including the attractiveness of the artificial nest compared with other areas of the cage (Appleby et al., 1985), internal circadian rhythms of hens that result in most egg laying occurring during morning hours (Boz et al., 2014), preference of hens for nests in specific locations (Lentfer et al., 2013; Riber and Nielsen, 2013), and gregarious nesting behavior, whereby the presence of other hens in a nest makes it more attractive for hens searching for a location to lay (Riber, 2010, 2012). Insufficient space for simultaneous use of the nest by all hens may prevent hens from performing pre-lay behaviors and oviposition in a preferred location and can result in litter or system-laid eggs by individuals unable to access the nest (Kruschwitz et al., 2008). There is also evidence of competition among hens in enriched colony cages for access to nests (Hunniford et al., 2014), suggesting that using the location of eggs laid as a measure of nest space or appropriate design is not sufficient.

Further comparative studies involving observation of nest box activity, aggression and displacement behavior (Odén et al., 2002), pre-lay behaviors of hens laying outside the nest box (Cronin et al., 2005), and tracking of eggs laid by individual hens would be beneficial to determine the role of pre-lay behaviors in egg lay pattern discrepancies between strains.

Incubation and Hatching

The incubation and hatching process for eggs from egg-type breeders is similar to that discussed in Chapter 11: Meat-Type Poultry. As stated in that chapter, factors that contribute to successful incubation and hatching of eggs include egg characteristics, egg cleanliness, egg storage, incubator and hatcher temperatures and humidity, and egg turning. When assessing egg quality and cleanliness, it is important to set eggs that are of sound shell texture, not cracked or damaged, and have a clean exterior shell. If fertile eggs are to be stored for any length of time they should be placed in incubation trays with the small (pointed) end of the egg facing down and stored in a cooler or cool room until pickup for the hatchery. Eggs from a collection period (morning and afternoon) should be stored at 15 to 18°C (59 to 64.4°F) with a relative humidity of 70 to 80% (Hy-Line International, 2020). When necessary to save eggs longer than 10 d, store at 13°C (55.4°F) with 70 to 80% relative humidity. Eggs can be stored for up to 7 to 8 d before hatchability decreases. After storage for 10 d, there is a marked decrease in hatchability. Incubation of eggs during the setting phase (days 1 to 18/19) requires temperature and humidity of 37.5°C (99.5°F) and 65% relative humidity, respectively. During the last 2 to 3 d in the hatcher, the temperature should be lowered to 36.9°C (98.4°F) and relative humidity increased to 70%. When eggs are transferred from the setter to the hatcher, they should be carefully moved and laid down flat in the hatcher trays. At this time (d 18/19), the ventilation and relative humidity in the hatcher are increased because embryos need extra moisture to be able to hatch. In addition, metabolic heat and the need for oxygen increase when chicks start to hatch. Following hatching (d 21), the chicks are carefully moved to a chick holding room for chick processing (beak treatment, vaccine administration).

Brooding Temperature and Ventilation

Because thermoregulatory mechanisms are poorly developed in young egg-laying chicks, supplemental heat is 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 generally increased gradually over the first few weeks of the brooding period. Whether ventilation is provided 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, such as in houses having windows for ventilation and with chicks kept in floor pens, draft shields may be beneficial for 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 possible and by avoiding or seeking contact with other individuals. Extreme huddling of young birds directly under the source of heat, especially during waking hours, usually indicates the 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 (cool room brooding), the temperature outside the brooding area is maintained at 20 to 25°C (68 to 77°F) during the first few weeks but should not be so high as to cause young birds to pant or show other signs of hyperthermy. When the entire room (whole house) is heated and chicks are not free to move to cooler areas, the minimum temperatures 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 non-responsiveness 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 under the brooder and weekly decreases are suggested until supplementary heat is no longer needed:

- Cool room for chicks: 32 to 35°C (90 to 95°F) ambient temperature 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).

- Whole house for chicks: 30 to 32°C (86 to 90°F) ambient temperature initially, decreasing by 2.5°C (4.5°F) weekly to 20°C (68°F); however, supplemental heat may be discontinued at 3 wk if indicated by pullet behavior and room temperature is 22 to 24°C (72 to 75°F).

Air Quality and Ventilation During Rearing and Laying Phases

After the brooding phase, ventilation and indoor air quality are maintained to provide for bird comfort and optimal rearing and egg-laying performance. The purpose of good ventilation is to maintain proper indoor temperature, remove moisture (particularly during the winter), and keep ammonia and dust levels to a minimum. Several types of pullet rearing and laying situations exist. Birds might be reared on a littered floor and then transferred to cages or kept in a cage-free facility with nest boxes. They might also be brooded and reared in cages and then transferred to cages or to a cage-free facility.

Good air quality and adequate ventilation must always be maintained in both cage-free and cage facilities. It is important to maintain proper house ventilation to avoid heat stress. Laying hens that are exposed to high environmental temperatures; that is, above 29.4°C (84.9°F), will decrease egg production and have poorer eggshell quality due to the thinning of shells that results when hens experience a "respiratory alkalosis" condition related to panting behavior. Panting is one means by which poultry thermoregulate. During extreme high temperatures and relative humidity, this condition may be unavoidable. Ventilation systems designed to avoid this problem are very important.

In addition to the effects of heat stress on laying hen performance and welfare, it is critical to maintain adequate poultry house ventilation to avoid the build-up of ammonia (NH_3) gases due to the degradation of nitrogenous compounds in poultry manure. Exposure to high levels of ammonia causes irritation of the mucous membranes of the respiratory tract and eyes, increasing susceptibility to respiratory diseases and corneal inflammation (Kristensen and Wathes, 2000; Aziz and Barnes, 2010). 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), exposure for humans must not exceed 5 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 it is recommended that levels not exceed 50 ppm for any considerable period (Lott and Donald, 2002).

