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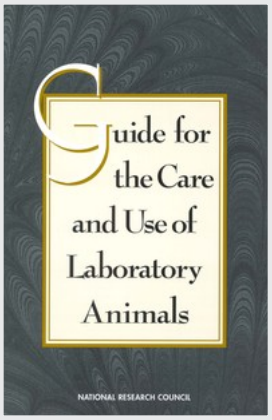

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Guide for the Care and Use of Laboratory Animals (1996)

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140 pages | 6 x 9 | PAPERBACK
ISBN 978-0-309-05377-8 | DOI 10.17226/5140

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SUGGESTED CITATION

National Research Council 1996. *Guide for the Care and Use of Laboratory Animals*. Washington, DC: The National Academies Press. https://doi.org/10.17226/5140.

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Animal Environment, Housing, and Management

Proper housing and management of animal facilities are essential to animal well-being, to the quality of research data and teaching or testing programs in which animals are used, and to the health and safety of personnel. A good management program provides the environment, housing, and care that permit animals to grow, mature, reproduce, and maintain good health; provides for their well-being; and minimizes variations that can affect research results. Specific operating practices depend on many factors that are peculiar to individual institutions and situations. Well-trained and motivated personnel can often ensure high-quality animal care, even in institutions with less than optimal physical plants or equipment.

Many factors should be considered in planning for adequate and appropriate physical and social environment, housing, space, and management. These include

- The species, strain, and breed of the animal and individual characteristics, such as sex, age, size, behavior, experiences, and health.
- The ability of the animals to form social groups with conspecifics through sight, smell, and possibly contact, whether the animals are maintained singly or in groups.
- The design and construction of housing.
- The availability or suitability of enrichments.
- The project goals and experimental design (e.g., production, breeding, research, testing, and teaching).

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- The intensity of animal manipulation and invasiveness of the procedures conducted.
- The presence of hazardous or disease-causing materials.
- The duration of the holding period.

Animals should be housed with a goal of maximizing species-specific behaviors and minimizing stress-induced behaviors. For social species, this normally requires housing in compatible pairs or groups. A strategy for achieving desired housing should be developed by animal care personnel with review and approval by the IACUC. Decisions by the IACUC in consultation with the investigator and veterinarian, should be aimed at achieving high standards for professional and husbandry practices considered appropriate for the health and well-being of the species and consistent with the research objectives. After the decision-making process, objective assessments should be made to substantiate the adequacy of animal environment, husbandry, and management.

The environment in which animals are maintained should be appropriate to the species, its life history, and its intended use. For some species, it might be appropriate to approximate the natural environment for breeding and maintenance. Expert advice might be sought for special requirements associated with the experiment or animal subject (for example, hazardous-agent use, behavioral studies, and immunocompromised animals, farm animals, and nontraditional laboratory species).

The following sections discuss some considerations of the physical environment related to common research animals.

PHYSICAL ENVIRONMENT

Microenvironment and Macroenvironment

The *microenvironment* of an animal is the physical environment immediately surrounding it—the primary enclosure with its own temperature, humidity, and gaseous and particulate composition of the air. The physical environment of the secondary enclosure—such as a room, a barn, or an outdoor habitat—constitutes the *macroenvironment*. Although the microenvironment and the macro-environment are linked by ventilation between the primary and secondary enclosures, the environment in the primary enclosure can be quite different from the environment in the secondary enclosure and is affected by the design of both enclosures.

Measurement of the characteristics of the microenvironment can be difficult in small primary enclosures. Available data indicate that temperature, humidity, and concentrations of gases and particulate matter are often higher in an animal's microenvironment than in the macroenvironment (Besch 1980; Flynn 1959; Gamble and Clough 1976; Murakami 1971; Serrano 1971). Microenvironmental

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conditions can induce changes in metabolic and physiologic processes or alterations in disease susceptibility (Broderson and others 1976; Schoeb and others 1982; Vesell and others 1976).

Housing

Primary Enclosures

The primary enclosure (usually a cage, pen, or stall) provides the limits of an animal's immediate environment. Acceptable primary enclosures

- Allow for the normal physiologic and behavioral needs of the animals, including urination and defecation, maintenance of body temperature, normal movement and postural adjustments, and, where indicated, reproduction.
- Allow conspecific social interaction and development of hierarchies within or between enclosures.
- Make it possible for the animals to remain clean and dry (as consistent with the requirements of the species).
- Allow adequate ventilation.
- Allow the animals access to food and water and permit easy filling, refilling, changing, servicing, and cleaning of food and water utensils.
- Provide a secure environment that does not allow escape of or accidental entrapment of animals or their appendages between opposing surfaces or by structural openings.
- Are free of sharp edges or projections that could cause injury to the animals.
- Allow observation of the animals with minimal disturbance of them.

Primary enclosures should be constructed with materials that balance the needs of the animal with the ability to provide for sanitation. They should have smooth, impervious surfaces with minimal ledges, angles, corners, and overlapping surfaces so that accumulation of dirt, debris, and moisture is reduced and satisfactory cleaning and disinfecting are possible. They should be constructed of durable materials that resist corrosion and withstand rough handling without chipping, cracking, or rusting. Less-durable materials, such as wood, can provide a more appropriate environment in some situations (such as runs, pens, and outdoor corrals) and can be used to construct perches, climbing structures, resting areas, and perimeter fences for primary enclosures. Wooden items might need to be replaced periodically because of damage or difficulties with sanitation.

All primary enclosures should be kept in good repair to prevent escape of or injury to animals, promote physical comfort, and facilitate sanitation and servicing. Rusting or oxidized equipment that threatens the health or safety of the animals should be repaired or replaced.

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Some housing Systems have special caging and ventilation equipment, including filter-top cages, ventilated cages, isolators, and cubicles. Generally, the purpose of these systems is to minimize the spread of airborne disease agents between cages or groups of cages. They often require different husbandry practices, such as alterations in the frequency of bedding change, the use of aseptic handling techniques, and specialized cleaning, disinfecting, or sterilization regimens to prevent microbial transmission by other than the airborne route.

Rodents are often housed on wire flooring, which enhances sanitation of the cage by enabling urine and feces to pass through to a collection tray. However, some evidence suggests that solid-bottom caging, with bedding, is preferred by rodents (Fullerton and Gilliatt 1967; Grover-Johnson and Spencer 1981; Ortman and others 1983). Solid-bottom caging, with bedding, is therefore recommended for rodents. Vinyl-coated flooring is often used for other species, such as dogs and nonhuman primates. IACUC review of this aspect of the animal care program should ensure that caging enhances animal well-being consistent with good sanitation and the requirements of the research project.

Sheltered or Outdoor Housing

Sheltered or outdoor housing—such as barns, corrals, pastures, and islands-is a common primary housing method for some species and is acceptable for many situations. In most cases, outdoor housing entails maintaining animals in groups.

When animals are maintained in outdoor runs, pens, or other large enclosures, there must be protection from extremes in temperature or other harsh weather conditions and adequate protective and escape mechanisms for submissive animals. These goals can be achieved by such features as windbreaks, shelters, shaded areas, areas with forced ventilation, heat-radiating structures, or means of retreat to conditioned spaces, such as an indoor portion of a run. Shelters should be accessible to all animals, have sufficient ventilation, and be designed to prevent buildup of waste materials and excessive moisture. Houses, dens, boxes, shelves, perches, and other furnishings should be constructed in a manner and made of materials that allow cleaning or replacement in accord with generally accepted husbandry practices when the furnishings are excessively soiled or worn.

