This PDF is available from The National Academies Press at http://www.nap.edu/catalog.php?record_id=20162

FROM THE ARCHIVES

Ruminants: Cattle, Sheep, and Goats: Guidelines for the Breeding, Care, and Management of Laboratory Animals (1974)

Pages
81

Size
5 x 8

ISBN
0309021499

Subcommittee on Standards for Large (Domestic) Laboratory Animals; Committee on Standards; Institute of Laboratory Animal Resources; National Research Council

Find Similar Titles | More Information

Visit the National Academies Press online and register for...

- Instant access to free PDF downloads of titles from the
  - NATIONAL ACADEMY OF SCIENCES
  - NATIONAL ACADEMY OF ENGINEERING
  - INSTITUTE OF MEDICINE
  - NATIONAL RESEARCH COUNCIL
- 10% off print titles
- Custom notification of new releases in your field of interest
- Special offers and discounts

Distribution, posting, or copying of this PDF is strictly prohibited without written permission of the National Academies Press. Unless otherwise indicated, all materials in this PDF are copyrighted by the National Academy of Sciences.

To request permission to reprint or otherwise distribute portions of this publication contact our Customer Service Department at 800-624-6242.

Copyright © National Academy of Sciences. All rights reserved.

NATIONAL ACADEMY OF SCIENCES
1863–2013
Celebrating 150 Years of Service to the Nation

Ruminants
Cattle, Sheep, and Goats

Guidelines for the breeding, care, and management of laboratory animals

A Report of the
Subcommittee on Standards for
Large (Domestic) Laboratory Animals
Committee on Standards
Institute of Laboratory Animal Resources
National Research Council

NAS-NAE
MAR 1 2 1974
LIBRARY

NATIONAL ACADEMY OF SCIENCES Washington, D.C. | 1974

QL1763
C.1

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, acting in behalf of the National Academy of Sciences. Such approval reflects the Board's judgment that the project is of national importance and appropriate with respect to both the purposes and resources of the National Research Council.

The members of the committee selected to undertake this project and prepare this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. Responsibility for the detailed aspects of this report rests with that committee.

Each report issuing from a study committee of the National Research Council is reviewed by an independent group of qualified individuals according to procedures established and monitored by the Report Review Committee of the National Academy of Sciences. Distribution of the report is approved, by the President of the Academy, upon satisfactory completion of the review process.

This publication was supported in part by Contract PH43-64-44 with the Drug Research and Development, Division of Cancer Treatment, National Cancer Institute, and the Animal Resources Branch, National Institutes of Health, U.S. Public Health Service; Contract AT (11-1)-3369 with the Atomic Energy Commission; Contract N00014-67-A-0244-0016 with the Office of Naval Research, U.S. Army Medical Research and Development Command, and U.S. Air Force; Contract 12-16-140-155-91 with the Animal and Plant Health Inspection Service, U.S. Department of Agriculture; Contract NSF-C310, Task Order 173, with the National Science Foundation; Grant RC-10 from the American Cancer Society, Inc.; and contributions from pharmaceutical companies and other industries.

Available from
Printing and Publishing Office, National Academy of Sciences
2101 Constitution Avenue, N.W., Washington, D.C. 20418

Library of Congress Cataloging in Publication Data

National Research Council. Institute of Laboratory Animal Resources. Subcommittee on Standards for Large (Domestic) Laboratory Animals.
Ruminants: cattle, sheep, and goats.

Bibliography: p.
1. Ruminants as laboratory animals. I. Title.
[DNLM: 1. Animals, Laboratory. 2. Cattle. 3. Goats. 4. Sheep. QY50 N2768r 1973]
SF407.R8N37 1974 636.2'08'85 73-22392
ISBN 0-309-02149-9

Printed in the United States of America

Order from
National Technical
Information Service,
Springfield, Va.
22151
Order No. AD 767-096

Preface

The use of cattle, sheep, and goats in research is increasing. It has been the aim of this subcommittee to furnish practical guidelines for the care and maintenance of these species under a variety of research situations. Since a wide variety of types of facilities can be designed, it was felt that only general recommendations should be made. This report is an initial effort to develop standards for these species when used under research conditions; recommendations may change as a result of new and improved management procedures.

SUBCOMMITTEE ON STANDARDS FOR LARGE (DOMESTIC) LABORATORY ANIMALS

DR. J. J. CALLIS, *Chairman*
DR. LANDIS L. BOYD
DR. ALFRED G. EDWARD
DR. WILLIAM P. FLATT
DR. N. L. JACOBSON
DR. LOUIS F. JENNINGS
DR. ALVIN F. MORELAND
DR. ALVIN L. NEUMANN
DR. CLYDE K. SMITH
DR. CLAIRE E. TERRILL
DR. EVERRETT J. WARWICK

Contents

I Background

HISTORY

Cattle

The commonly accepted zoological classification of cattle is as follows:

Order	Artiodactyla
Family	Bovidae
Genus	*Bos*
Species	*Bos taurus*: includes the ancestors of the European breeds of cattle
	Bos indicus: includes the Zebu breeds of India and the African and American breeds derived from those humped breeds

The most common cattle in the United States today are of the European breeds or crosses. These breeds originated in the more temperate zones of continental Europe and the British Isles. Cattle of these basic types were introduced to this continent by settlers along the east coast beginning in the early 1600's. These cattle truly served a dual role—as draft animals and as producers of meat and milk. Spanish cattle were brought to the West Indies at still an earlier date and formed the basis for the early buildup of cattle numbers in Mexico, Texas, and California prior to the Civil War. The Spanish cattle commonly referred to as "Texas Longhorn" largely lost their identity in the United States in the last half of the nineteenth century as a result of top-crossing with the British breeds of beef cattle such as the Shorthorn, Hereford, and Angus. Breeds of dairy cattle, as known in the United States, were introduced considerably later than the "dual-purpose" breeds.

Several distinct breeds of Zebu or Indian cattle, generally referred to simply as Brahman cattle in the United States, were introduced as early as the 1840's. Their apparent superior adaptation to the environments of Latin America and the southern United States has resulted in their finding a place in the breeding herds of these regions. They became important in the United States only after fairly extensive importation from 1908 to 1910. They are maintained as either straight Zebu-type cattle, or, more frequently, they are used in crossbreeding programs with the British breeds. Several distinct American breeds such as the Santa Gertrudis have now been developed that contain genetic backgrounds from both the British (*Bos taurus*) and the Zebu (*Bos indicus*) breeds of cattle.

Sheep

Sheep were domesticated in the New Stone Age. Carvings in Egypt as early as 4000 BC depict sheep in their role of producers of meat, wool, milk, tallow, and skins. Zoologically, sheep are generally classified according to the following scheme:

Order	Artiodactyla
Family	Bovidae
Genus	*Ovis*
Species	*Ovis aries*: domestic breeds of sheep

There are literally hundreds of breeds of sheep. Some have been developed so as to maintain a flocking instinct, but most are wholly dependent on man or his sheep dog for protection and movement. Some breeds have short, fat tails and others are long-tailed. Some produce only hair and others short, long, fine, or coarse wool. Presence or absence of horns still further differentiate the breeds. In some breeds, both sexes have horns and in others, only the male. Modern domestic sheep probably descend from two wild stocks—the Asiatic Mufflon and the Asiatic Urial.

Goats

Goats were probably domesticated earlier in the New Stone Age than cattle and possibly earlier than sheep. Very likely, the upper Nile region is the site of earliest domestication, and biblical references extol the versatility of the animal, in that it produced milk, meat, mohair, and skins. Zoologically, goats are classified as follows:

Order	Artiodactyla
Family	Bovidae
Genus	*Capra*
Species	*Capra hircus*

Although goats and sheep are closely related, goats may be distinguished from sheep by the absence of foot scent-glands, by the strong odor of the bucks (males), and by differences in structure of horns and skeleton. Those goats that are raised for their fibers, namely the Angora, produce mohair, which has distinct qualities different from those of wool.

The mohair-bearing goat was developed in Turkey and was introduced into this country in 1849. Today, almost all Angora goats are found in Texas, New Mexico, and Arizona. They make excellent use of the browse species of plants found in these semiarid regions. The Angora and a less-common "Spanish" goat are used in clearing brushy rangeland to enhance grass production by reducing the competition for moisture by undesirable plant species.

Milk goats are found virtually worldwide. They have been present in the United States from the time of the earliest settlements. Improved strains were introduced from the Alpine regions of France and Switzerland and from the upper Nile during the late nineteenth century.

CRITERIA FOR CHOICE OF SPECIES AND BREEDING TYPES

Users

Cattle, sheep, and goats are all ruminants, i.e., cud chewers. They have the unique ability to digest fibrous feedstuffs that are high in cellulose and to utilize nonprotein nitrogen compounds such as urea, biurette, and ammonium salts to meet all or a portion of their protein requirements. This is due to the unique symbiotic relationship existing between the host ruminant and the microflora found in the ruminoreticular portion of the gastrointestinal tract. These species hold a special place among research animals because of their production of milk, wool, or meat. Cattle, sheep, or goats can often be used interchangeably in the solution of common research problems. Differences in size of individual breeds, species and individuals within species, availability, cost, disposition, length of gestation and periods of lactation, and life span must be considered when choosing an experimental animal.

Ruminants should be given the opportunity to ingest colostrum in optimum amounts shortly after birth. Colostrum fed during this critical period will furnish the newborn animal with immunizing substances and

temporarily protect the animal against certain diseases, particularly those of the digestive tract. The ruminant is born with little or no ability to resist these diseases and if it does not secure colostrum, it can readily succumb to acute infections. Colostrum-deprived calves present special problems in rearing

Breeds

Cattle The common British cattle breeds—the Hereford, Angus, and Shorthorn or crosses between these breeds—represent typical American beef cattle. These cattle are sexually mature at about 12–14 months of age and live and reproduce to 12–15 years of age. The incidence of twins born to cattle is low. Larger breeds such as Charolais, Simmental, Holstein, and Brown Swiss gain weight rapidly and are 25–75 percent or more heavier at maturity than smaller breeds such as the Angus and Jersey. Cross-breeding is often practiced in commercial herds, and bulls of some of the larger breeds are often bred to cows of the British beef breeds.

The Brahman and those breeds derived from the Brahman, such as the Santa Gertrudis and Brangus, tend to be more excitable than European breeds and require sturdily built quarters. These cattle are sexually mature at a later age than other beef breeds; generally, under average or poor nutritional conditions, their reproductive efficiency is variable.