Lighting

Light is an important aspect of a laying hen's or breeder's environment. The various aspects of light quality—wavelength (i.e., the color of light), intensity, and duration—are important to achieve proper pullet growth and to stimulate production. Research has shown that the color of light has many different effects on behavior, growth, and reproduction in poultry. Birds sense light through their eyes (retinal photoreceptors) and through photosensitive cells in the brain (extraretinal photoreceptors). It has been well documented that long wavelengths of light (toward the red end of the spectrum) penetrate the skin and skull more efficiently than short wavelengths (the blue end of the spectrum). Growth and behavior are affected by shorter wavelengths of light, whereas production (egg laying) is stimulated more by long wavelengths. Therefore, blue-green light stimulates growth and orange-red light stimulates reproduction. The color of light is important for stimulating egg production and is related to the chromaticity of light. Chromaticity is a measure of a light source's warmth (warm light) or coolness (cool light), and it is expressed in degrees kelvin (K). A chromaticity value of light between 3000K and 3500K (a warm light) is preferred for stimulating production in layer breeders and laying hens. In addition, ultraviolet light can also have an effect on several responses in poultry. It has been shown that birds can perceive UVA light, which affects a variety of behaviors (Lewis and Gous, 2009), and UVB light affects vitamin D metabolism (de Matos, 2008), which could have a beneficial effect on egg quality and bone health. In research facilities, incandescent bulbs, fluorescent lamps, or LED lamps can be used with success and provide the correct color of light.

Another important lighting factor is light intensity. Light should not be too bright after the first few days following hatch and during the laying period for breeders and laying hens. However, during the first few days after hatching, light intensity should be relatively bright to enable chicks to find feed and water.

The third important aspect of lighting is the duration of light (i.e., photoperiod). Two basic rules must be followed for optimum growth and production performance: (1) never increase the duration or intensity of light during the growing period, and (2) never decrease the duration or intensity of light during the egg production period. These rules apply to both layer breeders and laying hens.

Many possible variations exist for the application of lighting programs to growing and laying birds that will not harm the birds. When the light environment can be controlled, the following guidelines promote optimum growth and production performance in laying hens and layer breeders. Pullet chicks need to have 20 to 22 h of continuous light at 30 to 50 lx (2.8 to 4.6 foot-candles, fc) intensity during the first week of age. After the first week of age, light intensity can be reduced to 10 lx (0.9 fc) at the feeder.

As far as day length (photoperiod) is concerned, the continuous light period should be reduced gradually to 8 to 12 h by 10 wk of age. If the pullets are grown in brown-out houses or open-sided houses, they need to be grown at a time of year when natural daylight is decreasing; if grown at other times of the year, artificial lighting should be applied so birds do not prematurely experience an increase in photoperiod. The light intensity in the growing period is usually kept the same as that used in the lay house.

It is important to remember that light stimulation (i.e., an increase in photoperiod) should not be provided until the flock has reached optimum BW. This is important because if hens are light stimulated before reaching optimum BW, there might be problems with a condition called prolapse. This is where the uterus (shell gland) of the hen has everted to the outside of the vent area and will not retract after the hen lays an egg. This could cause an unhealthy status for the hen and a possibility of pecking by other hens. Therefore, when target BW is reached (about 17 to 18 wk of age), day length can be increased from the growing photoperiod; that is, from 8 to 12 h/d to 14 to 17 h/d in 15- to 30-min increases per week. Additionally, the minimum light intensity needs to be 10 lx (0.9 fc), and intensities up to 30 to 40 lx (2.8 to 3.7 fc) are adequate. Higher intensities risk development of behavioral problems such as feather pecking and cannibalism.

When layer breeder hens and laying hens are subjected to a molt program, day length may be decreased to encourage hens to cease laying eggs, and then increased to its original length when hens are brought back into production. Other factors to keep in mind when inducing a molt are discussed later in this chapter. When initiating an induced molt, day length is generally reduced to 9 to 10 h per day at the start and kept at this level until hens begin to return to egg production around 3 wk later (Biggs et al., 2003, 2004; Mejia et al., 2010, 2011). This reduction in day length works best in enclosed, light-controlled houses, but it will also work in open-sided houses if done at the appropriate time of the year.

STANDARD PRODUCTION PRACTICES

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

Beak Trimming

Trimming the tip of the beak is done to minimize feather loss, injury or death due to feather pecking, aggression, and cannibalistic behavior. Outbreaks of cannibalism among egg-laying strains of chickens 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 the use of low light intensity in housing systems in which light control is feasible. Genetic stocks that show little tendency toward cannibalistic behavior and feather pecking should be used when possible (Hester and Shea-Moore, 2003; Lay et al., 2011). Use of enrichments to control cannibalism and feather pecking are discussed in Chapter 4: Environmental Enrichment.

Production, behavior, and physiological measurements of stress (Glatz, 2005) and pain, as indicated by neural transmission in the trimmed beak (Gentle, 1989), 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 (Freire et al., 2003). Disadvantages of beak trimming include short-term stress (Davis et al., 2004) as well as short-term, and perhaps long-term, pain following trimming of the beak (Cheng, 2005; Kuenzel, 2007). Because a bird's feeding behavior is usually modified by a new beak shape, their efficiency in eating may be impaired following a trim. Welfare advantages of beak trimming 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 can be 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 prospects for improving livability through genetic selection are good (Ellen et al., 2008). Therefore, when feasible, stocks that require either minimal or no beak trimming should be used. Nevertheless, beak trimming is justified in stocks that are otherwise likely to suffer extensive feather-pecking and cannibalistic losses. Management guides, available from most breeders, indicate methods for beak trimming to reduce these vices. The 2 acceptable methods of beak trimming are infrared beak treatment at the hatchery and hot-blade beak trimming at 6 to 10 d of age or younger (Hester and Shea-Moore, 2003; Glatz, 2005; Kuenzel, 2007; Schwean-Lardner et al., 2016). Janczak and Riber (2015) provided an exhaustive review of these beak trimming methods, and various circumstances would dictate when each method should be used. The amount of beak trimmed should be 50% or less to prevent 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 needs to 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 best done before the pullets are 8 wk of age to avoid a decrease in egg production (Andrade and Carson, 1975).

Toe Trimming

Toe trimming is rarely needed except in some research situations to identify different strains of laying hens when they are raised in a mixed flock. In this practice, it is common to remove only the nail portion of one toe at hatch from chicks to distinguish the strain. The disadvantages of toe trimming were reported by Honaker and Ruszler (2004), where Leghorn hatchlings whose claws were trimmed through use of microwave energy experienced slight bleeding with minor pain, increased mortality, and reduced feed consumption and BW during the pullet grow-out period. Removal of the claws resulted in 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 1,200 pullets whose claws were trimmed in one experiment. Compton et al. (1981a,b) reported similar results when using a hot blade to reduce claw length and suggested that chick movement in 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, except in certain situations where strain identification is needed.