Floors or ground-level surfaces of outdoor housing facilities can be covered with dirt, absorbent bedding, sand, gravel, grass, or similar material that can be removed or replaced when that is needed to ensure appropriate sanitation. Excessive buildup of animal waste and stagnant water should be avoided by, for example, using contoured or drained surfaces. Other surfaces should be able to withstand the elements and be easily maintained.

Successful management of outdoor housing relies on consideration of

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- An adequate acclimation period in advance of seasonal changes when animals are first introduced to outdoor housing.
- Training of animals to cooperate with veterinary and investigative personnel and to enter chutes or cages for restraint or transport.
- Species-appropriate social environment.
- Grouping of compatible animals.
- Adequate security via a perimeter fence or other means.

Naturalistic Environments

Areas like pastures and islands afford opportunities to provide a suitable environment for maintaining or producing animals and for some types of research. Their use results in the loss of some control over nutrition, health care and surveillance, and pedigree management. These limitations should be balanced against the benefits of having the animals live in more natural conditions. Animals should be added to, removed from, and returned to social groups in this setting with appropriate consideration of the effects on the individual animals and on the group. Adequate supplies of food, fresh water, and natural or constructed shelter should be ensured.

Space Recommendations

An animal's space needs are complex, and consideration of only the animal's body weight or surface area is insufficient. Therefore, the space recommendations presented here are based on professional judgment and experience and should be considered as recommendations of appropriate cage sizes for animals under conditions commonly found in laboratory animal housing facilities. Vertical height, structuring of the space, and enrichments can clearly affect animals' use of space. Some species benefit more from wall space (e.g., "thigmotactic" rodents), shelters (e.g., some New World primates), or cage complexities (e.g., cats and chimpanzees) than from simple increases in floor space (Anzaldo and others 1994; Stricklin 1995). Thus, basing cage-size recommendations on floor space alone is inadequate. In this regard, the Guide might differ from the AWRs (see footnote 1, p.2).

Space allocations should be reviewed and modified as necessary to address individual housing situations and animal needs (for example, for prenatal and postnatal care, obese animals, and group or individual housing). Such animal performance indexes as health, reproduction, growth, behavior, activity, and use of space can be used to assess the adequacy of housing. At a minimum, an animal must have enough space to turn around and to express normal postural adjustments, must have ready access to food and water, and must have enough clean-bedded or unobstructed area to move and rest in. For cats, a raised resting surface should be included in the cage. Raised resting surfaces or perches are also often

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desirable for dogs and nonhuman primates. Low resting surfaces that do not allow the space under them to be comfortably occupied by the animal should be counted as part of the floor space. Floor space taken up by food bowls, water containers, litter boxes, or other devices not intended for movement or resting should not be considered part of the floor space.

The need for and type of adjustments in the amounts of primary enclosure space recommended in the tables that follow should be approved at the institutional level by the IACUC and should be based on the performance outcomes described in the preceding paragraph with due consideration of the AWRs and PHS Policy (see footnote 1, p.2). Professional judgment, surveys of the literature and current practices, and consideration of the animals' physical, behavioral, and social needs and of the nature of the protocol and its requirements might be necessary (see Crockett and others 1993, 1995). Assessment of animals' space needs should be a continuing process. With the passage of time or long-term protocols, adjustments in floor space and height should be considered and modified as necessary.

It is not within the scope or size constraints of the *Guide* to discuss the housing requirements of all species used in research. For species not mentioned, space and height allocations for an animal of equivalent size and with a similar activity profile and similar behavior can be used as a starting point from which adjustments that take species-specific and individual needs into account can be made.

Whenever it is appropriate, social animals should be housed in pairs or groups, rather than individually, provided that such housing is not contraindicated by the protocol in question and does not pose an undue risk to the animals (Brain and Bention 1979). Depending on a variety of biologic and behavioral factors, group-housed animals might need less or more total space per animal than individually housed animals. Recommendations provided below are based on the assumption that pair or group housing is generally preferable to single housing, even when members of the pair or group have slightly less space *per animal* than when singly caged. For example, each animal can share the space allotted to the animals with which it is housed. Furthermore, some rodents or swine housed in compatible groups seek each other out and share cage space by huddling together along walls, lying on each other during periods of rest, or gathering in areas of retreat (White 1990; White and others 1989). Cattle, sheep, and goats exhibit herding behavior and seek group associations and close physical contact. Conversely, some animals, such as various species of nonhuman primates, might need additional individual space when group-housed to reduce the level of aggression.

The height of enclosures can be important in the normal behavior and postural adjustments of some species. Cage heights should take into account typical postures of an animal and provide adequate clearance for normal cage components, such as feeders and water devices, including sipper tubes. Some species of

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nonhuman primates use the vertical dimensions of the cage to a greater extent than the floor. For them, the ability to perch and to have adequate vertical space to keep the whole body above the cage floor can improve their well-being.

Space allocations for animals should be based on the following tables, but might need to be increased, or decreased with approval of the IACUC, on the basis of criteria previously listed.

Table 2.1 lists recommended space allocations for commonly used laboratory rodents housed in groups. If they are housed individually or exceed the weights in the table, animals might require more space.

Table 2.2 lists recommended space allocations for other common laboratory animals. These allocations are based, in general, on the needs of individually housed animals. Space allocations should be re-evaluated to provide for enrichment of the primary enclosure or to accommodate animals that exceed the weights in the table. For group housing. determination of the total space needed is not necessarily based on the sum of the amounts recommended for individually housed animals. Space for group-housed animals should be based on individual species needs, behavior, compatibility of the animals, numbers of animals, and goals of the housing situation.

TABLE 2.1 Recommended Space for Commonly Used Group-Housed Laboratory Rodents

Animals	Weight, g	Floor Area/Animal, in^2 [a]	Height.[b] in[c]
Mice	<10	6	5
	Up to 15	8	5
	Up to 25	12	5
	>25[d]	>15	5
Rats	<100	17	7
	Up to 200	23	7
	Up to 300	29	7
	Up to 400	40	7
	Up to 500	60	7
	>500[d]	>70	7
Hamsters	<60	10	6
	Up to 80	13	6
	Up to 100	16	6
	>100[d]	>19	6
Guinea pigs	<350	60	7
	>350[d]	>101	7

[a] To convert square inches to square centimeters. multiply by 6.45.
[b] From cage floor to cage top.
[c] To convert inches to centimeters. multiply by 2.54.
[d] Larger animals might require more space to meet the performance standards (see text).