Of the dairy breeds, the Holstein is most numerous and for this reason is often the animal of choice for dairy studies. It is a widely used breed in commercial dairy herds and, therefore, is readily available. Holstein cattle produce large quantities of milk with a lower fat content than other breeds. Cows of this breed are large, hardy, and long-lived. The Brown Swiss is another large dairy breed; however, they are available in smaller numbers than the Holstein. The Jersey is the smallest in size of the dairy breeds and has the highest milk-fat percentage of any breed. The Guernsey and Ayrshire are medium-sized breeds which have no unique attributes for research purposes and the numbers available for purchase in most areas are small. All the dairy breeds produce more milk than their offspring can consume and research plans must provide for disposition of excess milk. Provisions must be made for milking the cows, either by machine or by hand. Normal lactation periods of the dairy breeds last about 10 months. A 2-month rest period before the onset of the next lactation is desirable.

After 10 months of age, bulls—especially of the dairy breeds—become aggressive and dangerous and may not be suitable for many studies unless specialized quarters and restraint equipment are available.

The body weight for mature beef bulls ranges from 680 to 910 kg (1500–2000 lb), and for mature beef cows it ranges from 360 to 550 kg

(800–1200 lb). Mature dairy bulls will range in body weight from 680 to 1360 kg (1500–3000 lb) and mature dairy cows will range from 410 to 820 kg (900–1800 lb) in body weight.

Sheep Domestic breeds of sheep in the United States may be classified into four main types:

- "Western" types (fine-wool). Western fine-wool sheep, consisting largely of Rambouillet and some Merino breeding, form the foundation for most of the sheep raised in this country. These sheep are very hardy and small to average in size, varying in mature body weight from about 70 to 130 kg (150–280 lb) for rams and 55 to 75 kg (120–165 lb) for ewes. Western sheep are noted for their flocking instinct. They have a greater tendency to breed out-of-season or year-round than other domestic sheep breeds. Some become sexually mature early and may breed as lambs when maintained on a high plain of nutrition. In actual practice, only half are sexually mature at an early age. The numbers of lambs born per 100 ewes will vary from about 110 to 160 with an expected average of 135. The wool from western sheep is valued for its fineness and varies from about 51 to 102 mm (2–4 in.) in staple length. Fleece weights may average about 4.5 kg (10 lb); however, yields of clean wool may be 50 percent of the fleece weight. Ewes are usually polled (hornless) and rams are not, but polled rams are increasing in proportion.
- Long-wool types. Long-wool types of sheep are not widely raised and are used primarily to produce the crossbred types of sheep. They do not show the flocking instinct. The Romney, Lincoln, and Border Leicester are the principal breeds; however, a few Cotswold and Scottish Blackface may be found. They are large in size, their body weight varying from about 100 to 115 kg (225–250 lb) for rams, from 80 to 130 kg (175–280 lb) for ewes of the Lincoln and Border Leicester breeds, and from about 55 to 90 kg (120–200 lb) for ewes of other breeds. Lambing percentages are quite variable, ranging from 105–145 percent for the Romneys to 125–200 percent with an expected average of 160 percent for the Border Leicester. The breeding season is generally during the fall and winter months. The wool is coarse with staple lengths longer than 0.15 m (6 in.). The yield of fleece is in the range of 5 to 6 kg (12–14 lb) and clean wool may be 60 percent or higher. Both sexes are polled except for the Scottish Blackface.
- Medium-wool type (meat-type). This type includes breeds such as the Suffolk, Oxford, Hampshire, Shropshire, Dorset, Cheviot, and Southdown listed in general order of size from large to small. The body weights of Suffolk breeds range from 90 to 160 kg (200–350 lb) for rams and 70

to 120 kg (150–260 lb) for ewes; Southdowns range from 65 to 95 kg (140–210 lb) for rams and 40 to 75 kg (90–165 lb) for ewes. Medium-wool types of sheep regularly breed seasonally to drop their lambs in the spring; however, the breeding season may be variable. The Dorset is noted for a tendency to breed year-round. Under conditions of unlimited feed intake, sheep of these breeds will tend to become obese and short-lived. They may not be as hardy as the fine-wool types and generally do not show the flocking instinct. The weight of fleeces are light and somewhat variable in fineness and length. The faces may be almost completely covered with wool although the Suffolk has a completely bare head. They mature early sexually and produce more multiple births than do the fine-wool types. Lambing percentages will vary from 115 to 190 percent with an average of 150 percent. These breeds are usually polled, with the exception of the horned Dorset in which both sexes have horns.

- Crossbred types. Crossbred types consist of half to three fourths of Rambouillet or other fine-wool breeds and the remainder of long-wool breeds such as the Lincoln or Leicester. These are most numerous as the female is bred to produce market offspring when mated to meat-type rams. The Correidale, Columbia, Targhee, and Montadale are the principal breeds used in developing the crossbred type. Body weights vary from 70 to 140 kg (150–300 lb) for rams and from 50 to 100 kg (105–225 lb) for ewes. These breeds are characterized by heavy fleeces weighing 4.5 to 6.4 kg (10–14 lb) of medium to coarse wool but with staple lengths of 76.2 to 152.4 mm (3–6 in.) or longer. They are truly dual purpose in type, generally excelling the Rambouillet in lamb production, and the flocking instinct is not as well developed as in the Rambouillet. Lambing percentages vary from about 105 to 165 percent with expected averages in the range of 135 to 145 percent. When good feed is available, a fairly high proportion will be sexually mature as lambs. These crossbred sheep have bare white faces and have a high incidence of hornless animals in both sexes.

Additionally, the Finnsheep breed, not included in the four types above, was originally imported into the United States in 1968. It represents a highly prolific breed that may prove very useful for research. A high percent of ewes will lamb at 1 year of age with litters of two to four lambs generally produced. The lambing percentage can be 200–300 percent or more. [A 3-year-old ewe at Beltsville produced six normal lambs without any hormone treatment (Terrill, 1972). Records are reported from Finland of nine lambs born and seven surviving (Maijala, 1969).] This breed is polled, small in size, with bare face and legs. Their color is white; however, the recessive gene for black color is fairly common. Body weights

vary from about 80 to 90 kg (175-200 lb) for rams and 55 to 85 kg (120-190 lb) for ewes.

Goats The type of goat most likely to be used in ruminant studies is the milk goat. The more common breeds are Toggenberg, Saanen, Nubian, and French Alpine, each weighing about 68 kg (105 lb). Dairy goats will lactate 9-10 months or longer but should be given at least 6 weeks' rest between lactation periods. They will produce 1-2 gal of milk per day and can be milked by hand. The Angora goats are smaller than the milk goats and are generally less hardy. The Spanish and pygmy goats are also small, hardy, and prolific.

The pygmy goat is quite useful as an experimental animal because of its small size, hardiness, low feed requirements and because considerable information is available on its normal physiology. These goats were imported from zoos in Sweden and Germany some time ago. There are indications of descent from the Lapland dwarf goat and the African dwarf goat. They average 0.40 to 0.50 m (1.30-1.60 ft) in height and 18 to 40 kg (40-90 lb) in weight. They have horns, a small beard and tail, and may be colored silver gray or black and white with dark brown points. The female carries one or two fetuses per pregnancy with an average birth weight of 2 kg (4 lb). These animals can easily be trained to submit to experimental procedures. They are hardy, withstand the stress of surgery well, and heal rapidly. The pygmy goat is an ideal model for studies of placental and fetal physiology, rumen physiology, gnotobiotic programs, and endocrinology (Rogers *et al.*, 1969; Metcalfe and Hoversland, 1969).

Age

Cattle The age of cattle acquired for research purposes will be determined by the type of study to be conducted. Where larger numbers of male beef cattle of the same age are required on a year-round basis, either weaned calves about 7-8 months of age or "yearlings" about 16-20 months of age will be logical choices. Both ages of cattle are available in large numbers in the fall months, from September to November.

Dairy calves that can be used in milk-replacer studies, calf disease studies, etc., would more likely be purchased as 1- to 3-day-old calves. This type of calf may be found in the dairy regions throughout the year. Widest selection as to numbers, uniformity of age, weight, breed, and health conditions would be found in newly weaned heifer calves with yearlings and mature cows following in that order.

As a rule, cows that are sold from a dairy herd are culled for such reasons as old age, poor disposition, and poor reproductive performance

or for such problems as cancer eye, diseased or damaged udders, or crippling diseases. This type of animal rarely is desirable for research purposes. Cows with several more years of productive life are often difficult to buy and are more expensive.

Sheep Most ewes drop their lambs in the winter and spring months; if baby lambs are desired, they can be found in farm flocks at these times. Baby lambs may be less available in the western states due to the extensive nature of the sheep-ranching enterprise, except in those locations where shed (interior) lambing is practiced. During the late fall months large numbers of fine-wool or western lambs 5–6 months of age are available. Medium-wool or meat-type lambs are more likely to be found in farm states, and large numbers will be available from May to July, weighing about 45 kg (100 lb). Available western or range lambs will be at a lighter weight, from 36 to 45 kg (80–100 lb). Farm lambs will be fatter than western lambs and not as suitable for feeding trials. For use in reproductive studies, weanling ewe lambs or yearling ewes are preferred over mature ewes since they are more versatile to manage and are more likely to be healthier and more uniform. Most mature ewes offered for sale cannot be expected to be suitable for more than one or two additional lamb crops; however, ewe lambs or yearlings should be capable of producing four to six lamb crops.

Ewes may be obtained with dated pregnancies but this requires the somewhat expensive observation of matings and some failures may be expected. Pregnancies may be detected early by ultrasonic or other means of pregnancy diagnosis (Lindahl, 1971; Hulet, 1972). Hormone treatments including synchronization of estrus may be used to obtain relatively large numbers of dated pregnant ewes at prescribed times (Dziuk, 1972; Inskeep, 1972).

Lambs may be reared artificially from birth (after colostrum feeding) with commercially available artificial milk replacer for lambs (Frederiksen, 1972; Glimp, 1972).

Wether (castrated male) lambs are preferred for studies on wool growth and for studies involving metabolism cages that require separation of urine and feces. More years of use can be expected from this type of animal if fistulae and cannulae are to be installed.

Goats All goats should be dehorned at a few weeks of age. Horns are dangerous on adult animals and are both painful and difficult to remove.

Male kid goats are available at birth on most goat dairy farms. Since they often have little commercial value as meat animals, such kids are seldom saved unless plans for purchase have been made in advance. Since

kids can be started on milk-replacer rations, they could be removed from the producer's farm after colostrum feeding unless the experiment requires that the animal be deprived of colostrum. Female kid goats would often be more readily available after weaning (3–4 months).

Unless required in the experimental protocol or needed for breeding, all male goats should be castrated. Castration improves their disposition and generally eliminates the offensive male goat odor characteristic.

Most ranchers who rear Angora or Spanish goats do so for the production of mohair or for brush cleaning. Young goats of these types are seldom available in quantity. Goats being sold because of old age would rarely be suitable as research animals.