Partial Comb and Wattle Removal

The comb and wattles are important for thermoregulation in birds. Removal of part of the comb (dubbing) and wattles should not be performed on birds housed in facilities that are not appropriately cooled during the summer (Hester et al., 2015; Al-Ramamneh et al., 2016). Dubbing and wattle trims may be needed if birds are kept in cages. Combs and wattles can be caught in wire openings or feeders after significant comb and wattle growth has occurred (Card and Nesheim, 1972; Fairfull et al., 1985). This is more prevalent in cages with vertical wire cage fronts and has been mitigated with the development of horizontal wire cage fronts. 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 is 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, a scalpel blade, or an electrocautery/radiosurgery electrode (Bennett, 1993, 1994) is used to remove part of the comb and wattle during the first few days after hatching. To reduce risk of infection between birds, the surgical device needs to be disinfected.

Pinioning

Surgical pinioning is the act of surgically removing the wing at the pinion joint (the joint farthest from the body) to prevent flight. The portion removed is the metacarpal, the point on the wing where the primary flight feathers originate. The procedure is accomplished using a hot blade and a bar apparatus mounted in a Lyons trimmer. One wing (i.e., left or right) is extended and a cut made through the joint at the intracarpal ligament between the radius and ulna and the first phalanx of the third and fourth digit. Simultaneously, the hot blade cauterizes all cuts, stopping any bleeding and enabling the birds to recover much faster. The pain and distress associated with this procedure at 1 d of age is similar to that of beak trimming at 6 to 10 d (Startup, 1967). Pinioning is usually done as a means to reduce bird flightiness. If flightiness is problematic, the primary feathers of one wing may be clipped, a process called "temporary pinioning."

Induced Molting

As birds approach sexual maturity, their plumage is normally replaced through a natural molt. Birds also molt naturally after sexual maturity at some point, which results in a pause in egg production of varying duration, and individuals do not remain in synchronous egg production stages with others in the flock. Some triggers of a natural molt in birds include a reduction in the daily photoperiod, dramatic changes in environmental temperature, or food deprivation. An induced synchronized molt is used to rejuvenate laying flocks to extend the productive life of hens for an additional cycle of production. Molting remains a common procedure for commercial table-egg layers even though its use is declining. This is due to the use of egg-laying strains of hens that can lay persistently at a high rate with acceptable eggshell quality in a single cycle. In recycled commercial flocks of egg-laying strains of chickens, molting decreases the demand for chicks by 47%. Benefits of molting include feather rejuvenation, which improves thermoregulation (Anderson, 2012). After a molt, livability and egg quality were improved during the second cycle of egg production compared with a nonmolt control group (Bell, 2003).

Several procedures can be used to induce a molt, including manipulation of dietary energy (Dickey et al., 2010, 2012), protein levels (Anderson, 2002), and dietary ingredients such as calcium (Gilbert and Blair, 1975), iodine (Herbert and Cerniglia, 1979), sodium (Whitehead and Shannon, 1974), or zinc (Park et al., 2004); addition of feed additives that influence the neuroendocrine system such as iodinated casein (Kuenzel et al., 2005; Bass et al., 2007); and short-term (Ruszler, 1998) and long-term feed withdrawal.

Researchers have developed non-feed-withdrawal molting programs, which are preferred by the egg industry. Several researchers have used feed ingredients such as cassava meal and broken rice (Gongruttananun et al., 2013), bitter vetch (Sadeghi and Mohammadi, 2009), alfalfa meal (Donalson et al., 2005; Callaway et al., 2009; McReynolds et al., 2009), tomato pomace and safflower meal (Patwardhan et al., 2011a,b), alfalfa meal and barley (Sarıözkan et al., 2013), and corn distillers dried grains with solubles (Mejia et al., 2010, 2011; Bland et al., 2014) in molt diets with successful results. These procedures may be coupled with a reduction in daily photoperiod. These methods cause a cessation of egg production along with decreased BW and feather loss. A return to egg laying, feather regrowth, and BW gain are accomplished by feeding a diet designed to meet the nutritional requirements for non-ovulating, feather-growing hens (Anderson, 2002; 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 to induce 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 were 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 an additional behavioral repertoire of increased preening on d 8 to 10 after feed removal, most likely coinciding with the dropping of feathers.

ENVIRONMENTAL ENRICHMENT

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

HANDLING AND TRANSPORT

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

SPECIAL CONSIDERATIONS

Genetically Modified Birds

To date, there are no special animal care requirements for transgenic, cloned, or CRISPR (clustered regularly interspaced short palindromic repeats)-edited poultry. These 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. Refer to Chapter 1: Institutional Policies for general information on the care and use of genetically modified animals.

Surgeries

All intrathoracic and intra-abdominal invasive surgeries require anesthesia. Caponization (removal of the testes) and cecectomy (removal of the ceca) are invasive surgical procedures that require anesthesia; see sections in Chapter 2: Agricultural Animal Health Care that deal with surgery of experimental animals.

EUTHANASIA

Appropriate methods of euthanasia are covered in Chapter 2: Agricultural Animal Health Care and in the American Veterinary Medical Association (AVMA) *Guidelines for the Euthanasia of Animals* (AVMA, 2020). In addition, further information on the methods of euthanasia for poultry are also detailed in the *Practical Guidelines for On-Farm Euthanasia of Poultry* (PICC, 2016). For the purpose of euthanasia of poultry, the AVMA guidelines accept injection of overdoses of anesthetics, including barbiturates and barbituric acid derivatives. AVMA accepts, with conditions, the use of the following inhaled agents: carbon dioxide, carbon monoxide, nitrogen, argon, or mixtures of nitrogen or argon with carbon dioxide. The following physical methods are acceptable with conditions: cervical dislocation (performed manually or with mechanical assistance), decapitation, manually applied blunt force trauma, electrocution, gunshot (not recommended for captive poultry where restraint is feasible), and penetrating and nonpenetrating captive bolt. Intravenous or intracardiac administration of potassium chloride or magnesium sulfate and exsanguination are acceptable adjunctive methods, provided the bird is anesthetized or rendered unconscious first. Methods of euthanasia need to be selected to take into account any special requirements of experimental protocols so that useful data are not lost.

When relatively large numbers are involved, exposure to gas euthanasia agents, such as carbon dioxide, in enclosed chambers may be preferred. Atmospheres containing a significant amount of carbon dioxide cause birds to head shake and breathe deeply. These behavioral changes are not caused by irritation of mucosal epithelia in the nares or throat because they occur at carbon dioxide levels below the threshold of trigeminal nerve nociception; that is, 40 to 50% carbon dioxide based on a laboratory study of nerve fiber activity in chickens (McKeegan, 2004). Furthermore, although poultry can detect atmospheres containing 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% under moderate motivation to obtain food (Webster and Fletcher, 2004; McKeegan et al., 2005, 2006; Sandilands et al., 2011).