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TABLE 2.2 Recommended Space for Rabbits, Cats, Dogs, Nonhuman Primates, and Birds

Animals	Weight, kg[a]	Floor Area/Animal, ft^2 [b]	Height[c]in[d]
Rabbits	<2	1.5	14
	Up to 4	3.0	14
	Up to 5.4	4.0	14
	>5.4[e]	>5.0	14
Cats	<4	3.0	24
	>4[e]	>4.0	24
Dogs[f]	<15	8.0	-
	Up to 30	12.0	-
	>30[e]	>24.0	-
Monkeys[g, h]			
(including baboons)			
Group 1	Up to 1	1.6	20
Group 2	Up to 3	3.0	30
Group 3	Up to 10	4.3	30
Group 4	Up to 15	6.0	32
Group 5	Up to 25	8.0	36
Group 6	Up to 30	10.0	46
Group 7	>30[e]	15.0	46
Apes (pongidae)[h]			
Group 1	Up to 20	10.0	55
Group 2	Up to 35	15.0	60
Group 3	>35[i]	25.0	84
Pigeons[j]	-	0.8	-
Quail[j]	-	0.25	-
Chickens[j]	<0.25	0.25	-
	Up to 0.5	0.50	-
	Up to 1.5	1.00	-
	Up to 3.0	2.00	-
	>3.0[e]	>3.00	-

Table 2.3 lists recommended space allocations for farm animals commonly used in a laboratory setting. When animals, housed individually or in groups, exceed the weights in the table, more space might be required. If they are group-housed, adequate access to water and feeder space should be provided (Larson and Hegg 1976; Midwest Plan Service 1987).

Temperature and Humidity

Regulation of body temperature within normal variation is necessary for the well-being of homeotherms. Generally, exposure of unadapted animals to temperatures above 85ºF (29.4ºC) or below 40ºF (4.4ºC), without access to shelter or other protective mechanisms, might produce clinical effects (Gordon 1990),

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[a] To convert kilograms to pounds, multiply by 2.2.
[b] To convert square feet to square meters, multiply by 0.09.
[c] From cage floor to cage top.
[d] To convert inches to centimeters. multiply by 2.54.
[e] Larger animals might require more space to meet performance standards (see text).
[f] These recommendations might require modification according to body conformation of individual animals and breeds. Some dogs, especially those toward upper limit of each weight range, might require additional space to ensure compliance with the regulations of the Animal Welfare Act. These regulations (CFR 1985) mandate that the height of each cage be sufficient to allow occupant to stand in "comfortable position" and that the minimal square feet of floor space be equal to "mathematical square of the sum of the length of the dog in inches (measured from the tip of its nose to the base of its tail) plus 6 inches; then divide the product by 144."
[g] Callitrichidae, Cebidae. Cercopithecidae, and Papio. Baboons might require more height than other monkeys.
[h] For some species (e.g., Brachyreles, Hylobares, Symphalangus, Pongo, and Pan), cage height should be such that an animal can, when fully extended, swing from the cage ceiling without having its feet touch the floor. Cage-ceiling design should enhance brachiating movement.
[i] Apes weighing over 50 kg are more effectively housed in permanent housing of masonry, concrete, and wire-panel structure than in conventional caging.
[j] Cage height should be sufficient for the animals to stand erect with their feet on the floor.

which could be life-threatening. Animals can adapt to extremes by behavioral, physiologic, and morphologic mechanisms, but such adaptation takes time and might alter protocol outcomes or otherwise affect performance (Garrard and others 1974; Gordon 1993; Pennycuik 1967).

Environmental temperature and relative humidity can depend on husbandry and housing design and can differ considerably between primary and secondary enclosures. Factors that contribute to variation in temperature and humidity include housing material and construction, use of filter tops, number of animals per cage, forced ventilation of the enclosures, frequency of bedding changes, and bedding type.

Some conditions might require increased environmental temperatures, such as postoperative recovery, maintenance of chicks for the first few days after hatching, housing of some hairless rodents, and housing of neonates that have been separated from their mothers. The magnitude of the temperature increase depends on the circumstances of housing; sometimes, raising the temperature in the primary enclosure alone (rather than raising the temperature of the secondary enclosure) is sufficient.

In the absence of well-controlled studies, professional judgment and experience have resulted in recommendations for dry-bulb temperatures (Table 2.4) for several common species. In the case of animals in confined spaces, the range of

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daily temperature fluctuations should be kept to a minimum to avoid repeated large demands on the animals' metabolic and behavioral processes to compensate for changes in the thermal environment. Relative humidity should also be controlled, but not nearly as narrowly as temperature; the acceptable range of relative humidity is 30 to 70%. The temperature ranges in Table 2.4 might not apply to captive wild animals, wild animals maintained in their natural environment, or animals in outdoor enclosures that are given the opportunity to adapt by being exposed to seasonal changes in ambient conditions.

TABLE 2.3 Recommended Space for Commonly Used Farm Animals

Animals/Enclosure	Weight. kg[a]	Floor Area/Animal. ft^2 [b]
Sheep and Goats		
1	<25	10.0
	Up to 50	15.0
	>50[c]	20.0
2-5	<25	8.5
	Up to 50	12.5
	>50[c]	17.0
>5	<25	7.5
	Up to 50	11.3
	>50[c]	15.0
Swine		
1	Up to 25	12.0
	Up to 50	15.0
	Up to 100	24.0
	Up to 200	48.0
	>200[c]	>60.0
2-5	<25	6.0
	Up to 50	10.0
	Up to 100	20.0
	Up to 200	40.0
	>200[c]	>52.0
>5	<25	6.0
	Up to 50	9.0
	Up to 100	18.0
	Up to 200	36.0
	>200[c]	>48.0

Ventilation

The purposes of ventilation are to supply adequate oxygen; remove thermal loads caused by animal respiration, lights, and equipment; dilute gaseous and particulate contaminants; adjust the moisture content of room air; and, where

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appropriate, create static-pressure differentials between adjoining spaces. Establishing a room ventilation rate, however, does not ensure the adequacy of the ventilation of an animal's primary enclosure and hence does not guarantee the quality of the microenvironment.

Animals/Enclosure	Weight. kg[a]	Floor Area/Animal, ft^2 [b]
Cattle		
1	<75	24.0
	Up to 200	48.0
	Up to 350	72.0
	Up to 500	96.0
	Up to 650	124.0
	>650[c]	>144.0
2-5	<75	20.0
	Up to 200	40.0
	Up to 350	60.0
	Up to 500	80.0
	Up to 650	105.0
	>650[c]	>120.0
>5	<75	18.0
	Up to 200	36.0
	Up to 350	54.0
	Up to 500	72.0
	Up to 650	93.0
	>650[c]	>108.0
Horses	—	144.0
Ponies		
1-4	—	72.0
>4/Pen	<200	60.0
	>200[c]	>72.0

[a] To convert kilograms to pounds. multiply by 2.2.
[b] To convert square feet to square meters. multiply by 0.09.
[c] Larger animals might require more space to meet performance standards (see text).

The degree to which air movement (drafts) causes discomfort or biologic consequences has not been established for most species. The volume and physical characteristics of the air supplied to a room and its diffusion pattern influence the ventilation of an animal's primary enclosure and so are important determinants of its microenvironment. The relationship of the type and location of supply air diffusers and exhaust vents to the number, arrangement, location, and type of primary enclosures in a room or other secondary enclosure affects how well the primary enclosures are ventilated and should therefore be considered. The use of computer modeling for assessing those factors in relation to heat loading and air diffusion patterns can be helpful in optimizing ventilation of primary and

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secondary enclosures (for example, Hughes and Reynolds 1995; Reynolds and Hughes 1994).