Sex

Castrated animals are generally preferred for research unless reproduction or milk production, per se, are the subjects of interest. Estrus and possible pregnancy in females and libido in intact males cause disturbances among groups of animals being fed in conventional trials. These problems can be minimized if individual stables are used. Also, certain hormone-like compounds such as stilbesterol are available for use in males and MGA (melengesterol acetate) for use in females to minimize the above problems. These products can be administered orally, by implantation, or by injection. Knowledge of the physiological implications of these products and their use in accordance with United States Department of Agriculture (USDA) and Food and Drug Administration (FDA) regulations are essential. When metabolism studies are conducted, separate collection of feces and urine is simplified when male animals are used. In those instances where salvage value is a consideration, castrated males have a higher market return.

Lactating dairy cows and goats produce so much milk that some provision must be made for milking them, either by machine or by hand. If surplus milk is to be sold, mechanical milk cooling equipment must be provided to meet local and state health regulations pertaining to this product. Normal lactation periods are 7 months for beef cows, 10 months for dairy cows, 10 months for goats, and 4–5 months for ewes.

BIOMEDICAL RESEARCH USE OF LARGE LABORATORY ANIMALS

Ruminants are being used as animal models in biomedical research and comparative medicine because of similarities in some of their organs, physiology, and vascular structure. In other instances, their use is related to diseases that affect man and animals (zoonoses).

Sheep have proven valuable as models in studies relating to the Dublin-Johnson syndrome (Middleton, 1970). Sheep, goats, and cattle have served as animal models in the study of hemoglobinopathies (Middleton, 1970). These animals also have been used as experimental animals in the study of tissue and organ transplants (Lindsey, 1969). Sheep and goats have proven valuable in the study of slow virus diseases because of their susceptibility to scrapie and the similarity of this disease to multiple sclerosis and kuru in man. Ewes and does with dated pregnancies are used in fetal surgery.

The miniature goat is gaining in popularity as a representative ruminant specimen because of its small size, thus requiring less space, labor, and feed. These animals have been used as subjects in studies of the maternal and fetal circulations during pregnancy (McPherson, 1968).

Ruminants are commonly maintained at medical research institutes and are used for the production of human and veterinary biological products.

II Facilities

CONSTRUCTION

The type of housing required and management practices to be followed for cattle, sheep, and goats used as research animals will be determined by the nature and objectives of the research to be conducted. Conventional housing and management practices can usually be used in genetic, nutritional, and physiologic studies. However, these types of facilities and animal care practices would not lend themselves to studies involving animal disease agents. The latter type of studies requires specialized facilities and critical control of the animal's environment for valid research results and prevents the spread of disease agents.

Selection of the site for the proposed facility is important. Terrain features influence natural drainage of the area and will determine the suitability of the area in relation to runoff and possible pollution of waterways and water supplies.

The use of ruminants as research animals will present materials-handling problems, such as the large volumes of feed and bedding required and disposal of manure. Direct labor costs involved in the performance of these tasks can constitute a sizeable portion of the expense. Costs should be evaluated in both building design features and installed labor-saving equipment in relation to the materials-handling problems rather than solely on the basis of building costs per animal housed.

Climatic conditions existing in the area of proposed construction will largely influence the final choice of the type of facility used to house ruminants. Valuable assistance and guidance in determining the most suitable type of housing and management practices can be obtained from state university experiment station publications, extension services, and commercial companies. Design recommendations are usually made on a regional basis and are the result of actual field experience with the various

environmental factors to be met to satisfactorily house and maintain animals. Inexpensive plans are available from the Midwest Plan Service, Iowa State University. (Some examples are in the Appendix.) This service prepares publications under the direction of agricultural engineers and consulting specialists. The extension agricultural engineer of the nearest land grant university usually can either assist or furnish guidance to the planner. The engineer can usually recommend operational units that the planner may visit to determine if a given type of facility will meet his needs. This is especially important when departures from conventional housing designs and materials-handling systems are being considered.

Outdoor Facilities

Design Outdoor facilities are most suitable in moderate climates; however, they may be satisfactorily employed to house animals in cold climates if proper consideration is given to locations in relation to prevailing wind direction, drainage, and use of adequate bedding to keep the animals warm and dry. Outdoor facilities are usually open-front buildings that allow unrestricted movement of the animals between the building and outside lots. This type of housing is often referred to as loose housing. In temperate climates, it is often possible to confine animals to lots without shelter other than that provided by trees, terrain, wind fences, or sun shades.

Ruminants require a resting area, whether it is provided in a well-drained, outside area or within a bedded shelter. Table 1 indicates the minimum areas per animal when animals are kept in groups under conventional type housing (see Appendix, Item 1). Space requirements have been made for cattle allowing access to outside lots. The lot area to be provided for sheep and goats should be at least double the resting space allowed.

Dairy cattle are often housed in shelters provided with individual bedding areas known as comfort stalls, which the animal may enter or leave at will. These resting areas are provided with divided panels between animals which prevent injuries to the udder when the animals enter or leave the stall. Stall dimensions (Table 2) are designed in accordance with both body size and weight (see Appendix, Items 1 and 11).

It becomes readily apparent that paving of outside lots can allow a marked increase in the number of animals to be held in the same space.

The chief advantage of outdoor housing is lower initial costs; however, the user of such facilities must accept both the uncontrolled environmental conditions not usually present in well-designed indoor facilities and the potential of variability in research results. Experienced researchers recognize the inherent risks they assume with such facilities and do not use

TABLE 1 Minimum Resting Areas Required Per Animals in Groups

	m^2	ft^2
CATTLE		
Resting area		
Mature	2.33–2.79	25–30
272 kg (600 lb)	1.86–2.33	20–25
Calves to 272 kg (600 lb)	1.40–1.86	15–20
Lot area/head		
Unsurfaced	37.20	400
Partially surfaced	13.95	150
Surfaced–no shelter	5.12	55
Surfaced–open housing	2.79	30
SHEEP AND GOATS		
Resting area		
Ewes and rams	0.93–1.30	10–14
Ewes with lamb	1.12–1.49	12–16

them unless they wish to simulate conventional animal-rearing programs. Outdoor holding facilities are generally considered to be adequate for animals being held during the pre-experimental quarantine and conditioning period.

Materials Choice of materials for construction of outdoor animal holding facilities will be governed by their cost and availability. A variety of materials can be used, ranging from wood to metal or masonry construction. Metal and masonry buildings require less maintenance than do wooden buildings. Clear span structures using steel roof trusses have been found to be very satisfactory.

Metal buildings must be provided with splash boards of heavy material to prevent damage to the side walls by both the animals and mechanical equipment used to remove manure from these buildings. These sidewall barriers will also reduce the corrosive action of manure on metals used

TABLE 2 Stall Dimensions

Weight of Cow	Stall Length	Stall Width
545 kg (1200 lb)	1.70 m (5 ft 7 in.)	1.30 m (4 ft 3 in.)
636 kg (1400 lb)	1.80 m (5 ft 11 in.)	1.37 m (4 ft 6 in.)
726 kg (1600 lb and over)	1.91 m (6 ft 3 in.)	1.45 m (4 ft 9 in.)

for outside wall construction, as they prevent direct contact between bedding and metal surfaces. Caution should be exercised in the choice of preservatives used for wood in areas or portions of buildings accessible to the animals; the pentachlorophenol preservatives may be toxic to young animals.

The floor surfaces of buildings used for outdoor or loose housing under commercial or conventional systems are often not covered with concrete; this practice is not recommended for research holding conditions since complete disinfection of earthen surfaces is not possible. Feeding inside these structures is possible; however, increased labor will be required to remove the manure buildup in bunk areas.

Durability should be a major consideration in the choice of materials for construction of fences, corrals, and feed mangers. Loose housing constructed of lightweight materials can be readily damaged when heavy, large-sized animals crowd against them.

In designing loose housing systems, provisions should be made for sorting, treating, and loading and unloading facilities (see Chapter 2, pp. 22-23, 27). These can be readily incorporated in the design of fencing for the outside lot. Fences can be constructed with heavy posts and plank materials or steel posts and cable. Feed bunks can be of either post and plank or concrete construction, and can be located along the fence line to allow feeding from outside of the lot. Examples of design recommendations applicable to a wide variety of loose housing installations are described in publications furnished by the Midwest Plan Service (see Appendix, Items 2 and 8).

Environmental Considerations Only limited control of environmental conditions is possible for animals housed under outdoor or loose housing conditions since the temperatures within the building will be very close to that outside. Ruminants can be housed in this type of building and can be maintained in a satisfactory state of health if they are protected from direct drafts and if sufficient bedding is used to keep them dry. Ventilation within these structures is largely limited to natural air movement within the building and openings should be provided along the eaves and at the roof ridge to allow warm, humid air to escape. If this is not done, condensation can occur and greatly increase the moisture load within the building. During hot weather periods, air movement through the building can be increased if sliding doors are installed on the side of the building facing the prevailing winds.

Drainage Adequate drainage is often difficult to attain without concrete floors and a paved lot. Large outdoor holding lots should have paved sur-

faces along the areas of greatest animal traffic, such as in front of the building and along the feed bunks, to reduce the muddy conditions that can readily occur in unpaved lots. Animals on dirt lots will be less likely to have leg and foot problems common to animals housed for long periods on concrete. The user of dirt lots must assume the continuous risk of disease and parasite transmission between successive groups housed in the area.

The buildings should be provided with eave troughs or gutters to divert rain to a drainage system. Holding lot surfaces should have the proper degree of slope away from buildings and feeding areas for drainage of all liquids, such as urine and rain or snow, into a holding area for disposal. These liquids should not be allowed to seep into a natural water course.

Sanitation When ruminants are held in outdoor facilities, the degree of sanitation possible will largely be governed by the judgment exercised in building design, selection of construction materials, and the adequacy of drainage and waste disposal methods.

Consideration must be given to the areas designated for the initial collection of wastes. The ground should have a hard, impervious surface, preferably of concrete. Building materials should be capable of withstanding steam or pressure cleaning and should resist the action of such decontamination solutions as may be applied. A good supply of water under high pressure is essential for effective flushing of paved surfaces.

Indoor Facilities

Design Design criteria for indoor or confined housing must meet specialized needs for specific kinds of research. Buildings designed for use in studies of infectious diseases of ruminants require specialized air-handling systems such as high-efficiency filtration, as well as decontamination facilities to render sewage from these areas innocuous. Temperatures, humidity, and air movement within these structures should be under the full control of the researcher.

Recommended designs for conventional indoor facilities can be obtained from the same sources as for outdoor facilities.

Confinement housing can be adapted for use during the pre-experimental holding period in many research situations where it is desired to eliminate some of the problems inherent to outdoor housing such as drifting snow and muddy outdoor lots and to provide better control of wastes. Indoor facilities that can be environmentally controlled to provide dry, draft-free, well-ventilated quarters are essential to rear young animals in cold climates and to avoid death losses (see Appendix, Item 5).