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., 2007), and concentrations of carbon dioxide above 50% quickly kill adult birds (Raj and Gregory, 1990a), it is not necessary to measure the carbon dioxide concentration closely when performing euthanasia. However, the process needs to 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, anoxia caused by the high gas concentration promotes convulsive wing flapping after loss of posture, which can be disagreeable to human observers. Slower induction of unconsciousness using lower concentrations of carbon dioxide, with or without supplemental oxygen, appears to sedate birds and reduce convulsions after loss of posture (Raj and Gregory, 1990a; Webster and Fletcher, 2001; Coenen et al., 2009; Gerritzen et al., 2013). Newly hatched poultry may have a greater tolerance to carbon dioxide, so higher concentrations may be needed for euthanasia of these birds (AVMA, 2020).

Anoxia using argon or nitrogen, or mixtures of these gases with carbon dioxide, is effective to kill poultry with minimal distress, but residual oxygen should be kept low; for example, $\leq 2\%$ (Raj and Gregory, 1990b; Raj and Whittington, 1995). Anoxia causes convulsive wing flapping after loss of posture. Although convulsions may occur at a time when a degree of consciousness is possible (McKeegan et al., 2007; Coenen et al., 2009), the bird's experience would be short. Anoxia by controlled reduction of atmospheric pressure may also be a humane way to kill chickens with appropriate equipment (McKeegan et al., 2013). When using anoxia, the final gas concentration should be achieved quickly enough to avoid development of ataxia in conscious birds (Woolley and Gentle, 1988).

Blunt force trauma and shooting with a captive bolt cause immediate insensibility due to brain damage and are effective methods of euthanasia when properly applied (Erasmus et al., 2010a,b; Bader et al., 2014; Cors et al., 2015). Sufficient force and accuracy in the application of either technique is essential (Raj and O'Callaghan, 2001; Cors et al., 2015). A second blow or shot must be administered immediately if it is evident that the first one was not effective. Monitoring of birds is important to ensure that death follows. It is acceptable for a properly trained individual to use cervical dislocation without stunning or anesthesia when a limited number of birds of an appropriate size require euthanasia. Following cervical dislocation, the necks of birds should be checked for separation of vertebrae at or near the base of the skull. Use of a burdizzo to crush the cervical vertebrae is not considered acceptable unless the bird is rendered unconscious first (AVMA, 2020). Death from blunt force trauma or captive bolt shot appears to follow from direct disruption of brain function, whereas cervical dislocation appears to cause death by cerebral hypoxia and ischemia (Gregory and Wotton, 1990; Erasmus et al., 2010b). Blunt force trauma, captive bolt shooting, and cervical dislocation result in vigorous convulsive wing flapping.

Embryonated eggs may be destroyed by chilling at 4°C for 4 h or freezing (Close et al., 1997), or by exposure to CO_2 for 20 min (AVMA, 2020). 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 an acceptable method for killing embryos and surplus neonatal chicks (AVMA, 2020).

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CHAPTER 13: WATERFOWL

INTRODUCTION

In commercial meat duck production today, the Pekin duck is the predominant breed, followed by Muscovy and Mule ducks. A typical Pekin duck can reach market weight of about 3.1 kg (6.8 lb) at 5 wk, with a feed conversion ratio of approximately 1.7. Breast meat yield, which is considered the most important selection trait in Western countries, averages 20% of carcass weight. The Muscovy duck is slower growing, with less fat and greater sexual dimorphism in body weight (BW). Female Muscovy ducks are generally marketed 2 to 3 wk earlier than males to limit carcass fat deposition. Mule ducks are a hybrid sterile cross between Pekin and Muscovy ducks and have comparable BW between the 2 sexes, removing the obstacle associated with marketing females at a different age. Mule ducks are favored by certain markets for their good carcass composition with more meat and less fat than Pekin ducks. Both Muscovy and Mule ducks are usually grown to around 10 wk of age to a market weight of 2.75 to 3 kg (6.1 to 6.6 lb) with a feed conversion ratio of approximately 2.75. For meat goose production, a typical goose can reach a market weight of 4 kg (8.8 lb) at 8 to 10 wk of age, whereas a heavy-type goose will go to market at 12 wk at a BW of 6.0 kg (13.2 lb).

In the wild, dabbling waterfowl—the ancestors of domestic waterfowl—are aquatic birds that obtain their food either by foraging on land or along the water's edge, in grass, or through mud by filtering food from non-food through the lamellae in their bills ("dabbling," Guillemain et al., 2000; Cherry and Morris, 2008). In addition to species-specific feeding behaviors, wild waterfowl perform a considerable amount of preening, which allows them to remove dirt and parasites from their feathers. In a commercial setting, waterfowl display similar behaviors to their undomesticated ancestors. Generally, waterfowl are social animals, so housing in isolation should be avoided unless necessary for the experimental design. Also, unless necessary for experimental design or teaching purposes, it is recommended that bill trimming and molting be avoided. Although Pekin ducks may not require nail trimming, larger waterfowl species such as Muscovy ducks or geese may need to be nail-trimmed for the protection of conspecifics and humans working with these animals. The necessity of nail trimming should be left to the discretion of the investigator. Refer to Chapter 12: Egg-Type Poultry for detailed discussions of molting and bill trimming. The purpose of this chapter is to provide guidelines for the care and use of waterfowl in research and teaching as suggested by studies of the specific species whenever possible.

FACILITIES AND ENVIRONMENT

Space Utilization

Use of floor area by birds within groups follows a diurnal pattern and is influenced by the dimensions and design of the facility. Waterfowl may huddle together for shared warmth or spread out for heat dissipation. Birds generally use less area during resting and grooming than during periods of higher activity and will often seek the protection offered by the walls of the enclosure (Newberry and Hall, 1990; Cornetto and Estevez, 2001). Recommendations for minimum floor area for multiple-bird pens and cages as well as individually housed birds are presented in Table 13-1. Because of a relative absence of research on well-being indicators for ducks, and especially for geese and other waterfowl poultry species, these recommendations are based on professional judgment and experience. Generally, area allowances are assumed adequate when productivity of the individual birds is optimal and conditions that are likely to produce injury and disease are minimal.