TABLE 2.4 Recommended Dry-Bulb Temperatures for Common Laboratory Animals

	Dry-Bulb Temperature	
Animal	ºC	ºF
Mouse, rat, hamster, gerbil, guinea pig	18-26	64-79
Rabbit	16-22	61-72
Cat, dog, nonhuman primate	18-29	64-84
Farm animals and poultry	16-27	61-81

The guideline of 10-15 fresh air changes per hour has been used for secondary enclosures for many years and is considered an acceptable general standard. Although it is effective in many animal housing settings, the guideline does not take into account the range of possible heat loads; the species, size, and number of animals involved; the type of bedding or frequency of cage-changing; the room dimensions; or the efficiency of air distribution from the secondary to the primary enclosure. In some situations, the use of such a broad guideline might pose a problem by overventilating a secondary enclosure that contains few animals and thereby wasting energy or by underventilating a secondary enclosure that contains many animals and thereby allowing heat and odor accumulation.

To determine more accurately the ventilation required, the minimal ventilation rate (commonly in cubic feet per minute) required to accommodate heat loads generated by animals can be calculated with the assistance of mechanical engineers. The heat generated by animals can be calculated with the average-total-heat-gain formula as published by the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE, 1993). The formula is species-independent, so it is applicable to any heat-generating animal. Minimal required ventilation is determined by calculating the amount of cooling required (total cooling load) to control the heat load expected to be generated by the largest number of animals to be housed in the enclosure in question plus any heat expected to be produced by nonanimal sources and heat transfer through room surfaces. The total-cooling-load calculation method can also be used for an animal space that has a fixed ventilation rate to determine the maximal number of animals (based on total animal mass) that can be housed in the space.

Even though that calculation can be used to determine minimal ventilation needed to prevent heat buildup, other factors-such as odor control, allergen control, particle generation, and control of metabolically generated gases-might necessitate ventilation beyond the calculated minimum. When the calculated minimal required ventilation is substantially less than 10 air changes per hour, lower ventilation rates might be appropriate in the secondary enclosure, provided

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that they do not result in harmful or unacceptable concentrations of toxic gases, odors, or particles in the primary enclosure. Similarly, when the calculated minimal required ventilation exceeds 15 air changes per hour, provisions should be made for additional ventilation required to address the other factors. In some cases, fixed ventilation in the secondary enclosure might necessitate adjustment of sanitation schedules or limitation of animal numbers to maintain appropriate environmental conditions.

Caging with forced ventilation that uses filtered room air and other types of special primary enclosures with independent air supplies (i.e., air not drawn from the room) can effectively address the ventilation requirements of animals without the need to ventilate secondary enclosures to the extent that would be needed if there were no independent primary-enclosure ventilation. Nevertheless, a secondary enclosure should be ventilated sufficiently to provide for the heat loads released from its primary enclosures. If the specialized enclosures contain adequate particulate and gaseous filtration to address contamination risks, recycled air may be used in the secondary enclosures.

Filtered isolation caging without forced ventilation, such as that used in some types of rodent housing, restricts ventilation. To compensate, it might be necessary to adjust husbandry practices-including sanitation, placement of cages in the secondary enclosure, and cage densities-to improve the microenvironment and heat dissipation.

The use of recycled air to ventilate animal rooms saves considerable amounts of energy but might entail some risk. Many animal pathogens can be airborne or travel on fomites, such as dust, so exhaust air to be recycled into heating, ventilation, and air-conditioning (HVAC) systems that serve multiple rooms presents a risk of cross contamination. The exhaust air to be recycled should be HEPA filtered (high-efficiency particulate air-filtered) to remove airborne particles before it is recycled; the extent and efficiency of filtration should be proportional to the estimated risk. HEPA filters are available in various efficiencies that can be used to match the magnitude of risk (ASHRAE 1992, 1993). Air that does not originate from animal use areas but has been used to ventilate other spaces (e.g., some human-occupancy areas and food, bedding, and supply storage areas) may be recycled for animal space ventilation and might require less-intensive filtration or conditioning than air recycled from animal use space. The risks in some situations, however, might be too great to consider recycling (e.g., in the case of nonhuman-primate and biohazard areas).

Toxic or odor-causing gases, such as ammonia, can be kept within acceptable limits if they are removed by the ventilation system and replaced with air that contains either a lower concentration or none of these gases. Treatment of recycled air for these substances by chemical absorption or scrubbing might be effective; however, the use of nonrecycled air is preferred for ventilation of animal use and holding areas. The use of HEPA filtered recycled air without

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gaseous filtration (such as with activated-charcoal filters) can be used but only in limited applications, provided that

- Room air is mixed with at least 50% fresh air (that is, the supply air does not exceed 50% recycled air).
- Husbandry practices, such as bedding-change and cage-washing frequency, and the preparation of recycled air used are sufficient to minimize toxic gases and odors.
- Recycled air is returned only to the room or area from which it was generated, except if it comes from other than animal housing areas.
- Recycled air is appropriately conditioned and mixed with sufficient fresh air to address the thermal and humidity requirements of animals in that space.

Frequent bedding changes and cage-cleaning coupled with husbandry practices, such as low animal density within the room and lower environmental temperature and humidity, can also reduce the concentration of toxic or odor-causing gases in animal-room air. Treatment of recycled air for either particulate or gaseous contaminants is expensive and can be rendered ineffective by improper or insufficient maintenance of filtration systems. These systems should be properly maintained and monitored appropriately to maximize their effectiveness.

The successful operation of any HVAC system requires regular maintenance and evaluation, including measurement of its function at the level of the secondary enclosure. Such measurements should include supply-and exhaust-air volumes, as well as static-pressure differentials, where applicable.

Illumination

Light can affect the physiology, morphology, and behavior of various animals (Brainard and others 1986; Erkert and Grober 1986; Newbold and others 1991; Tucker and others 1984). Potential photostressors include inappropriate photoperiod, photointensity, and spectral quality of the light (Stoskopf 1983). Numerous factors can affect animals' needs for light and should be considered when an appropriate illumination level is being established for an animal holding room. These include light intensity, duration of exposure, wavelength of light, light history of the animal, pigmentation of the animal, time of light exposure during the circadian cycle, body temperature, hormonal status, age, species, sex, and stock or strain of animal (Brainard 1989; Duncan and O'Steen 1985; O'Steen 1980; Saltarelli and Coppola 1979; Semple-Rowland and Dawson 1987; Wax 1977).

In general, lighting should be diffused throughout an animal holding area and provide sufficient illumination for the well-being of the animals and to allow good housekeeping practices, adequate inspection of animals—including the bottom-most cages in racks—and safe working conditions for personnel. Light in

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animal holding rooms should provide for adequate vision and for neuroendocrine regulation of diurnal and circadian cycles (Brainard 1989).

Photoperiod is a critical regulator of reproductive behavior in many species of animals (Brainard and others 1986; Cherry 1987) and can also alter body weight gain and feed intake (Tucker and others 1984). Inadvertent light exposure during the dark cycle should be minimized or avoided. Because some species will not eat in low light or darkness, such illumination schedules should be limited to a duration that will not compromise the well-being of the animals. A time-controlled lighting system should be used to ensure a regular diurnal cycle, and timer performance should be checked periodically to ensure proper cycling.