Indoor housing consists of either open buildings with natural ventilation or, more commonly, closed buildings that are ventilated with mechanical equipment. Bedding or liquid manure handling systems can be used in these buildings. Slatted floors over manure collection pits are being used in beef cattle, dairy cattle, and sheep confinement housing systems as they offer a means of reducing the labor required to dispose of daily manure accumulations. Metal mesh floors have also been used in sheep holding areas both as a means of manure handling and internal parasite control. A small rubber mat for a resting area is desirable when metal mesh floors are used to rear calves or kid goats.

Space allocations and the numbers of animals that can be housed in a given animal holding area, whether it be a pen or animal room, are largely a matter of professional judgment and experience. Space recommendations for animals held under conventional or farm-type conditions are available for cattle, sheep, and goats. Confined or indoor housing of beef cattle is being adapted in many areas as a solution to problems encountered in drylots caused by drifting snow, wind, and mud and as an aid in the control of waste materials. Both bedded and liquid manure handling systems are employed, the choice being largely determined by cost, availability of bedding, and available labor for manure removal.

Recommended space allotments for cattle held in open-front housing relying on natural, year-round ventilation are as follows: 2.79 m^2/454-kg (30 ft^2/1000-lb) animal on solid bedded floors or 1.86 m^2/454-kg (20 ft^2/1000-lb) animal on slatted floors, plus feeders and alleys.

Recommended space allotments for cattle held in warm or fan-ventilated buildings are 1.86 m^2/454-kg (20 ft^2/1000-lb) animal plus feeders and alleys. Bedding is not used, or the animals are on slatted floors (see Appendix, Item 2).

Total confinement of dairy cattle utilizing free stalls is being practiced in northern dairy areas. Stall dimensions have been given; however, additional building space allotments will be determined by the methods followed in feeding and removal of manure. The ventilation rate and insulation in this type of building are critical to maintain satisfactory animal health (see Appendix, Items 1 and 11).

Housing requirements for indoor rearing of sheep and goats can be met if the following minimum space is allotted:

Ewes and rams	0.93–1.30 m^2/animal	(10–14 ft^2/animal)
Ewes with lambs	1.12–1.49 m^2/ewe	(12–16 ft^2/ewe)

These space allowances do not include space for feeders and alleys (see Appendix, Item 3).

A reduction of one third in the amount of required floor space is possible if animals are maintained on slatted floors.

Many experiments in environmentally controlled conditions require a pen for each animal. Recommended minimum space to be allowed for routine housing under laboratory conditions, as taken from the 1972 *Guide for the Care and Use of Laboratory Animals*, Department of Health, Education and Welfare Publication No. 73-23 (NIH), are found in Table 3.

Animal rooms should be capable of accommodating the largest species of animals to be used in the research program. More widespread use of the room can thus be achieved if feeding and restraint equipment can be readily removed and replaced by equipment suitable for other species. Flexibility can be achieved by the use of removable room dividers.

Materials To the extent possible, all materials used for indoor facilities should be impervious to moisture, insects, and vermin. Concrete and metal are the preferred building materials; however, wood may be satisfactory. Wood is not satisfactory if extensive cleaning and disinfection procedures must be carried out at the completion of the experiment.

The surface of interior concrete walls should be treated with an epoxy-type paint or material to prevent moisture penetration and also to provide a surface that can be cleaned more readily. Lead-based paints should never be used where there will be direct contact with animals. The use of glazed tile installed with waterproof grout for animal-room wall surfaces to be cleaned and decontaminated after each use will greatly reduce main-

TABLE 3 Space Recommendations for Laboratory Animals

Species	Weight (kg)	Type of Housing	Floor Area/Animal (Square)
Sheep and goats	Up to 25	Pen	0.93 m (10 ft)
	25- 50	Pen	1.40 m (15 ft)
	Over 50	Pen	1.86 m (20 ft)
Cattle	Up to 350	Stanchion	1.5 m (16 ft)
	350–450	Stanchion	1.7 m (19 ft)
	450–550	Stanchion	2.0 m (21 ft)
	550–650	Stanchion	2.2 m (24 ft)
	Over 650	Stanchion	2.5 m (27 ft)
	Up to 75	Pen	2.2 m (24 ft)
	75–200	Pen	4.7 m (50 ft)
	200–500	Pen	9.3 m (100 ft)
	500–600	Pen	11.2 m (120 ft)
	600–700	Pen	13.0 m (140 ft)

tenance costs. The surface of all concrete floors should be rough to prevent slippage of the animals' footing.

Fences, pen dividers, and gates should be well constructed and durable. Heavy wood planking is often used for this purpose in many animal holding facilities; however, metal pipe material is preferred as it is easy to clean and maintain. Pipe or cable construction does not restrict air flow within the building or between animal pens.

For better ventilation control, many new facilities have eliminated windows in the sidewalls and have substituted roof skylights and artificial illumination. However, when windows are used, they should be fixed and mounted flush with the inside surface so moisture and dust will not collect. If movable windows are used, they should have metal frames and a simple means of opening, closing, and locking.

Environmental Considerations Environmental control is mandatory within indoor or total-confinement buildings to ensure normal, healthy research animals. Climatic conditions, age of animals, and population density within the building will affect the required rate of ventilation. Open-front buildings do not present special ventilation problems as natural air movement will maintain inside temperatures within a few degrees of outside conditions. Air movement is limited by openings at the eaves and at the roof ridge. Closed buildings must be provided with mechanical ventilation to provide air movement and humidity control. Guidelines for ventilation requirements of conventional buildings are available to design engineers (see Appendix, Items 1, 2, 6, 8, 10, 11, and 14). However, newer designs of total-confinement buildings equipped with slatted floors and manure pits require specialized air-handling equipment to effectively control the humidity and odor that can quickly develop at the time of cleaning (see Appendix, Item 1).

Recommended insulation and supplemental heat requirements for indoor (closed) facilities are dependent on regional requirements. Direct drafts on the animals should be avoided and this factor should be carefully evaluated in the design of the ventilation system. In regions of high ambient temperature, the facility cannot be kept lower than the recommended environmental temperature, and supplemental air conditioning capability may be necessary.

Indoor (closed) facilities are usually designed with fans for air movement. Insulation and a vapor barrier are required. Supplemental heat is required if condensation control is to be achieved at temperatures below -12.2 °C (10 °F) if the indoor facility is to be maintained above 1.7 °C (35 °F). A ventilation system capable of exhausting 0.42 cmm (cubic

meters per minute)/454-kg (15-cfm/1000-lb) animal weight under minimum winter conditions, 2.80 cmm (100 cfm) during fall and spring periods, and at least 5.6 cmm (200 cfm) during summer periods is considered essential for maintenance of animal health.

Sanitation Sanitation of indoor facilities is best accomplished if floors and other surfaces are impervious to moisture and can withstand the frequent washing and decontamination necessary to prevent buildup of disease organisms. If the scheduled use of animal holding facilities will permit, it is advisable to allow the area to remain idle for several weeks after decontamination.

Feeding and watering facilities should be located away from the bedding areas. Facilities for feeding and other operations should be designed to minimize disease transmission and to ensure greater operator safety. Pen partitions, if not permanent, should be easily removed for sanitizing between experiments. Wood should not be used for indoor construction as it cannot be effectively cleaned and disinfected.

Drainage Adequate drainage must be provided in total-confinement buildings. Even though most of the liquids will be absorbed in the bedding, some liquids may drain from the building and contribute to waterway pollution. In some research situations, animals may be maintained in animal rooms or holding areas without bedding material and the body wastes flushed into the sewage system. When the wastes are flushed into the sewer, it is advisable to provide drains with a continuous flush system to ensure that large volumes of water are incorporated into the discharges to prevent drain stoppage. Grinding of hay or the use of pelleted feeds is necessary to prevent drain stoppage.

FEED PREPARATION AND STORAGE

The location of feed storage and equipment used to prepare rations for experimental animals will depend on the feed ingredients used, rations to be formulated, and the feed distribution system employed. Forages normally constitute the major portion of the ration of ruminants, and the tonnage of feed required to maintain them can necessitate the design of specialized storage facilities and materials-handling equipment. The rations for ruminants used in research will be determined by the researcher, and when these parameters are established, engineers can design storage, feed processing, and handling systems from established data (see Appendix, Item 4).

EQUIPMENT

Breeding and Maternity

Natural Mating Animals to be mated are placed together in enclosures with sufficient room for free movement and with floor surfaces that provide good footing. If males are kept in individual pens, mating is often facilitated if the female is introduced into the male's pen.

If aged or very heavy bulls are used for breeding, especially with heifers or cows of smaller size, a breeding rack that restrains the female and provides support for the front feet of the bull is advisable (Ensminger, 1952, 1968).

Semen Collection and Artificial Insemination Semen is usually collected from bulls, rams, and bucks by means of the artificial vagina. Collection requires either a dummy or a chute in which the female can be restrained for the male to mount. An alternative method of semen collection is electrical ejaculation (Salisbury and Vandemark, 1961). For insemination of the female a chute or stanchion providing restraint is required (Salisbury and Vandemark, 1961).

Maternity For animals under confined conditions, the young should be born in clean, well-bedded stalls with ample room for the female to freely turn and move. Cattle stalls should be equipped with a swinging gate, or there should be a nearby chute for restraint in case assistance in the delivery of the calf is necessary, or to remove retained placental membranes, or to administer medication. Skilled personnel should be available to render assistance in case of difficult calving. Following parturition, ewes and does that are not under specific research regimes should be placed with their young in individual pens about 1.2 X 1.8 m (4 X 6 ft) for 12 hours to a few days. Cows and their calves can be kept in the calving stall.

Multiple nursing is possible. A good milk cow can support more than one calf. The cow should be tied and the calves turned from their box to nurse. Generally, the calves may be weaned in 2 months. Additional calves may then be placed on the nurse cow.

Feeding

Nursing Equipment Metal buckets, preferably made of stainless steel, incorporating a neoprene or rubber nipple are used in feeding calves. These are available at most farm stores. Orphan kids and lambs are fed with 800-ml

bottles capped with rubber or neoprene nipples. Plastic containers with nipples also are available for calves and *are frequently used*. Automatic dispensing nursing equipment has been used to rear animals in groups. Heated milk replacer is available. The major problem in using such equipment is the necessary cleaning and disinfection following each use. All of these animals may be trained to drink warm milk directly from the pail by being coaxed to suck on a finger that is slowly immersed until the animal learns to drink. However, animals will often accept nippled containers and may be weaned in 4–8 weeks by gradually supplying small amounts of concentrates and hay.

Feeding Bunks Metal or concrete bunks (with no sharp edges) and rubber, neoprene, or heavy plastic containers are suggested to feed pellets, concentrates, salt, and supplemental minerals. The bunks, if permanently installed, should be designed to slope toward a drain that may be stoppered or covered with a screw cover to allow periodic cleaning. Prefabricated concrete bunks 2.44 m (8 ft) long are available in most areas.