Flooring

Most research on flooring types for waterfowl has been conducted on ducks; however, observations suggest that geese may have similar requirements. However, the expertise of researchers and educators for all waterfowl species should be considered. Ducks may be kept on solid floors with litter or in cages or pens with raised wire floors of appropriate gauge and mesh dimension. Solid floors are better for heavy strains of waterfowl. When waterfowl reside on solid floors, litter provides a cushion during motor activity and resting and absorbs

Table 13-1. Minimum floor area/bird for ducks raised in confinement

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

[1]Space for drinkers is included.

[2]Developing breeders raised outdoors should have a minimum of 1,290 cm^2 (200 in^2) of shelter area/bird.

[3]Does not include space for feeder, drinkers, or a hen's nest.

water from droppings. Typically, floor litter in duck barns is made up of pine shavings or straw, although other substrates may be used. The ideal litter can absorb large quantities of water and 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 waterfowl. When sampled away from the drinkers, the litter should be moist but not so wet that it forms into a ball resistant to crumbling when compressed in the hand. Litter should not emit excessive dust when disturbed. The poultry house should be ventilated to prevent litter from becoming overly moist. Avoiding excess moisture in the litter improves bird health by preventing feces and dirt from adhering to the foot, which can lead to foot pad dermatitis, hock lesions, leg defects, and stress, as measured by fecal corticosterone levels (Stamp Dawkins et al., 2004).

Particular attention should be paid to the type of floor provided in pens or cages for the common duck; flooring type should consider experimental design necessity balanced with the fact that the epidermis on the feet and legs of this species is less cornified than that of domesticated land fowl (duck feet are more susceptible to injury; Koch, 1973). Properly designed, nonirritating floor surfaces minimize risk of injury to the foot pad and hock and reduce the incidence of subsequent joint infections. 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 with proper design may be used without serious adverse effects if ducks are not kept on them for more than 3 mo. Young ducks or smaller egg-type breeds (e.g., Khaki Campbell) are less susceptible to irritation from wire flooring than are older ducks or 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. Twelve-gauge welded wire with a 2.5-cm (1-in) mesh is usually satisfactory for all ducks over 3 wk of age. 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. Raised plastic flooring is commonly used in commercial duck production, and welfare quality assessments are similar to those for pine litter flooring (Fraley et al., 2013; Karcher et al., 2013).

Irritation to the feet (footpad dermatitis) 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. Provision of drinking devices over the wire-covered section of the pen greatly reduces deposition of water into 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, provision of extra litter and removal of excess water vapor by the ventilation system are essential. Supplemental heat may be necessary to aid in moisture control.

Brooding Temperatures and Ventilation

Because thermoregulatory ability is poorly developed in young ducklings, higher environmental temperatures are required during the brooding period. Heat requirements of ducklings 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 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. In relatively open brooding facilities, such as in barns with windows or curtains for ventilation, draft shields may be 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, ducklings can maintain appropriate body temperatures by moving away from or toward sources of heat when possible and by avoiding or seeking contact with other individuals. The huddling of young birds in a single group directly under the heat source, especially during waking hours, usually indicates the need for more supplemental heat, whereas over-dispersal away from the heat source or other birds, characteristically 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 so high as to cause the young birds to pant or show other signs of hyperthermy. When the entire room is heated but chicks are not free to move to cooler areas, temperatures may be too high. Thus, during the first week after hatching, a lower temperature (e.g., approximately 29.5°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. Minimum temperatures of 26.5 to 29.5°C (80 to 85°F) and weekly decreases of 3.3°C (6°F) are suggested until supplementary heat is no longer needed. After birds have fully feathered (about 23 d of age), ducks are comfortable at environmental temperatures of 10 to 15°C (50 to 60°F).

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

Lighting

A lighting program providing 18 h of light with 6 h of dark is ideal, but waterfowl are adaptable to a range of diurnal photo- and scotoperiods. Waterfowl are typically housed under LED, incandescent, or fluorescent lighting or even kerosene lanterns in commercial settings around the world. No adverse effects have been noted for any of the light sources. It has been suggested that fluorescent lights that utilize older ballasts allow light "flicker" that may produce an environment stressful to chickens; however, this has not been specifically tested (Rogers et al., 2015). The use of fluorescent lights with modern digital ballasts is recommended to eliminate such concerns. The output of light (i.e., wavelength and photonic energy) is important, rather than the particular bulb type (e.g., LED, fluorescent, or incandescent).

Red or white light provides the best environmental conditions for waterfowl at any age, and blue light should be avoided unless necessary for the experimental design. The effect of red or blue lighting has been minimally studied in ducks, but research has suggested that in grow-out ducks, red light may have some advantage in terms of reduced activity and feather picking (on self) or feather pecking (on conspecifics); however, the reduced activity does not translate to improved growth rates or carcass quality (Campbell et al., 2015). Interestingly, unlike chickens, housing ducks under blue light may have detrimental effects in terms of behavior, growth rate, and carcass quality (Campbell et al., 2015). The negative effects of blue light have also been observed in the endocrine profiles of the hypothalamic-pituitary-adrenal and somatotropic axes (Campbell et al., 2015). A single study showed that blue LED light was not appropriate for white Roman breeder geese (Chang et al., 2016). Experimental design should ensure that white light sources among treatment groups emit light in the same ranges of wavelengths (i.e., have similar color temperature in degrees kelvin) and that the lux meter used is capable of measuring the wavelengths emitted. However, the effects of higher or lower light intensities on waterfowl welfare have not been examined to date.

Table 13-2. Minimum feeder space/bird for ducks[1]

	Linear trough space[2]	
Bird type and age	cm	in
Growing ducks		
1 wk	0.9	0.35
2 wk	1.0	0.40
3 wk	1.3	0.50
4 wk	1.5	0.60
5 wk	1.7	0.65
6 wk	1.8	0.70
7 wk	1.9	0.75
Developing breeders (feed restricted)		
>8 wk	10.2	4.0

[1]Feeder space allocations may be slightly more than needed for smaller breeds of ducks.

[2]Linear trough space assumes 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.

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 birds are housed. If feed troughs are located outside the space in which 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 access to both sides of the trough. Minimum feeder space recommendations for ducks are shown in Table 13-2. Feeder space allocation in the tables is presented as linear trough space per bird assuming both sides of the trough are available. If only one side of the trough is available, then the amount of feeder space per bird should be doubled.

The parental stocks of meat-type ducks (breeders) are prone to excessive BW gain that leads to obesity-related health issues unless energy intake is controlled beginning early in life. Breeders should be allocated limited amounts of feed to allow for a gradual increase in BW each week. Under feed restriction, breeders may show stereotypic pecking on non-nutritive objects and excessive drinking of water. Overfeeding or excessive food restriction may reduce fertility (Savory et al., 1993).