The most commonly used laboratory animals are nocturnal. Because the albino rat is more susceptible to phototoxic retinopathy than other species, it has been used as a basis for establishing room illumination levels (Lanum 1979). Data for room light intensities for other animals, based on scientific studies, are not available. Light levels of about 325 lux (30 ft-candles) about 1.0 m (3.3 ft) above the floor appear to be sufficient for animal care and do not cause clinical signs of phototoxic retinopathy in albino rats (Belihorn 1980), and levels up to 400 lux (37 ft-candles) as measured in an empty room 1 m from the floor have been found to be satisfactory for rodents if management practices are used to prevent retinal damage in albinos (Clough 1982). However, the light experience of an individual animal can affect its sensitivity to phototoxicity; light of 130-270 lux above the light intensity under which it was raised has been reported to be near the threshold of retinal damage in some individual albino rats according to histologic, morphometric, and electrophysiologic evidence (Semple-Rowland and Dawson 1987). Some guidelines recommend a light intensity as low as 40 lux at the position of the animal in midcage (NASA 1988). Young albino and pigmented mice prefer much-lower illumination than adults (Wax 1977), although potential retinal damage associated with housing these rodents at higher light levels is mostly reversible. Thus, for animals that have been shown to be susceptible to phototoxic retinopathy, light at the cage level should be between 130 and 325 lux.

Management practices, such as rotating cage position relative to the light source (Greenman and others 1982) or providing animals with ways to modify their own light exposure by behavioral means (e.g., via tunneling or hiding in a structure), can be used to reduce inappropriate light stimulation of animals. Provision of variable-intensity light controls might be considered as a means of ensuring that light intensities are consistent with the needs of animals and personnel working in animal rooms and with energy conservation. Such controls should have some form of vernier scale and a lockable setting and should not be used merely to turn room lighting on and off. The Illuminating Engineering Society of North America (IESNA) handbook (Kaufman 1984, 1987) can assist in decisions concerning lighting uniformity, color-rendering index, shielding, glare control, reflection, lifetime, heat generation, and ballast selection.

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Noise

Noise produced by animals and animal care activities is inherent in the operation of an animal facility (Pfaff and Stecker 1976). Therefore, noise control should be considered in facility design and operation (Pekrul 1991). Assessment of the potential effects of noise on an animal warrants consideration of the intensity, frequency, rapidity of onset, duration, and vibration potential of the sound and the hearing range, noise-exposure history, and sound-effect susceptibility of the species, stock, or strain.

Separation of human and animal areas minimizes disturbances to both the human and animal occupants of the facility. Noisy animals—such as dogs, swine, goats, and nonhuman primates—should be housed away from quieter animals, such as rodents, rabbits, and cats. Environments should be designed to accommodate animals that make noise, rather than resorting to methods of noise reduction. Exposure to sound louder than 85 dB can have both auditory and nonauditory effects (Fletcher 1976; Peterson 1980), including eosinopenia and increased adrenal weights in rodents (Geber and others 1966; Nayfield and Besch 1981), reduced fertility in rodents (Zondek and Tamari 1964), and increased blood pressure in nonhuman primates (Peterson and others 1981). Many species can hear frequencies of sound that are inaudible to humans (Brown and Pye 1975; Warfield 1973), 50 the potential effects of equipment and materials that produce noise in the hearing range of nearby animals—such as video display terminals (Sales 1991) should be carefully considered. To the greatest extent possible, activities that might be noisy should be conducted in rooms or areas separate from those used for animal housing.

Because changes in patterns of sound exposure have different effects on different animals (Armano and others 1985; Clough 1982), personnel should try to minimize the production of unnecessary noise. Excessive and intermittent noise can be minimized by training personnel in alternatives to practices that produce noise and by the use of cushioned casters and bumpers on carts, trucks, and racks. Radios, alarms, and other sound generators should not be used in animal rooms unless they are parts of an approved protocol or an enrichment program.

BEHAVIORAL MANAGEMENT

Structural Environment

The structural environment consists of components of the primary enclosure—cage furniture, equipment for environmental enrichment, objects for manipulation by the animals, and cage complexities. Depending on the animal species and use, the structural environment should include resting boards, shelves or perches, toys, foraging devices, nesting materials, tunnels, swings, or other objects

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that increase opportunities for the expression of species-typical postures and activities and enhance the animals' well-being. Much has been learned in recent years about the natural history and environmental needs of many animals, but continuing research into those environments that enhance the well-being of research animals is encouraged. Selected publications that describe enrichment strategies for common laboratory animal species are listed in Appendix A and in bibliographies prepared by the Animal Welfare Information Center (AWIC 1992; NRC In press).

Social Environment

Consideration should be given to an animal's social needs. The social environment usually involves physical contact and communication among members of the same species (conspecifics), although it can include noncontact communication among individuals through visual, auditory, and olfactory signals. When it is appropriate and compatible with the protocol, social animals should be housed in physical contact with conspecifics. For example, grouping of social primates or canids is often beneficial to them if groups comprise compatible individuals. Appropriate social interactions among conspecifics are essential for normal development in many species. A social companion might buffer the effects of a stressful situation (Gust and others 1994), reduce behavioral abnormality (Reinhardt and others 1988, 1989), increase opportunities for exercise (Whary and others 1993), and expand species-typical behavior and cognitive stimulation. Such factors as population density, ability to disperse, initial familiarity among animals, and social rank should be evaluated when animals are being grouped (Borer and others 1988; Diamond and others 1987; Drickamer 1977; Harvey and Chevins 1987; Ortiz and others 1985; Vandenbergh 1986, 1989). In selecting a suitable social environment, attention should be given to whether the animals are naturally territorial or communal and whether they should be housed singly, in pairs, or in groups. An understanding of species-typical natural social behavior will facilitate successful social housing.

However, not all members of a social species can or should be maintained socially; experimental, health, and behavioral reasons might preclude a successful outcome of this kind of housing. Social housing can increase the likelihood of animal wounds due to fighting (Bayne and others 1995), increase susceptibility to such metabolic disorders as atherosclerosis (Kaplan and others 1982), and alter behayior and physiologic functions (Bernstein 1964; Bernstein and others 1974a,b). In addition, differences between sexes in compatibility have been observed in various species (Crockett and others 1994; Grant and Macintosh 1963; Vandenbergh 1971; vom Saal 1984). These risks of social housing are greatly reduced if the animals are socially compatible and the social unit is stable.

It is desirable that social animals be housed in groups; however, when they must be housed alone, other forms of enrichment should be provided to compensate

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for the absence of other animals, such as safe and positive interaction with the care staff and enrichment of the structural environment.

Activity

Animal activity typically implies motor activity but also includes cognitive activity and social interaction. Animals maintained in a laboratory environment might have a more-restricted activity profile than those in a free-ranging state. An animal's motor activity, including use of the vertical dimension, should be considered in evaluation of suitable housing or assessment of the appropriateness of the quantity or quality of an activity displayed by an animal. Forced activity for reasons other than attempts to meet therapeutic or approved protocol objectives should be avoided. In most species, physical activity that is repetitive, is non-goal-oriented, and excludes other behavior is considered undesirable (AWIC 1992; Bayne 1991; NRC In press; see also Appendix A, "Enrichment").