When the animals have access to only one side of a bunk, allow 0.61 m (2 ft) for dehorned cattle, 0.76 m (2.5 ft) for horned cattle, and 0.46 m (1.5 ft) for calves, sheep, or goats.

Automatic and Self-Feeding A programmed work routine must be developed in moving feed in most research or teaching facilities. A feed storage area that is vermin proof should be provided, using covered containers or bulk tanks. Several methods of delivering feed from central storage areas have been devised. These include auger conveyors from trucks, chutes from overhead feed areas, auger or screw conveyors along the bottom of feed troughs, and chains with scoops and bars to move the feed along bunks. This type of equipment is suited for production-type research. Cleaning and decontamination are made difficult because of the dust that is created and the many irregular surfaces and spaces inherent in the equipment. Hand trucks are useful to move quantities of feed while a fork lift may be required to move pallet-sized loads of feed.

Hay racks mounted with pipe or taut 12.7-mm (0.5-in.) steel cable at 0.46 to 0.92 m (1.5–3 ft) above the bunks will keep cattle out of the bunks. If steel pipe is used to construct the hay racks, the pipes should be at least 0.23 m (9 in.) apart to allow the animal full access to the hay.

When calves, lambs, and kids are maintained with their dams, a creep should be provided to enable the young to obtain supplementary feed. A barrier with a narrow opening prevents the dam from entering and competing for the concentrate.

Watering

Water should be available to the animals at all times. It may be offered to young animals in neoprene, rubber, or heavy plastic containers located on the outside of the pen. Troughs and metal tubs are often used to supply larger quantities; however, these need frequent cleaning and are difficult to sanitize.

A number of styles and types of automatic watering devices are available. Some types can be mounted on the wall, others are self-supporting above floor level. The height of the watering device should accommodate the ruminants housed. The automatic watering device is common and contains a bowl in which a lever is mounted. The bowl fills with water when the animal depresses the lever with its muzzle. This type often causes vibration of the water line resulting in considerable noise. In cold climates, automatic waterers should incorporate a heating element. The waterer should be located near a drain in an area sloped away from a bedded area.

Milking Equipment

A number of electrically powered milking machines in various sizes are available on the market. Proper operation is essential to prevent teat and udder damage. Every organization maintaining lactating animals should have at least one person competent at hand milking. Dairy animals should be milked twice daily at regular intervals with the maximum time between milkings not to exceed 14 hours.

Restraint

The ease of handling and working cattle, sheep, and goats is largely dependent on serviceable restraint equipment. A wide variety of restraint equipment is available but certainly one should consider as a desirable minimum a corral, squeeze chute, and headgate. Plans for constructing this equipment are generally available from the USDA and agricultural extension services in various states. Also, the equipment can be purchased from commercial sources (see Appendix, Item 2).

Corral A corral is a pen or series of pens designed in such a way that ruminants may be herded together in close confinement. Sorting, separating, and individual handling of animals can be accomplished with minimal effort and manpower when equipped with gates.

Squeeze Chute and Headgate A squeeze chute is a narrow passage with moveable or adjustable side panels that securely "squeeze" the animal between the sides so that its movement is minimized or prevented. Such chutes are usually equipped with a "headgate" hinged at the bottom center to form a V-shaped opening. When the animal's head is placed through the upper portion of the V, the upper arms of the V are brought close together and secured. This prevents withdrawal of the animal's head. When the headgate is used in combination with the squeeze chute, even the most excited animal can be effectively immobilized. Squeeze chutes are either stationary or portable and are available with various easily removable panels that allow access to specific areas of the animal's body. They may be constructed on site or purchased commercially.

The headgate is sometimes used by itself at the end of a narrow fixed-sided corral; when used in this manner, restraint is incomplete..

Cutting Chute A cutting chute is a narrow passage equipped with a "crowding gate" at the rear and "cutting gates" on either side at the front (Williams, 1955; Neumann and Snapp, 1969). It is used to separate or "cut" animals into pens on either side. Frequently, it is located in tandem with the squeeze chute, thus facilitating the handling operation.

Hand Hurdle In working with sheep or goats in corral confinement, a lightweight wood panel maneuvered by one or more men is an effective means of crowding the animals and moving them into and along narrow passages or into chutes or dip tanks. Plywood panels of appropriate height and length with "cut outs" for holding in the hands will suffice. A door or "dodge gate" may be made in the hurdle near its center, hinged to permit opening to either side, which allows it to be used to separate animals into groups (Williams, 1955).

Surgery Tables Hydraulic, manually operated, small-animal (dog and cat) surgery tables, which are commercially available, can be used (sometimes with minor modifications) for sheep, goats, and calves. Adult cattle, because of their massive size, are difficult to manipulate manually in the anesthetized state. Electrically operated, hydraulic tables specially designed for surgical restraint and manipulation are also available commercially and can be invaluable in an active, large-animal research program.

Transport Carts or Pens In moving hoofed animals within a research facility, smooth finished floors are hazardous to the animals. Nonslip floors or mats are desirable to prevent injury. Small carts equipped with two fixed

and two swiveled casters greatly facilitate indoor transport. Wheels are best equipped with pneumatic tires but hard rubber or steel casters can be used. The carts should be constructed of stainless or galvanized steel. Sanitation will be easier if carts are equipped with pans and an absorbent litter. Varnished or well-painted plywood carts equipped with excreta pan may suffice if well maintained.

Halters Halters made of leather or rope are essential items for leading and controlling individual animals, particularly in outdoor situations. Intractable animals can be controlled by use of a double halter that allows them to be led by a caretaker on each side, thus reducing possibilities of injury to either the animal or caretaker.

Nose Leads Intractable cattle can be restrained with nose tongs that, if fitted with a lead rope, will apply pressure to the sensitive nasal septum when the animal resists. Care should be exercised in the use of the tongs to prevent nose damage. They are also useful when securing the head in the headgate for jugular venipuncture or surgical procedures requiring precise restraint. Most ranch, farm, or veterinary supply stores stock them.

Tranquilizing Drugs Chemical restraint through use of tranquilizing drugs is frequently advantageous. As with most pharmacologic agents, experience in the proper use is best. Usually these agents are safely used by veterinarians or others specifically trained for their use in a particular species.

Cleaning

To meet needs of certain experiments, such as infectious disease studies, *all equipment* used to remove litter and manure such as manure loaders, spreaders, shovels, forks, and brushes should be cleaned following their use. Physical cleaning of the area should be thorough and, in some instances, followed by disinfection.

Barn Cleaning is essential to reduce odors, to keep animals dry, to reduce the potential of microorganism buildup, and to protect the health of newborn calves, kids, and lambs. This is often accomplished by housing animals on warm slatted floors to keep the young animals dry and free of contamination. The use of shavings under the slats or as a bedding for the newborn, if kept in a loose stall, may increase labor but reduces odors and humidity. An industrial wet-type vacuum could be used to clean these areas; however, where large numbers of animals are housed, hand cleaning is re-

quired before washing the area. There must not be any compromise with sanitation in rearing calves, lambs, and kids.

A reduction of time and labor required to clean areas occupied by animals can be realized if they are maintained in stalls that have no bedding or are on warm slatted floors. Where bedding is used, it must be cleaned out before washing the area. Barn cleaners are used in some commercial operations but are difficult to sanitize and may not be useful in some research or teaching situations.

Liquid manure handling systems are essential in units that house animals on slatted floors. In this type of installation, precautions should be taken to minimize buildup of dangerous gases and objectionable odors within the building. Livestock should be removed from the closed barns prior to emptying manure storage tanks or measures should be taken to increase ventilation rates.

Equipment Units equipped with a supply of hot water 71.1 °C (160 °F) under pressure up to 500 psi are available for cleaning outlying areas. Steam-generating units are useful for heating water for cleaning purposes and, because of the pressure, are also useful for cleaning a variety of surfaces. High-pressure hoses of the type used in dairies are recommended because they are resistant to heat and pressure and are safe.

Disposal

Refrigerators Consideration should be given, during the planning phase of any large animal facility, to provide a refrigerated area to hold carcasses of dead animals prior to necropsy and final disposal. Rapid chilling of the carcass is essential to minimize postmortem changes that would obscure necropsy findings or render them totally unreliable. Freezing of the carcass should be avoided when histopathologic studies are to be done. Refrigeration or freezing of dead animals is of value when a rapid collection and disposal service for dead animals is not available. Refrigerator floors should be adequately sloped and provided with interior floor drains to facilitate cleaning and to prevent odor buildup.

Incinerators Any incinerator selected for the disposal of dead animals, pathologic materials, bedding, and other burnable materials should be of a size adequate for the amount of material to be burned. Reserve capacity should be provided to meet future requirements and unusual heavy loading conditions. The type of material to be incinerated and its moisture content are important considerations in the selection of the proper type of

incinerator. Many package-type units that have proven to give dependable service are commercially available. Design criteria and standards for incinerators can be obtained from the Incinerator Institute of America (630 Third Avenue, New York, New York). Federal, state, and local pollution laws must be complied with and approval should be obtained during the planning stages and prior to purchase of the equipment.

Closed Containers Garbage cans provided with plastic bag inner liners can be used as waste receptacles. The use of plastic bags reduces the labor required to dump the material and clean the cans. (For information on organic wastes see below.)

Truck Transported Containers Such containers are large, open or closed, box-type units which can be picked up, transported, and dumped by a specialized truck. These units have a large carrying capacity and are watertight. One truck can service many units placed at various points. The major advantages of units of this type are that they act both as storage and transport containers.

Specialized Waste Disposal The disposal of animal carcasses and body wastes from animals used in infectious disease studies requires special treatment to render them innocuous. Studies involving the use of radioactive material create highly specialized collection, concentration, and disposal problems. Radioactive waste collection facilities have been designed for several species and may be applicable to ruminants (see Appendix, Item 13).

Infectious wastes should be incinerated, heated or chemically treated, or autoclaved prior to removal from the research area. The method used will depend upon the available facilities. Treatment at 82.2 °C (180 °F) for 30 min will render sewage safe for release.

Carcass Transport Equipment should be available to load and transport animal carcasses to areas for refrigerated holding and necropsy and then to the final disposal area. A low tilt-type trailer with a hand or power winch greatly simplifies loading. The trailer body and sides should be watertight to prevent dripping and possible contamination of other areas. The vehicle should be constructed of metal to allow more effective cleaning and disinfection between periods of use. A trailer of this type can be pulled by a tractor or truck. In some areas, an overhead rail of the type used in the packing industry may also be useful to transport animal carcasses.

Manure The manner in which liquid and solid animal wastes can best be disposed of is determined by the location of the research facility, the type

of housing employed, and the research situation itself. The wastes from normal animals housed outdoors can be disposed of by conventional means if sufficient land area on which to spread the waste is available. If field spreading is not practical, the manure may be composted and periodically removed to a suitable disposal site. Incineration is another possible means of disposal; however, air pollution ordinances must be considered and it is expensive.