Feed should be allocated and BW routinely monitored to maintain the recommended BW for the particular stock and age. Inhibition of feeding by subordinate birds is likely if feeder space is limited (Cunningham and van Tienhoven, 1984). Rations may be offered as a fixed amount of feed allotted daily or according to various alternate-day feeding schemes. Alternate-day feed restriction as opposed to limited feed each day allows subordinate birds access to feed, resulting in better flock uniformity (Bell and Weaver, 2002). Therefore, procedures that require restricted feeding should provide enough feeder space so that all birds can eat concurrently. It may also be helpful to use low-density diets and provide birds with environmental enrichment devices that they can manipulate to satisfy their feed-seeking behaviors (Colton and Fraley, 2014).

Ducks experience difficulty consuming mash-type feed because as the mash becomes moist from saliva or drinking water, it may cake on their mouthparts and lead to physical restriction to ingest feed. Therefore, it is recommended that feeds for ducks be provided in pelleted form.

Nutrition

The nutrient requirements of waterfowl vary depending upon species, age, production purpose (meat vs. reproduction), environment, season (Raveling, 1978), and experimental needs for BW gain, feed efficiency, or carcass yield. In addition to nutrient specifications, other factors should be taken into consideration, including form of the feed and feed safety.

Feed Safety. Ensuring feed safety is crucial when raising waterfowl. No anti-coccidial medications should be included in the feed because waterfowl housed in clean conditions are less susceptible to coccidial infections than chickens. Anti-coccidial medications in feed can be toxic to ducks. It is recommended that waterfowl feed ingredients and finished feeds be tested to ensure the absence of the major mycotoxins. Waterfowl, Pekin ducks in particular, are extremely sensitive to mycotoxins (Davis et al., 1994) such as aflatoxin. Levels as low as 0.1 mg of aflatoxin B_1/kg of diet can lead to significantly impaired growth, liver function, and immune dynamics in Pekin ducklings. Given that it is common practice to include multiple feedstuffs in typical diets, simultaneous exposure to multiple mycotoxins is possible, which may have synergistic effects on the health of a bird. In addition, feeding low-protein diets can exacerbate the negative effects of mycotoxins; therefore, extra caution is needed when low-protein diets are fed (Chen et al., 2014, 2016). Most species of waterfowl are very susceptible to heavy metals such as cadmium, lead, and arsenic (Leeson and Summers, 2009), although toxic levels are unlikely to be encountered.

Table 13-3. Minimum drinker space/bird for ducks

Bird type and age	Linear trough space[1,2] cm	Linear trough space[1,2] in	Nipple lines (maximum no. of birds/pin)
Growing			
0 to 10 d	>0.5	0.2	8
11–21 d	>0.5	0.2	6
>21 d	>0.5	0.2	4
Breeders			
0–17 d	>0.5	0.2	8
18 d to developer	>0.5	0.2	5
>28 wk	>0.5	0.2	3

[1]Linear trough space assumes that both sides of the trough are available. If only one side of the trough is available, double the amount of drinker space/bird.

[2]Water trough dimensions are according to RSPCA Guidelines (RSPCA, 2015); however, open water sources should be avoided as described in the Water subsection of this chapter.

Water. Water is an essential and critical nutrient for waterfowl, which consume water in much greater quantities than other poultry species. In general, water consumption by waterfowl is at least 4 times greater than their feed intake. Clean, fresh drinking water must be provided at all times. Contrary to popular belief, there is no need to provide swimming water for ducks or geese. Waterfowl should have access to clean water for drinking at all times unless the experimental design specifically limits access. Table 13-3 lists the minimum requirement for water access in ducks; similar data are not available for geese. Thus, the expertise and recommendations of researchers or educators should be considered when evaluating water access for geese. Nipple drinker water lines should be arranged to ensure a maximum density of 3 adult ducks per nipple.

In the European Union, the use of nipple water lines has been criticized for not allowing ducks to perform behaviors such as dabbling, head-dipping, bathing, swimming, or wet preening and thus not adequate for the welfare of waterfowl, specifically ducks (Rodenburg et al., 2005; Jones et al., 2009; Jones and Dawkins, 2010). However, these studies typically relied upon very small sample sizes and their conclusions contradict the findings of original studies (reviewed by Rodenburg et al., 2005) that demonstrated wet preening did in fact occur with nipple water line systems. The purpose of preening is to maintain feather quality and cleanliness in healthy birds. A recent study showed that commercially housed ducks preen effectively and just as often, regardless of where they are in relation to the water source within a barn (Rice et al., 2014). Several studies have shown that ducks housed in systems with nipple water lines show excellent body condition, particularly eye and feather quality and feather cleanliness, regardless of other differences in management or environmental conditions (Fraley et al., 2013; Karcher et al., 2013;

Campbell et al., 2014, 2015; Colton and Fraley, 2014; Rice et al., 2014). Therefore, waterfowl should be given access to water via nipple water lines, and open water sources should be avoided unless necessary for the study design. Bacterial contamination must be considered if open water sources are used.

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. If ducks are provided water for swimming or some other wet environment (such as showers), they should also have access to a clean and dry place; otherwise, the protection normally provided by their waterproof, insulated feathers might be lost. The use of nipple water lines should be the standard for waterfowl in teaching and research settings, unless the proposed experimental or teaching program specifically requires an environment with an open water source.

HUSBANDRY

Handling of Waterfowl

Unlike other poultry species, waterfowl cannot be caught and picked up by the wings or legs because this could cause physical damage to their limbs. Ducks may be grasped around the upper (distal third) neck, taking care not to restrict airways or blood vessels on the anterior throat area. A duck correctly lifted from the floor in this manner will remain calm and allow itself to be carried a short distance. Small to medium-size ducks (up to ~1,500 g) may be picked up with thumbs restraining the wings and fingers wrapped gently around the rest of the body, but care should be taken to ensure that the thoracic cavity can expand for respiration. When carrying ducks for extended distances (>5 m), the duck should be cradled in one arm with its abdomen resting on the caretaker's forearm, wings restrained between the caretaker's forearm and body, legs held gently between the fingers, and the duck's head in the armpit area. Carrying a duck properly restrained in this fashion will greatly minimize risk of injury to the duck and caretaker. Because of differences in body size and temperament, extreme caution should be used when handling larger waterfowl such as geese.