Animals should have opportunities to exhibit species-typical activity patterns. Dogs, cats, and many other domesticated animals benefit from positive human interaction (Rollin 1990). Dogs can be given opportunities for activity by being walked on a leash, having access to a run, or being moved into another area (such as a room, larger cage, or out door pen) for social contact, play, or exploration. Cages are often used for short-term housing of dogs for veterinary care and some research purposes, but pens, runs, and other out-of-cage areas provide more space for movement, and their use is encouraged (Wolff and Rupert 1991). Loafing areas, exercise lots, and pastures are suitable for large farm animals, such as sheep, horses, and cattle.

HUSBANDRY

Food

Animals should be fed palatable, noncontaminated, and nutritionally adequate food daily or according to their particular requirements unless the protocol in which they are being used requires otherwise. Subcommittees of the National Research Council Committee on Animal Nutrition have prepared comprehensive treatments of the nutrient requirements of laboratory animals (NRC 1977, 1978, 1981a,b, 1982, 1983, 1984, 1985a,b, 1986, 1988, 1989a,b, 1994, 1995). Their publications consider issues of quality assurance, freedom from chemical or microbial contaminants and presence of natural toxicants in feedstuffs, bioavailability of nutrients in feeds, and palatability.

Animal-colony managers should be judicious in purchasing, transporting, storing, and handling food to minimize the introduction of diseases, parasites, potential disease vectors (e.g., insects and other vermin), and chemical contaminants into animal colonies. Purchasers are encouraged to consider manufacturers'

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and suppliers' procedures and practices for protecting and ensuring diet quality (e.g., storage, vermin-control, and handling procedures). Institutions should urge feed vendors to provide data from feed analysis for critical nutrients periodically. The date of manufacture and other factors that affect shelf-life of food should be known by the user. Stale food or food transported and stored inappropriately can become deficient in nutrients. Careful attention should be paid to quantities received in each shipment, and stock should be rotated so that the oldest food is used first.

Areas in which diets and diet ingredients are processed or stored should be kept clean and enclosed to prevent entry of pests. Food should be stored off the floor on pallets, racks, or carts. Unused, opened bags of food should be stored in vermin-proof containers to minimize contamination and to avoid potential spread of disease agents. Exposure to temperatures above 21ºC (70ºF), extremes in relative humidity, unsanitary conditions, light, oxygen, and insects and other vermin hasten the deterioration of food. Precautions should be taken if perishable items—such as meats, fruits, and vegetables—are fed, because storage conditions are potential sources of contamination and can lead to variation in food quality. Contaminants in food can have dramatic effects on biochemical and physiologic processes, even if the contaminants are present in concentrations too low to cause clinical signs of toxicity. For example, some contaminants induce the synthesis of hepatic enzymes that can alter an animal' 5 response to drugs (Ames and others 1993; Newberne 1975). Some experimental protocols might require the use of pretested animal diets in which both biologic and nonbiologic contaminants are identified and their concentrations documented.

Most natural-ingredient, dry laboratory-animal diets that contain preservatives and are stored properly can be used up to about 6 months after manufacture. Vitamin C in manufactured feeds, however, gene rally has a shelf-life of only 3 months. The use of stabilized forms of vitamin C can extend the shelf-life of feed. If a diet containing outdated vitamin C is to be fed to animals that require dietary vitamin C, it is necessary to provide an appropriate vitamin C supplement. Refrigeration preserves nutritional quality and lengthens shelf-life, but food-storage time should be reduced to the lowest practical period and the recommendations of manufacturers should be considered. Purified and chemically defined diets are often less stable than natural-ingredient diets, and their shelf-life is usually less than 6 months (Fullerton and others 1982); these diets should be stored at 4ºC (39ºF) or lower.

Autoclavable diets require adjustments in nutrient concentrations, kinds of ingredients, and methods of preparation to withstand degradation during sterilization (Wostman 1975). The date of sterilization should be recorded and the diet used quickly. Irradiated diets might be considered as an alternative to autoclaved diets.

Feeders should be designed and placed to allow easy access to food and to minimize contamination with urine and feces. When animals are housed in groups,

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there should be enough space and enough feeding points to minimize competition for food and ensure access to food for all animals, especially if feed is restricted as part of the protocol or management routine. Food-storage containers should not be transferred between areas that pose different risks of contamination, and they should be cleaned and sanitized regularly.

Moderate restriction of calorie and protein intakes for clinical or husbandry reasons has been shown to increase longevity and decrease obesity, reproduction, and cancer rates in a number of species (Ames and others 1993; Keenan and others 1994). Such restriction can be achieved by decreasing metabolizable energy, protein density, or both in the diet or by controlling ration amount or frequency of feeding. The choice of mechanism for calorie restriction is species-dependent and will affect physiologic adaptations and alter metabolic responses (Leveille and Hanson 1966). Calorie restriction is an accepted practice for long-term housing of some species, such as some rodents and rabbits, and as an adjunct to some clinical and surgical procedures.

In some species (such as nonhuman primates) and on some occasions, varying nutritionally balanced diets and providing "treats," including fresh vegetables, can be appropriate and improve well-being. However, caution should be used in varying diets. A diet should be nutritionally balanced; it is well documented that many animals offered a cafeteria of unbalanced foods do not select a balanced diet and become obese through selection of high-energy, low-protein foods (Moore 1987). Abrupt changes in diet (which are difficult to avoid at weaning) should be minimized because they can lead to digestive and metabolic disturbances; these changes occur in omnivores and carnivores, but herbivores (Eadie and Mann 1970) are especially sensitive.

Water

Ordinarily, animals should have access to potable, uncontaminated drinking water according to their particular requirements. Water quality and the definition of potable water can vary with locality (Homberger and others 1993). Periodic monitoring for pH, hardness, and microbial or chemical contamination might be necessary to ensure that water quality is acceptable, particularly for use in studies in which normal components of water in a given locality can influence the results obtained. Water can be treated or purified to minimize or eliminate contamination when protocols require highly purified water. The selection of water treatments should be carefully considered because many forms of water treatment have the potential to cause physiologic alterations, changes in microflora, or effects on experimental results (Fidler 1977; Hall and others 1980; Hermann and others 1982; Homberger and others 1993). For example, chlorination of the water supply can be useful for some species but toxic to others (such as aquatic species).

Watering devices, such as drinking tubes and automatic waterers, should be

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checked daily to ensure their proper maintenance, cleanliness, and operation. Animals sometimes have to be trained to use automatic watering devices. It is better to replace water bottles than to refill them, because of the potential for microbiologic cross-contamination; however, if bottles are refilled, care should be taken to replace each bottle on the cage from which it was removed. Animals housed in outdoor facilities might have access, to water in addition to that provided in watering devices, such as that available in streams or in puddles after a heavy rainfall. Care should be taken to ensure that such accessory sources of water do not constitute a hazard, but their availability need not routinely be prevented.

Bedding

Animal bedding is a controllable environmental factor that can influence experimental data and animal well-being. The veterinarian or facility manager, in consultation with investigators, should select the most appropriate bedding material. No bedding is ideal for any given species under all management and experimental conditions, and none is ideal for all species (for example, bedding that enables burrowing is encouraged for some species). Several writers (Gibson and others 1987; Jones 1977; Kraft 1980; Thigpen and others 1989; Weichbrod and others 1986) have described desirable characteristics and means of evaluating bedding. Softwood beddings have been used, but the use of untreated softwood shavings and chips is contraindicated for some protocols because they can affect animals' metabolism (Vesell 1967; Vessell and others 1973, 1976). Cedar shavings are not recommended, because they emit aromatic hydrocarbons that induce hepatic microsomal enzymes and cytotoxicity (Torronen and others 1989; Weichbrod and others 1986, 1988) and have been reported to increase the incidence of cancer (Jacobs and Dieter 1978; Vlahakis 1977). Heat treatments applied before bedding materials are used reduce the concentration of aromatic hydrocarbons and might prevent this problem. Manufacturing, monitoring, and storage methods used by vendors should be considered when purchasing bedding products.