Total or indoor confinement of animals is becoming commonplace in both commercial and research facilities. Animals may be held under these conditions on concrete floors or a combination of a concrete floor area and wooden or concrete slats over manure pits. To maintain animal health and to reduce odors, housing of animals under total confinement systems requires critical control of ventilation, humidity, and temperature. Bedding may or may not be used in this type of installation.

In many new installations, solid and liquid wastes are discharged into lagoons of a sufficient size to allow digestion to occur. Digestion tanks should be equipped with comminutor pumps that are capable of reducing straw and manure to a slurry of such a consistency that it can be pumped into an irrigation system or tank used to spread the liquid on fields or inject it into the top layers of the soil. Wood shavings are not recommended for bedding where final disposal will be in lagoon systems since they do not readily decompose.

Miscellaneous Equipment

Loading Chute A loading chute is essentially a narrow passage constructed with an inclined floor allowing animals to be herded and driven from ground level to the level of the floor of transport vehicles or vice versa. These chutes may be stationary or portable and may be simply constructed from heavy timbers or elaborately made from concrete or steel. The floor is either cleated or equipped with low stairstep risers to provide better footing for the animals (Williams, 1955; Neumann and Snapp, 1969).

Portable Scale Scales equipped with side panels so that animals may be penned and weighed are commercially available. Some scales also may be incorporated into chutes, thus allowing the weighing of large numbers of animals quickly.

Tack A variety of small items such as ropes, lines, halters, and lariats of various sizes and types prove valuable when handling cattle, sheep, and goats. Such tack should be kept in a safe place, out of reach of animals, and protected from the weather.

Quick-Release Honda A quick-release honda is a fitted slip ring that may be opened against spring pressure so that the lariat noose may be quickly removed without the necessity of slipping it over the animal's head. In certain situations it is extremely valuable. Most ranch or tack supply stores stock this item.

Dip Tanks and Insecticide Sprayers Dip tanks in which animals are totally immersed in an insecticide solution are useful in controlling ectoparasites of large animals. Dipping may be required for interstate shipping of some animals (USDA, 1917; USDA, 1968). Tanks are expensive and require more chemical than spray techniques. Sprayers not only can be used for infested animals but also are useful for insect pest control. Sprayers are available commercially in a wide range of sizes, materials, and prices.

Clippers and Shears Electric and gasoline-powered clippers and shears are available from farm and ranch suppliers. Small-animal (dog and cat) clippers are available from pet or veterinary suppliers. Clippers are indispensable for preparation of a surgical operative site in cattle, sheep, and goats and for freeze branding.

Tractors Tractors, specially equipped with front-end loaders or pallet lifts, are quite useful in moving feed from storage to feeding sites. Also, in smaller facilities where manure disposal is not automated, such tractor operated equipment is highly useful.

Animal Transport Equipment Tractors equipped with stock trailers are useful for on-the-farm transport. However, if large numbers of animals are used and must be hauled from farm to market and vice versa, trucks or tractor-trailer trucks may be required. Special stock trailers are available.

Winch or Overhead Rail In research facilities, especially those in which cattle postmortem studies are made, chain hoists or electric winches and an overhead rail system from pens to necropsy and incinerator rooms are highly desirable and strongly recommended.

Sanitation Equipment Water hoses and nozzles, rubber squeegees, high-pressure cleaners and portable steam-cleaning machines, garbage cans, buckets, and brushes are essential items of equipment in a large-animal research facility. Unless all manure, dirt, and bedding are completely removed, efforts to disinfect following cleaning will be largely ineffective.

FIGURE 1 Metal metabolism crate for sheep (side A). (Courtesy of M. E. McCullough, University of Georgia Agricultural Experiment Stations)

Specialized Equipment

Metabolism Stalls There are numerous specialized areas of research that require specifically designed apparatus to obtain data. A metabolism stall is used to restrain individual animals and to enable the researcher to collect feces and urine and to measure feed intake quantitatively.

Numerous designs have been used for the construction of metabolism stalls. Construction materials include wood, galvanized pipes, stainless steel, and plastic-coated metal. For studies with trace minerals, plastic-coated metal is often used. Metabolism stalls are usually custom-built, but some may be obtained from commercial sources.*

Thorough information on methods employed in nutrition research has been written by Lindahl (1959) and Schneider (in press). Digestion equipment and metabolism stalls for ruminants have been described by numerous workers (Hobbs *et al.*, 1950; Bratzler, 1951; Erwin *et al.*, 1952; Gorski *et al.*, 1957).

Metal metabolism crates for sheep are illustrated in Figures 1, 2, and 3.

*The Clay Equipment Corporation, Cedar Falls, Iowa.

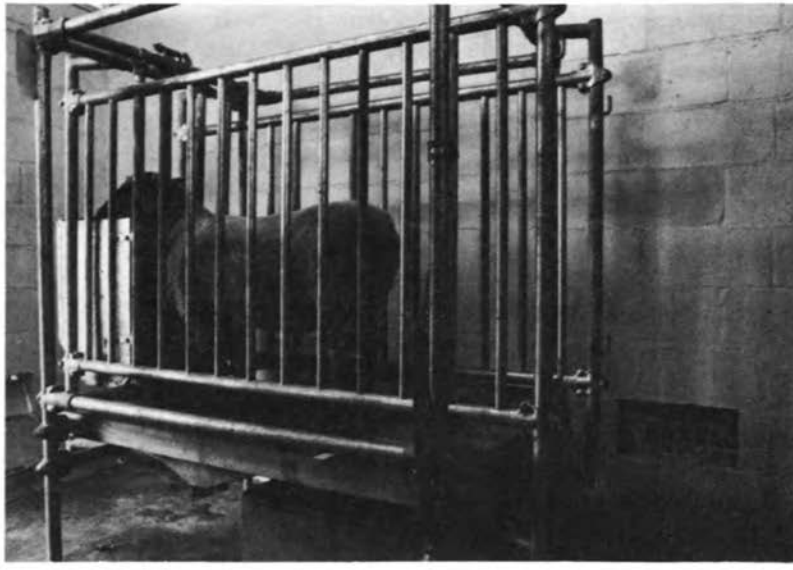

FIGURE 2 Metal metabolism crate for sheep (side B). (Courtesy of M. E. McCullough, University of Georgia Agricultural Experiment Stations)

A metabolism crate constructed of wood is illustrated in Figure 4. Crates constructed of angle iron or metal pipe have been modified for use with sheep and cattle because the animal is more visible. In all of these crates, the male animal is confined so that he cannot turn around, and the length of the crate is adjusted to the body size in such a way that the feces fall into a properly placed receptacle. Stalls or crates are of such length that the animal has little room to move backward or forward. They are usually set on legs from 0.5 m to 1 m (1.64–3.3 ft) high to permit the collection of feces and urine.

A metabolism stall for steers is illustrated in Figure 5. The standing part of the stall for steers should be 1.2 to 1.8 m (3.9–5.9 ft) long and 0.6 to 0.8 m (2–2.6 ft) wide. A feed box measuring 0.6 m (2 ft) may be added to the front and a feces box or gutter added to the rear, making a total unit 2.4 to 3 m (7.9–9.8 ft) long from front to rear. Wooden uprights of a stall of this type may be 102.08 mm (4 in.) thick, or if a more sturdy unit is required, pieces 51.04 X 152.12 mm (2 X 6 in.) may be used. The crate can be made portable by putting it on large casters or wheels (Schneider, in press).

The animal must have freedom of movement. Fatigue may result if the

stall is too confining, making it difficult for animals to lie down and stand up. Soreness and edema in the neck region may result when the animal is forced to press against the stanchion when lying in a prone position. These undesirable features must be eliminated in the design of any metabolism stall.

Mangers should be designed and constructed so that no feed is lost; this is essential for quantitative measurement of feed intake. Feed boxes fastened on the outside of the stall prevent wasting feed and the scattering of feed inside the stall, cage, or crate.

Adequate cleaning of the feed box is essential in a metabolism stall; therefore, the design, materials, and construction should be such that clean-

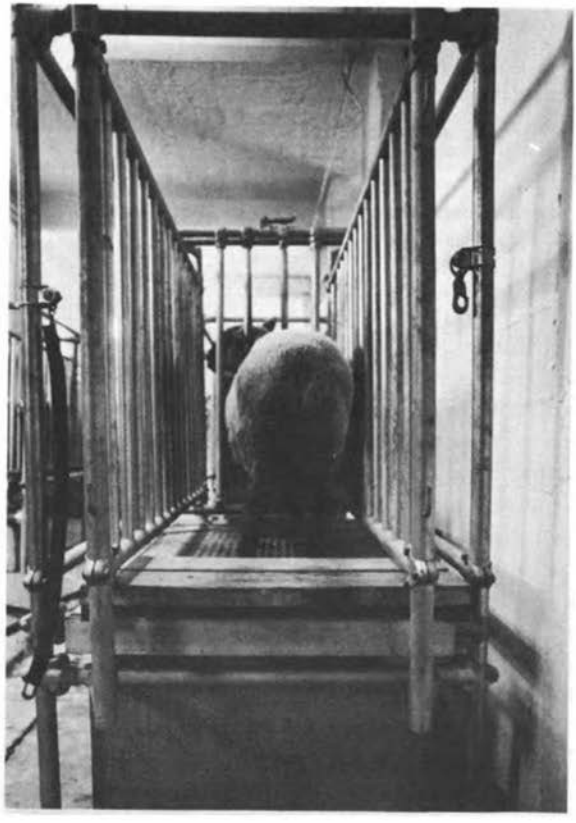

FIGURE 3 Metal metabolism crate for sheep (side C). (Courtesy of M. E. McCullough, University of Georgia Agricultural Experiment Stations)

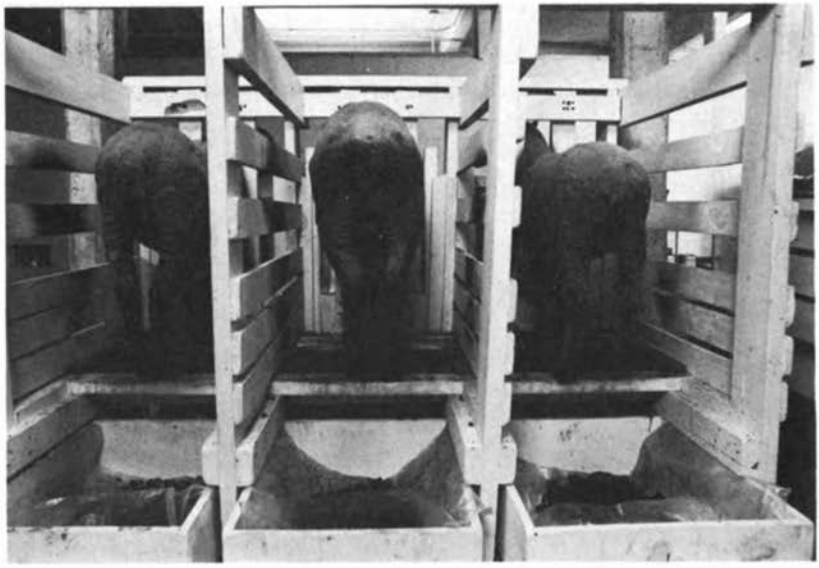

FIGURE 4 Wooden metabolism crate for sheep. (Courtesy of M. E. McCullough, University of Georgia Agricultural Experiment Stations)

ing can be facilitated. Feed boxes may be constructed of concrete, metal, wood, strong plastic, wood lined with metal, or with removable galvanized iron boxes placed inside. The bottom of each metal feed box should be made of one continuous piece of smooth sheet metal to eliminate joints or corners where feed may accumulate and make cleaning difficult.