Social Environment

Ducks and geese are highly social animals and should be kept in groups when possible. The social repertoire has been extensively described for dabbling ducks and, to a lesser extent, for domestic geese and Muscovy ducks. Research on the behavior of ducks and geese in commercial flocks is relatively sparse. When housed in small groups, geese and ducks exhibit socially coordinated movements (Ramseyer et al., 2009; Liste et al., 2014) and can be observed sharing resources when open resources are available (Waitt et al., 2009; Makagon and Mench, 2011). Behavioral observations conducted on commercial duck farms also highlight social tolerance and resource sharing (Jones and Dawkins, 2010; Rice et al., 2014). Like other poultry species, ducks and geese communicate using visual and vocal signals (McKinney, 1969; Miller, 1977). Tactile contact plays a key role in promoting social flexibility among ducklings (Gottlieb, 1993). Social experiences with age-matched ducklings within the first days of life have significant effects on subsequent social preferences and behaviors (reviewed by Lickliter et al., 1993) and sexual preferences (Bossema et al., 1982). Therefore, for normal behavioral development, waterfowl should have social interaction starting at an early age. When group housing is not possible, birds should, at minimum, be able to hear, see, and touch one another through a wire partition.

When birds are kept in group housing, a fear response may result in birds trampling each other and piling up against barriers or in corners, with resulting injury and mortality. Mule and Pekin ducks show a more pronounced fear response than Muscovy ducks (Arnaud et al., 2010). Husbandry methods should be used to prevent death caused by smothering. Sudden changes to the environment should be minimized unless dictated by the experimental design. Feather pecking, picking, and cannibalism can occur in duck flocks, more commonly among Muscovy ducks (Rodenburg et al., 2005). Although the specific causes leading to feather pecking are not well understood, high stocking density can be a contributing factor (as reviewed by Rodenburg et al., 2005). Other risk factors include genetic strain, light schedule, and nutrition (Gustafson et al., 2007a,b). Injury to females that results from excessive mounting by drakes is a concern for sexually mature breeder ducks. The current recommendation for Pekin duck breeders is that the ratio of males to females not exceed 1:5; the flock may require periodic sex ratio adjustment throughout the breeding cycle to prevent harm to females (Cherry and Morris, 2008).

Nest Boxes

Although details of nest box design and placement may depend on experimental or teaching needs, nest boxes should be provided for all sexually mature breeder flocks because they provide for easier egg collection, cleaner eggs, and a decreased risk of cloacal cannibalism. It is recommended that nest boxes be dark inside and offer maximal concealment. 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 to prevent injury to the ducks' feet. The provision of loose litter material inside and outside nests can be useful for training hens to use nests. Nest boxes should be regularly inspected and cleaned as necessary to ensure that there is minimal manure accumulation. Birds should have easy access to nest boxes. Nest boxes should be placed at ground level for geese and most domestic duck breeds. Muscovy ducks are cavity dwellers; therefore, Muscovy nests can be raised above ground level.

Outdoor Access or Free Range

Information for porches or winter gardens for ducks is not available. When immature ducks are first introduced to the range, they need to be shown the location of feeders, drinkers, and shelters. It is recommended that outdoor feeders and drinkers be surrounded by slatted or solid flooring to prevent the ground in the immediate area from becoming saturated with water. If ponds are available, they should be well maintained to prevent accumulation of stagnant water that contains decaying vegetation. Serious consideration should be given to the likelihood of predation or fecal contamination from wild birds in flight. Botulism in ducks can be a problem when pond water is not well aerated or not filtered to remove plant debris (Shin et al., 2010; Raymundo et al., 2012). 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.

STANDARD AGRICULTURAL PRACTICES

Incubation

The biology of incubation is a fascinating process when the unique differences among species are considered, in particular, egg and embryo temperature regulation and correlated physiologic adaptations (Webb, 1987). Egg turning or rotation is a necessity for all avian species, and waterfowl are no exception. Methods for egg rotation, or turning, in the incubator are identical to those for other poultry species. As such, please refer to other chapters for details. It has been recognized for many years that incubation temperature is only one of many factors that can influence day-old hatchling quality (Tona et al., 2005) and post-hatch performance (Ducuypere, 1984). Romanoff (1935) is the most frequently cited literature source for the widely accepted "optimal" incubation temperature of 37.5°C (99.5°F) for continuously incubated eggs. Romanoff (1936) recommended that mean incubation temperature be decreased to approximately 36°C (96.8°F) after 16 d of incubation in consideration of the metabolic heat produced by older embryos. The recommended temperatures for chicks confirmed the earlier studies in turkeys and correlated effects on length of incubation and post-hatch growth (Romanoff, 1935). Increased temperatures during the early stages of incubation decrease the overall length of the incubation period (Romanoff and Faber, 1933; Henderson, 1939). Romanoff (1936) observed a linear decline in hatchability with each 1°C (1.8°F) increase from 37.5 to 40.5°C, which was the basis for his suggested 36.5°C as the optimal temperature from 16 d to hatch in chickens. The latter observation of heat production by older embryos is the reason that current commercial incubation practice includes a gradual reduction in temperature over the latter half of the incubation period and this is true for all commercial poultry. Lourens et al. (2005) suggested that eggshell temperature was the most accurate, nondestructive assessment of actual embryo temperature, and the practice of monitoring eggshell temperature has been implemented in many commercial hatcheries with a target temperature of 37.5 to 37.8°C (99.5 to 100°F). In commercial practice, either air temperature or eggshell temperature together with relative humidity (~56%) are the most common standard industry metrics that are routinely monitored. As alluded to above, these metrics will vary by age of the embryo and incubation practice (single-stage vs. multi-stage).

ENVIRONMENTAL ENRICHMENT

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

HANDLING AND TRANSPORT

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

SPECIAL CONSIDERATIONS

Anesthesia

Anesthesia for birds in general and ducks in particular is vastly different than that for mammals. Physiological and metabolic differences as well as responses to stress vary widely. Usually, the dose of anesthetic is higher in birds than in mammals because of their higher metabolic rate (Machin et al., 2004). Handling of birds may reduce respiratory function, and placing birds on their backs can compromise respiratory function due to the weight of abdominal viscera pressing on the air sacs (Ludders et al., 1995). Thoracic compression in small birds often results in respiratory depression and death (Machin et al., 2004). Due to the diving response, ducks can have bradycardia and apnea from masks placed over the bill or if the bill is taped or tied to maintain proper placement of endotracheal tubes (Ludders et al., 1995).