Bedding should be transported and stored off the floor on pallets, racks, or carts in a fashion consistent with maintenance of quality and minimization of contamination. During autoclaving, bedding can absorb moisture and as a result lose absorbency and support the growth of microorganisms. Therefore, appropriate drying times and storage conditions should be used.

Bedding should be used in amounts sufficient to keep animals dry between cage changes, and, in the case of small laboratory animals, care should be taken to keep the bedding from coming into contact with the water tube, because such contact could cause leakage of water into the cage.

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Sanitation

Sanitation—the maintenance of conditions conducive to health—involves bedding change (as appropriate), cleaning, and disinfection. Cleaning removes excessive amounts of dirt and debris, and disinfection reduces or eliminates unacceptable concentrations of microorganisms.

The frequency and intensity of cleaning and disinfection should depend on what is needed to provide a healthy environment for an animal, in accord with its normal behavior and physiologic characteristics. Methods and frequencies of sanitation will vary with many factors, including the type, physical properties, and size of the enclosure; the type, number, size, age, and reproductive status of the animals; the use and type of bedding materials; temperature and relative humidity; the nature of the materials that create the need for sanitation; the normal physiologic and behavioral characteristics of the animals; and the rate of soiling of the surfaces of the enclosure. Some housing systems or experimental protocols might require specific husbandry techniques, such as aseptic handling or modification in the frequency of bedding change.

Agents designed to mask animal odors should not be used in animal housing facilities. They cannot substitute for good sanitation practices or for the provision of adequate ventilation, and they expose animals to volatile compounds that might alter basic physiologic and metabolic processes.

Bedding Change

Soiled bedding should be removed and replaced with fresh materials as often as is necessary to keep the animals clean and dry. The frequency is a matter of professional judgment of animal care personnel based on consultation with the investigator and depends on such factors as the number and size of the animals in the primary enclosure, the size of the enclosure, urinary and fecal output, the appearance and wetness of the bedding, and experimental conditions, such as those of surgery or debilitation, that might limit an animal's movement or access to areas of the cage that have not been soiled with urine and feces. There is no absolute minimal frequency of changing bedding, but it typically varies from daily to weekly. In some instances, frequent bedding changes are contraindicated, such as during some portions of the prepartum or postpartum period, when pheromones are essential for successful reproduction, or when research objectives do not permit changing the bedding.

Cleaning and Disinfection of Primary Enclosures

For pens or runs, frequent flushing with water and periodic use of detergents or disinfectants are usually appropriate to maintain sufficiently clean surfaces. If animal waste is to be removed by flushing, this will need to be done at least once

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a day. Animals should be kept dry during such flushing. The timing of pen or run cleaning should take into account normal behavioral and physiologic processes of the animals; for example, the gastrocolic reflex in meal-fed animals results in defecation shortly after food consumption.

The frequency of sanitation of cages, cage racks, and associated equipment, such as feeders and watering devices, is governed to some extent by the types of caging and husbandry practices used, including the use of regularly changed contact or noncontact bedding, regular flushing of suspended catch pans, and the use of wire-bottom or perforated-bottom cages. In general, enclosures and accessories, such as tops, should be sanitized at least once every 2 weeks. Solid-bottom caging, bottles, and sipper tubes usually require sanitation at least once a week. Some types of cages and racking might require less-frequent cleaning or disinfection; these might include large cages with very low animal density and frequent bedding changes, cages that house animals in gnotobiotic conditions with frequent bedding changes, individually ventilated cages, and cages used for special circumstances. Some circumstances, such as microisolator housing or more densely populated enclosures, might require more frequent sanitation.

Rabbits and some rodents, such as guinea pigs and hamsters, produce urine with high concentrations of proteins and minerals. Minerals and organic compounds in the urine from these animals often adhere to cage surfaces and necessitate treatment with acid solutions before washing.

Primary enclosures can be disinfected with chemicals, hot water, or a combination of both. Washing times and conditions should be sufficient to kill vegetative forms of common bacteria and other organisms that are presumed to be controllable by the sanitation program. When hot water is used alone, it is the combined effect of the temperature and the length of time that a given temperature (cumulative heat factor) is applied to the surface of the item that disinfects. The same cumulative heat factor can be obtained by exposing organisms to very high temperatures for short periods or exposing them to lower temperatures for longer periods (Wardrip and others 1994). Effective disinfection can be achieved with wash and rinse water at 143-180ºF or more. The traditional 82.2ºC (180ºF) temperature requirement for rinse water refers to the water in the tank or in the sprayer manifold. Detergents and chemical disinfectants enhance the effectiveness of hot water but should be thoroughly rinsed from surfaces before reuse of the equipment.

Washing and disinfection of cages and equipment by hand with hot water and detergents or disinfectants can be effective but require attention to detail. It is particularly important to ensure that surfaces are rinsed free of residual chemicals and that personnel have appropriate equipment to protect themselves from exposure to hot water or chemical agents used in the process.

Water bottles, sipper tubes, stoppers, feeders, and other small pieces of equipment should be washed with detergents, hot water, and, where appropriate, chemical agents to destroy microorganisms.

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If automatic watering systems are used, some mechanism to ensure that microorganisms and debris do not build up in the watering devices is recommended. The mechanism can be periodic flushing with large volumes of water or appropriate chemical agents followed by a thorough rinsing. Constant-recirculation loops that use properly maintained filters, ultraviolet lights, or other devices to sterilize recirculated water are also effective.

Conventional methods of cleaning and disinfection are adequate for most animal care equipment. However, if pathogenic microorganisms are present or if animals with highly defined microbiologic flora or compromised immune systems are maintained, it might be necessary to sterilize caging and associated equipment after cleaning and disinfection. Sterilizers should be regularly calibrated and monitored to ensure their safety and effectiveness.

Cleaning and Disinfection of Secondary Enclosures

All components of the animal facility, including animal rooms and support spaces (such as storage areas, cage-washing facilities, corridors, and procedure rooms) should be cleaned regularly and disinfected as appropriate to the circumstances and at a frequency based on the use of the area and the nature of likely contamination.

Cleaning utensils should be assigned to specific areas and should not be transported between areas that pose different risks of contamination. Cleaning utensils themselves should be cleaned regularly and should be constructed of materials that resist corrosion. Worn items should be replaced regularly. The utensils should be stored in a neat, organized fashion that facilitates drying and minimizes contamination.

Assessing the Effectiveness of Sanitation

Monitoring of sanitation practices should be appropriate to the process and materials being cleaned; it can include visual inspection of the materials, monitoring of water temperatures, or microbiologic monitoring. The intensity of animal odors, particularly that of ammonia, should not be used as the sole means of assessing the effectiveness of the sanitation program. A decision to alter the frequency of cage-bedding changes or cage-washing should be based on such factors as the concentration of ammonia, the appearance of the cage, the condition of the bedding and the number and size of animals housed in the cage.