Drinking water should be available at all times. The watering facilities should be constructed and located to minimize spillage of water into feed or vice versa. Automatic drinking fountains for cattle are recommended. A water tank for measuring consumption may be located near the metabolism stall. It may be connected to a water fountain with a leveling device to enable the animal to drink the water and permit refilling of the water fountain (Balch *et al.*, 1962).

Respiration Chambers Respiration chambers may be used for the measurement of complete energy balance of animals. A respiration chamber is an airtight enclosure large enough to enclose an animal and a metabolism cage such as those described previously. It enables the investigator to measure quantitatively the consumption of oxygen and the production of carbon dioxide and methane. It is also possible to collect feces and urine and mea-

sure quantitatively the feed and water intake during the time that the animal is enclosed in these airtight compartments.

There are basically two types of respiration chambers—open-circuit and closed-circuit systems (Figures 6 and 7); both these systems were described by Flatt (1969). Methods of calorimetry have been discussed by Brody (1945), Kleiber (1961), and Blaxter (1962).

Specialized Lamb-Rearing Pens The control of parasites in lambs can be achieved by rearing until weaning or finishing age in pens fitted with either wire mesh or wood slatted floors to prevent access to contact with feces. Small ewes can be housed in 1.22 X 1.22-m (4 X 4-ft) pens and large ewes

FIGURE 5 Metabolism stall for steers. (Courtesy of M. E. McCullough, University of Georgia Agricultural Experiment Stations)

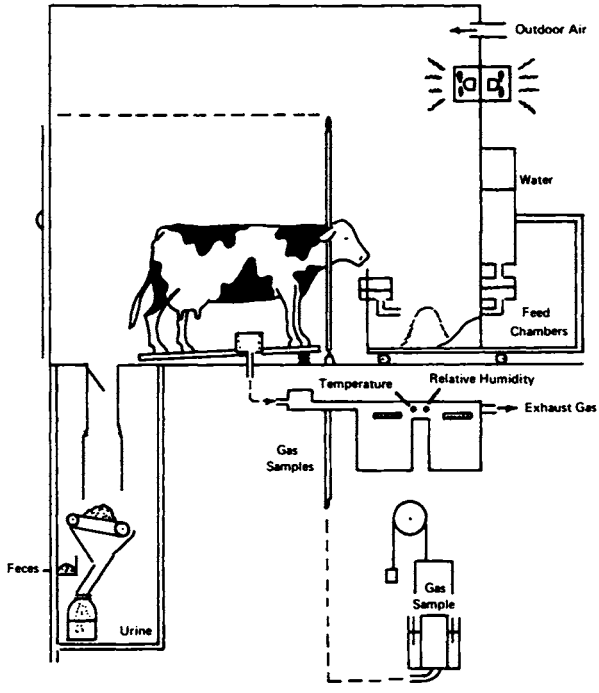

FIGURE 6 Example of an open circuit respiration chamber. (Courtesy of Sir David Cuthbertson, Royal Infirmary, Glasgow, *International Encyclopaedia of Food & Nutrition*, 1969, with permission from Pergamon Press Limited)

with two or more lambs require a pen at least 1.22 X 2.44 m (4 X 8 ft) for lambing and rearing. The floor of the pens is usually 0.61 to 0.92 m (2–3 ft) above the ground to allow for accumulation of manure between cleaning intervals.

Floors are constructed with either expanded metal or 50.8 X 50.8-mm (2 X 2-in.) lumber. If expanded metal is used, material 3.2-mm (1/8-in.) thick and 1.22 X 2.44-m (4 X 8-ft) sheets with flat rolled surfaces are fastened to 0.61- to 1.83-m (2–6-ft) wood frames. The frames are supported every 1.22 m (4 ft) to prevent sagging of the mesh. If lumber is used to construct slats, the lower edge of the slat should be beveled so that these will be 15.88 mm (5/8 in.) between the upper edges of the slats and 19.05 mm (3/4 in.) between the lower edges of the slats. This spacing will prevent manure buildup between slats. The slats should also be supported every 0.45 m (18 in.).

The sides of the rearing pen should be at least 0.75 m (30 in.) high. Feed and water containers should be attached to the outside of the pen.

Slatted or mesh floor rearing systems may also be used satisfactorily if the ewe and lambs are moved from the conventional lambing pen to the slatted or mesh floor within 4–5 days following lambing. Lambs are weaned at 60 days of age and finished in the pen. When reared under these conditions, practically all lambs will be free of internal parasites.

Specific-Pathogen-Free Ruminants Specific-pathogen-free (SPF) ruminants may be obtained by hysterectomy or cesarean section within 2 days prior to expected parturition. The gravid uterus is decontaminated in a germicidal bath, and the young are removed from the uterus in a decontaminated environment. The young are then transferred to isolation units where they are reared under conditions that preclude contamination with specific pathogenic organisms (Grace *et al.*; 1959; Sweat *et al.*, 1965). The equipment required for these procedures is an isolation unit with a decontamination tank attached, a transfer isolator or bag, and isolation pens. Temperature regulation can usually be satisfactorily attained by using a heating

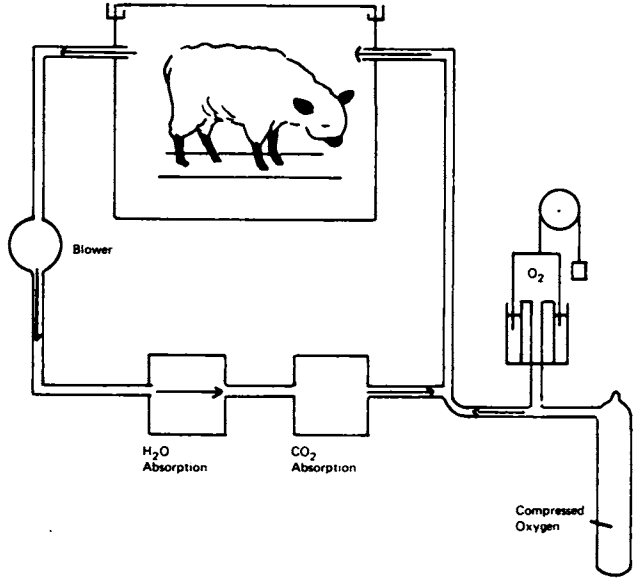

FIGURE 7 Example of a closed circuit respiration chamber. (Courtesy of Sir David Cuthbertson, Royal Infirmary, Glasgow, *International Encyclopaedia of Food & Nutrition*, 1969, with permission from Pergamon Press Limited)

lamp during the first days; room temperature is satisfactory thereafter. Dried milk or milk replacer formulas are available for each species. Investigators using animals for periods of 3 weeks or more should consider solid feed supplements.

Gnotobiotes The procurement and rearing of germfree or gnotobiotic ruminants have been described (Smith, 1961; Trexler, 1971; Oxenrider *et al.*, 1971). The germfree animal is obtained by hysterectomy as above or cesarean section. In the case of a cesarean section, a flexible vinyl isolator is adhered to the surgically prepared gravid female and the operation performed by making the necessary incision through the isolator and removing the fetus. The young are then passed into a sterile isolator and reared during the experimental period.

The isolators used to rear germfree ruminants are usually fabricated from a combination of flexible vinyl film, stainless steel, or molded fiberglass. The confinement pen may be a part of the isolator, or it may be contained within the isolator. All pen and isolator materials should be resistant to corrosion with 2 percent peracetic acid. The air supply is filtered through four layers of glass-wool mat, and exhaust air may be passed through a liquid trap, a glass-wool filter, or incinerated. Food and equipment may be passed through the double-door entrance chamber after appropriate sterilization. The rubber plastic gloves are affixed to the isolator wall to allow manipulations within the isolator.

Equipment Storage and Maintenance

Adequate storage space is essential. Items should be arranged neatly to allow easy access. Dirty equipment should be cleaned, and broken or damaged equipment repaired before being placed in storage. Inventory cards should be used to monitor stock levels. Operating instruction manuals and parts lists should be kept on file to ensure best use and to prolong usable life of the equipment.

III Procurement Considerations and Specifications

SOURCES OF ANIMALS

Since animals of given breeds, ages, or sizes may not be available from all vendors, the purpose and type of research are important factors in determining sources for ruminants. Research animals may be obtained from any breeder, producer, market, or dealer whose reliability is proven. In most cases, it is important that personal contacts be made with the supplier to determine his ability to furnish animals of the kind(s) and quantities required on the schedules dictated by research needs. Personal inspections of the animals may be desirable. For complex studies requiring a variety of animal types or a single type of animal in large numbers, it may be necessary to deal with several suppliers. In most cases, fewer disease hazards will be encountered if animals are purchased directly from the farm or ranch where they are produced, instead of obtaining animals from public markets or from dealers who may have mixed animals from several original sources. A basic requirement for all suppliers is to furnish animals of known health status. Developing contracts with producers–suppliers are sometimes difficult. The state extension livestock specialists can generally furnish a potential list of such suppliers.

Genetic Background

Genetically diverse types of ruminants are available. Examples are beef and dairy cattle, fine- and coarse-wool sheep and dairy and mohair-producing goats. For most research, it is important that a genetic type or types appropriate to the specific research be acquired.

For some research, genetic uniformity may be desirable. In the great majority of cases, however, a known and controlled array of genetically

different types is preferable so that general applicability of results to the species as a whole or to a particular type within the species can be determined.

Highly inbred lines of ruminants have not been generally developed and are thus not available for research use. A limited number of lines with inbreeding coefficients up to 40-60 percent have been developed in a few breeds by the USDA and state agricultural experiment stations. These are not generally available for purchase, but limited numbers can sometimes be acquired or used cooperatively in special studies under special arrangement with the institution maintaining the line. No formal catalog of these partially inbred lines is available. However, personnel of the USDA (Beltsville Station) will usually be able to furnish information on existing lines.

For most animals, whether acquired directly from the producer or through an intermediary dealer, sources are from either purebred or grade herds.