Intubation with artificial ventilation is preferred in waterfowl when using inhalant anesthesia. Inhalant anesthetics, including isoflurane, sevoflurane, enthurane, and desflurane, have been used for various bird species (Machin et al., 2004). Although inhalant anesthetics allow for rapid adjustment of the depth of anesthesia, hypoventilation by birds can make it more difficult to maintain anesthesia depth. For most birds, isoflurane is the anesthetic of choice because induction and recovery are generally rapid and isoflurane is less likely than some other agents to cause cardiac issues (Goelz et al., 1990). For ducks, the minimal anesthetic concentration for isoflurane is typically $1.3 \pm 0.2\%$, with an adequate oxygen flow rate to deliver the anesthesia and provide for adequate ventilation. If a non-rebreathing system is being used, an oxygen flow rate of approximately 200 mL/kg per minute is standard (Machin et al., 2004). Although nitrous oxide can supplement anesthesia, it can cause subcutaneous emphysema in waterfowl and therefore is not recommended (Ludders et al., 1995; Grimm et al., 2007).

Injectable anesthetics include barbiturates, α_2-agonists, propofol, benzodiazepines, opioids, and ketamine, administered intravenously, intramuscularly or intracoelomic alone or in combination. However, intramuscular administration of anesthetics in waterfowl is often not effective (Machin et al., 2004). The main disadvantage of injectable agents is the inability to reverse the drugs. The duration of pentobarbital is short and can be unsafe in some bird species. Methohexital is contraindicated in waterfowl (Forbes, 1998; Machin et al., 2004). Ketamine has been used in many species of birds with variable results, and because ketamine alone does not eliminate pain, it must be combined with an analgesic agent (Machin et al., 2004). Wing flapping can occur during recovery, so care must be taken to prevent injury. α_2-Agonists are rarely used alone but augment other agents by providing analgesia. They can cause hypothermia, muscle tremors, and salivation and usually do not completely immobilize birds when used alone (Forbes, 1998; Machin et al., 2004). Ducks may not respond to combinations of ketamine and α_2-agonists. Benzodiazepines such as diazepam and midazolam have been used successfully in birds and have minimal cardiac and respiratory depressive effects. They can be combined with ketamine and opioids for better relaxation and can be reversed by flumazenil. Opioids are rarely used alone for anesthesia in birds because of respiratory depression but can be effective analgesics in combination with other anesthetics (Concannon et al., 1995; Machin and Caulkett, 1998a). Propofol is a fast acting, continuously or bolus-administered intravenous anesthetic with a short recovery period (Sebel and Lowdon, 1989). It is usually only used for short and minimally invasive procedures. Artificial ventilation is recommended with continuous propofol administration and, because it does not provide analgesia, pain must be addressed with other drugs (Machin and Caulkett, 1998b).

Analgesia

Any procedure performed must include an appropriate pain management protocol, unless the experimental design requires otherwise and is approved by the institution's animal care and use committee. Some analgesics are believed to work well in poultry species (i.e., ketoprofen and some opioids), but research in this field is continually advancing. Therefore, it is imperative that any individual protocol be devised based on the best information currently available (Greenacre, 2008; Hawkins and Paul-Murphy, 2011).

EUTHANASIA

Euthanasia ("humane death") is appropriate for small numbers of individuals or larger flocks. The most commonly used reference is the *Guidelines for the Euthanasia of Animals* by the American Veterinary Medical Association (AVMA, 2020). Regardless of the method used, death should be confirmed by at least two separate measures such as lack of respiration, lack of heart rate, lack of deep pain response, and so on. The only unconditionally approved method of euthanasia is an overdose of barbiturates. Methods that are acceptable with conditions for non-neonatal birds include an overdose of inhaled gas (CO_2, CO, N, Ar, or gas anesthetics) and physical methods (cervical dislocation, blunt force trauma, electrocution or decapitation with adjunctive methods, captive bolt, or gunshot). Embryonated eggs may be euthanized via CO_2, chilling, and freezing. Maceration may be used for pipped eggs and neonates up to 72 h old.

Advantages of overdose of injectable barbiturates for euthanasia include positive public perception and the ability to easily euthanize larger birds. The disadvantages include the need to use these agents in a secure area (most of these injectable drugs must be stored in a locked container with accurate record keeping, and evacuation of gases must be done in a way that does not injure human operators) and large doses are required for most bird species. Accidental injection of the operator with barbiturates can result in significant injury. In addition, the purchase, storage, and record-keeping of all Scheduled pharmaceuticals requires the supervision of an accredited and US Drug Enforcement Agency (DEA)-licensed individual.

Using gaseous agents is advantageous when euthanizing larger numbers of birds. Most adult birds will be killed quickly with CO_2 at 100% concentration. However, gas often requires longer exposure times for waterfowl because of the diving reflex. In addition, escaped gases, such as CO and gas anesthetics, can have implications for human and environmental health. Birds often react to rapid administration of gas by open mouth breathing, head shaking, and wing flapping.

Cervical dislocation results in rapid death. Anyone performing cervical dislocation must be well trained in the procedure. The AVMA recommends that anyone performing cervical dislocation be trained using already deceased birds or birds destined for euthanasia that have been anesthetized before dislocation (AVMA, 2020). According to the AVMA guidelines, "the legs of the bird should be grasped (or wings if grasped at the base) and the neck stretched by pulling on the head while applying a ventrodorsal rotational force to the skull" (AVMA, 2020). However, grasping the wings instead of legs of waterfowl may cause wing breakage before euthanasia occurs, so gripping the legs is generally recommended for these species. The dislocation must be directly behind the skull at C1–C2 to avulse the brain stem from the spinal cord. Dislocation or crushing of lower cervical vertebrae is an unacceptable method of euthanasia. Large birds and birds with longer and thicker necks can pose injury to the operator and are more difficult to cervically dislocate, so other methods are recommended. The necks of all birds must be examined for separation of the vertebrae after euthanasia.

Non-penetrating or penetrating captive bolt devices have been used for larger poultry and can be an alternative, provided that the velocity and angle of impact are appropriate for the specific species. Proper restraint for this method of euthanasia is paramount to minimize stress to the bird, improper implementation, and injury to the human operator.

All personnel performing euthanasia must be trained and proficient in whatever method is performed. It is also imperative to confirm death before disposal. Dilated pupils without a light reflex and lack of audible or palpable heartbeat, breathing, corneal reflex or withdrawal during toe pinch should be used in combination to confirm death. Ultimately, the method of euthanasia must be chosen based on what would cause the least distress to the bird and the least potential harm to the human operator and the environment.

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APPENDIX I

U.S. 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 U.S. 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 prepared by the Institute of Laboratory Animal Resources, National Academy of Sciences.

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