Waste Disposal

Conventional, biologic, and hazardous waste should be removed and disposed of regularly and safely (NSC 1979). There are several options for effective waste disposal. Contracts with licensed commercial waste-disposal firms usually

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provide some assurance of regulatory compliance and safety. On-site incineration should comply with all federal, state, and local regulations.

Adequate numbers of properly labeled waste receptacles should be strategically placed throughout the facility. Waste containers should be leakproof and equipped with tight-fitting lids. It is good practice to use disposable liners and to wash containers and implements regularly. There should be a dedicated wastestorage area that can be kept free of insects and other vermin. If cold storage is used to hold material before disposal, a properly labeled, dedicated refrigerator, freezer, or cold room should be used.

Hazardous wastes must be rendered safe by sterilization, containment, or other appropriate means before being removed from the facility (US EPA 1986). Radioactive wastes should be maintained in properly labeled containers. Their disposal should be closely coordinated with radiation-safety specialists in accord with federal and state regulations. The federal government and most states and municipalities have regulations controlling disposal of hazardous wastes. Compliance with regulations concerning hazardous-agent use (Chapter 1) and disposal is an institutional responsibility.

Infectious animal carcasses can be incinerated on-site or collected by a licensed contractor. Procedures for on-site packaging, labeling, transportation, and storage of these wastes should be integrated into occupational health and safety policies.

Hazardous wastes that are toxic, carcinogenic, flammable, corrosive, reactive, or otherwise unstable should be placed in properly labeled containers and disposed of as recommended by occupational health and safety specialists. In some circumstances, these wastes can be consolidated or blended.

Pest Control

Programs designed to prevent, control, or eliminate the presence of or infestation by pests are essential in an animal environment. A regularly scheduled and documented program of control and monitoring should be implemented. The ideal program prevents the entry of vermin into and eliminates harborage from the facility. For animals in outdoor facilities, consideration should also be given to eliminating or minimizing the potential risk associated with pests and predators. Pesticides can induce toxic effects on research animals and interfere with experimental procedures (Ohio Cooperative Extension Service 1987a,b), and they should be used in animal areas only when necessary. Investigators whose animals might be exposed to pesticides should be consulted before pesticides are used. Use of pesticides should be recorded and coordinated with the animal care management staff and be in compliance with federal, state, or local regulations. Whenever possible, nontoxic means of pest control, such as insect growth regulators (Donahue and others 1989; Garg and Donahue 1989; King and Bennett 1989) and nontoxic substances (for example, amorphous silica gel), should be

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used. If traps are used, methods should be humane; traps used to catch pests alive require frequent observation and humane euthanasia after capture.

Emergency, Weekend, and Holiday Care

Animals should be cared for by qualified personnel every day, including weekends and holidays, both to safeguard their well-being and to satisfy research requirements. Emergency veterinary care should be available after work hours, on weekends, and on holidays.

In the event of an emergency, institutional security personnel and fire or police officials should be able to reach people responsible for the animals. That can be enhanced by prominently posting emergency procedures, names, or telephone numbers in animal facilities or by placing them in the security department or telephone center. Emergency procedures for handling special facilities or operations should be prominently posted.

A disaster plan that takes into account both personnel and animals should be prepared as part of the overall safety plan for the animal facility. The colony manager or veterinarian, responsible for the animals should be a member of the appropriate safety committee at the institution. He or she should be an "official responder" within the institution and should participate in the response to a disaster (Casper 1991).

POPULATION MANAGEMENT

Identification and Records

Means of animal identification include room, rack, pen, stall, and cage cards with written or bar-coded information; collars, bands, plates, and tabs; colored stains; ear notches and tags; tattoos; subcutaneous transponders; and freeze brands. Toe-clipping, as a method of identification of small rodents, should be used only when no other individual identification method is feasible and should be performed only on altricial neonates. Identification cards should include the source of the animal, the strain or stock, names and locations of the responsible investigators, pertinent dates, and protocol number, when applicable. Animal records are useful and can vary in type, ranging from limited information on identification cards to detailed computerized records for individual animals.

Clinical records for individual animals can also be valuable, especially for dogs, cats, nonhuman primates, and farm animals. They should include pertinent clinical and diagnostic information, date of inoculations, history of surgical procedures and postoperative care, and information on experimental use. Basic demographic information and clinical histories enhance the value of individual animals for both breeding and research and should be readily accessible to investigators, veterinary staff, and animal care staff. Records of rearing histories, mating

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histories, and behavioral profiles are useful for the management of many species, especially nonhuman primates (NRC 1979a).

Records containing basic descriptive information are essential for management of colonies of large long-lived animals and should be maintained for each animal (Dyke 1993; NRC 1979a). These records often include species, animal identifier, sire identifier, dam identifier, sex, birth or acquisition date, source, exit date, and final disposition. Such animal records are essential for genetic management and historical assessments of colonies. Relevant recorded information should be provided when animals are transferred between institutions.

Genetics and Nomenclature

Genetic characteristics are important in regard to the selection and management of animals for use in breeding colonies and in biomedical research (see Appendix A). Pedigree information allows appropriate selection of breeding pairs and of experimental animals that are unrelated or of known relatedness.

Outbred animals are widely used in biomedical research. Founding populations should be large enough to ensure the long-term heterogeneity of breeding colonies. To facilitate direct comparison of research data derived from outbred animals, genetic-management techniques should be used to maintain genetic variability and equalize founder representations (for example, Lacy 1989; Poiley 1960; Williams-Blangero 1991). Genetic variability can be monitored with computer simulations, biochemical markers, DNA markers, immunologic markers, or quantitative genetic analyses of physiologic variables (MacCluer and others 1986; Williams-Blangero 1993).

Inbred strains of various species, especially rodents, have been developed to address specific research needs (Festing 1979; Gill 1980). The homozygosity of these animals enhances the reproducibility and comparability of some experimental data. It is important to monitor inbred animals periodically for genetic homozygosity (Festing 1982; Hedrich 1990). Several methods of monitoring have been developed that use immunologic, biochemical, and molecular techniques (Cramer 1983; Groen 1977; Hoffman and others 1980; Russell and others 1993). Appropriate management systems (Green 1981; Kempthome 1957) should be designed to minimize genetic contamination resulting from mutation and mismating.

Transgenic animals have at least one transferred gene whose site of integration and number of integrated copies might or might not have been controlled. Integrated genes can interact with background genes and environmental factors, in part as a function of site of integration, so each transgenic animal can be considered a unique resource. Care should be taken to preserve such resources through standard genetic-management procedures, including maintenance of detailed pedigree records and genetic monitoring to verify the presence and zygosity of transgenes. Cryopreservation of fertilized embryos, ova, or spermatozoa

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should also be considered to safeguard against alterations in transgenes over time or accidental loss of the colony.

Accurate recording, with standardized nomenclature where it is available, of both the strain and substrain or of the genetic background of animals used in a research project is important (NRC 1979b). Several publications provide rules developed by international committees for standardized nomenclature of outbred rodents and rabbits (Festing and others 1972), inbred rats (Festing and Staats 1973; Gill 1984; NRC 1992a), inbred mice (International Committee on Standardized Genetic Nomenclature for Mice 1981 a,b,c), and transgenic animals (NRC 1992b).

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