Purebred Herds Breeders strive to maintain the animals in these herds to improve the commercial usefulness of the breed to which they belong. Records of ancestry are maintained by the breeder and by the breed association. Thus, lineage of any animal is known or can be established. Further, individual performance records of individual animals or their ancestors are sometimes available as an aid in determining suitability for a particular research effort. Often, although by no means universally, standards of management and disease and parasite control programs are higher in purebred herds than in herds of commercial producers. Against the foregoing advantages are the facts that the numbers of animals of a specific age or sex may be limited in some areas and at given times and that purebred animals have an intrinsic value for breeding purposes beyond that of commercial types. Thus, costs are higher and may represent a needless extra expense if commercial animals would serve needs of the given research as well.

Commercial Herds These herds are maintained for production of food or fiber. Animals can be purebred, grade, or crossbred. Herds vary greatly in the amount of information available on ancestry and breed composition.

Animals from these herds are usually available for research use at commercial prices. Commercial herds vary not only in size but also in supplying groups of uniform age and sex large enough to meet needs at a given time. They also vary in level of management, disease, and parasite control.

Specialized Suppliers Most ruminants available for research purposes are types with commercial usefulness for production of food and fiber. An

exception to this is the pygmy goat produced for research purposes to provide a small ruminant to minimize feed costs and facility expenses. When lambs or kids are required in large quantities, the purchaser may have to resort to western sources. Pregnant animals with known breeding dates are available.

Health Status

The current health status and history of disease must be known to properly evaluate the suitability of animals for research use. The genetic constitution of an animal may play a vital role in a particular research project; however, meaningful and reproducible results can be obtained only when normal, healthy subjects are used.

The past history of disease and genetic background of animals purchased at a livestock auction barn are extremely difficult to determine without extensive tracing procedures. Lots offered for sale are likely to be comprised of animals from several sources. While a quarantine period is recommended for all animals obtained from healthy herds or flocks, it becomes especially important when purchased from livestock auctions. The regular user of cattle, sheep, and goats will have the most optimum control of the factors of health status and genetic background if producer-supplier herds or flocks are chosen as a continuous source of supply.

The health status of a potential supply herd or flock can be determined in several ways:

- Clinical examination of the supplier's herd or flock and of all animals offered for sale.
- With the permission of the supplier, consultation with the veterinary practitioner employed to conduct the supplier's routine herd or flock health program.
- Consultation with state and federal animal disease control officials who can render valuable background information on a supplier's herd, as well as the disease status of other herds in the area.

Full compliance with state and federal health requirements governing movement of livestock is required. Health requirements that govern the admission of livestock and poultry into each state are set forth in state and federal health requirements. The researcher should become familiar with the health requirements for cattle, sheep, and goats for the state of origin of the ruminants as well as for his own state. The Interstate Health Certificate certifies a negative status for brucellosis and tuberculosis in cattle and goats. Freedom from scabies is also required for cattle, sheep,

and goats. The Interstate Health Certificate also states that the animals have been examined by an accredited veterinarian and are found to be free from the symptoms of an infectious, contagious, or communicable disease or exposure thereto.

The following considerations should be included in procurement specifications for all animals:

- Degree of isolation of the supplier's herd from other herds
- Medical history and laboratory tests
- Vaccination history
- Shipping arrangements or requirements to be met
- Nutritional history or status
- Weighing conditions and payment procedures

Nutritional History

Details of the nutritional history of all animals are desirable. This should include not only the feeding program at the time the animals are supplied but also—insofar as possible—the salient features of the entire program from birth. If the supplier's herd is seen, this information can be supplemented with direct evaluation of the herd and by an appraisal of the dietary regimen.

In the case of young animals, the colostrum, milk or milk replacer, and starter feeding schedules should be noted. Types of feed additives (such as antibiotics and hormones), level of feeding, and period of feeding should be indicated. Dates, months, and amounts of hormone administration should be ascertained. Information on the use of treatments for the control of parasites should be provided.

FEED AND BEDDING

The following should be considered in drafting feed procurement specifications:

- Quality, quantity, and composition
- Palatability and physical form
- Additives and contaminants
- Availability of bulk components to manufacturers
- Feed analysis (ingredients and date of mixing and proximate analysis)
- Delivery requirements (including packaging and pre-delivery storage)
- Payment procedures

Feeds

Since the feed requirements of ruminants, particularly cattle, are substantial, bulk delivery of feed should be considered whenever practical. This procedure can reduce initial cost, as well as labor involved in feed handling. Bulk feeds can be transferred from delivery truck to storage bins, from which they can be delivered either into feed carts, directly to the mangers, or to other feed containers. Where bulk delivery and storage are impractical, the feed should be delivered in paper, cloth, or burlap bags that are new and of good quality. Each bag should have a tag attached to indicate proximate analysis, ingredients, and date of mixing.

Pelleted feeds reduce handling and feeding labor, storage space, and waste. Dust produced in feeding is lessened and the animal has little opportunity to select preferred diet ingredients. Complete feeds (all ingredients mixed together) are more easily handled, usually reduce labor requirements, and ensure a more uniform feed intake when finely ground and pelleted and fed in limited amounts. The physical nature of such feeds (sometimes when accompanied by a low fiber level) has resulted in certain problems in ruminants such as rumen parakeratosis, abnormal appetites, wool chewing, depressed rumination, bloat, and depressed fat percentage in lactating animals. The incidence of these problems can be reduced if supplemental roughage such as hay is provided. Whether any of these problems occurs will depend on the ingredients used to formulate the ration, the fineness of the grind of the fibrous ingredients, and the processing methods. Under usual conditions, roughage such as hay or silage is included in the ration. Coarsely ground or chopped hay or silage can be incorporated into a complete feed at or near the animal quarters. Because of its high moisture content, silage must be fed soon after its removal from the silo to avoid rapid spoilage. The moisture content of any stored feed, except silage, must be maintained at a level sufficiently low to prevent deterioration.

In calculating the specific diet amount needed by the animal, the moisture content must be considered. Many feeding recommendations and feed analyses are now stated on a dry-matter basis.

An adequate supply of clean, fresh water must be provided. Salt (NaCl) is also needed. Often it is added to the concentrate mixture at levels of about 0.5–1.0 percent and it can be made available in granular or block form. Other mineral and vitamin supplementation will depend on the composition of the rations. Feed requirements and specific nutrient needs have been specified (Committee on Animal Nutrition, 1968, 1971a, 1971b).

Requirements for goats can be estimated from recommendations for

dairy cattle and by consulting other publications (Canada Department of Agriculture, 1957; Rogers *et al.*, 1969).

Bedding

In many situations, bedding should be provided for cleanliness and comfort of the animals (see Chapter 4, p. 45). Straw, ground corn cobs, and wood shavings are common materials used for this purpose. Rubber mats manufactured especially for this purpose sometimes are a desirable alternative and are commercially available.

SHIPPING

Quality research animals can be obtained if detailed procurement specifications are applied and followed in their selection at point of origin. Unless equal consideration is given to conditions to which animals may be subjected during the transport period, any benefits obtained by rigid selection criteria can largely be lost. Transportation can subject animals to a wide variety of adverse conditions. Every effort should be made by both the shipper and trucker to minimize or eliminate potential hazards to ensure that animals arrive in the best possible physical condition.

Vehicles previously used to transport other animals may expose susceptible animals to pathogens and result in the introduction of disease into the research unit. The certification of cleaning and disinfection of the transport vehicle may be made part of contract provisions. The requirement for cleaning and disinfection of any vehicle used to transport animals will add to the cost of shipment. However, this is a minor cost compared to disease inadvertently introduced due to inadequately disinfected vehicles.

Every effort should be made to minimize stress imposed on animals during transportation, including the avoidance of excessively long hauls. Overcrowding is a major problem and is often practiced to reduce animal transport costs by utilizing all available space within the vehicle, resulting in many injuries and deaths from heat exhaustion, suffocation, and trampling. The effects of overcrowding are increased when the animals are exposed to high temperatures and poor air circulation within the vehicle, particularly when it is not in motion. Sheep are especially vulnerable to the above conditions.

The use of divider panels within the vehicle will reduce many injuries by preventing the intermingling of animals of different sizes and weights. Panels also prevent shifting of groups should the vehicle make a sudden stop. The driver should make every attempt to drive at a constant speed

and avoid jerks or sudden stops. Liberal sanding of the floor will provide good footing and also assist an animal to regain its footing if it should fall.

During cold weather, the animals should be furnished with bedding. Bedding conserves body heat and aids in keeping animals dry.

Space to be allotted to the various species of animals will be determined by their size and weight. Sufficient standing room should be available within the vehicle to enable the animal to make normal postural adjustment.

IV Management and Laboratory Procedures

GENERAL CONSIDERATIONS

Quarantine

Quarantine is the segregation of newly received animals from those already on the premises. Newly received animals should be quarantined until their health status has been determined. The duration of quarantine will depend on the reliability of the supplier and an objective assessment or judgment of the animals' health. Since transportation, change of diet, and change of physical surroundings can be stressful, thus lowering an animal's normal level of resistance to disease, a period of adjustment allowing for observation of signs of disease may be indicated. Since most infectious diseases have incubation periods of less than 2 weeks before clinical signs are observed, 14 days has been accepted by many as a reasonable minimum observation period.

Animals should be inspected upon arrival. Those in poor or questionable health should either be rejected or be provided with separate housing and placed in the care of the veterinarian responsible for disease control. A conditioning program should be conducted during the quarantine period that may entail physical examination, clinical and laboratory tests for communicable diseases, veterinary care and treatment of external and internal parasites and any other necessary prophylactic and therapeutic measures, immunizations that are required to protect against communicable diseases, and adaptation to the proposed experimental diet, including supplementation necessary to meet nutritional requirements.

Preferably, caretaker personnel assigned to the quarantine area should not attend other animals or visit other research areas. All handling, feeding, watering, and cleaning equipment used in the quarantine area should remain exclusively in that area. Where such rigid procedures are not practical, special precautions, such as change of footwear and clothing, equip-

ment decontamination, and scheduling of servicing in these areas, should be taken to prevent disease dissemination.

Sanitation

The facility should be kept clean and a regular schedule of sanitation carried out. All facilities should undergo a regular physical cleaning to prevent the accumulation of dirt, debris, and resident contamination. (Special procedures must be used to deal with radioactive, toxic, and certain infectious materials.) Where feasible, detergents should be used for cleaning, followed by sanitization with an effective disinfectant appropriate to the type of construction. Sweeping should be avoided because of the production of aerosols.

If bedding is used, the area should be cleaned frequently. Soiled bedding should either be placed in closed containers or removed from the building periodically. If manure is permitted to accumulate, the area should be bedded in a manner that will keep the animals dry. Approaches to the pen, or pens lacking bedding, should have a rough surface to provide good footing for the animals and should be capable of being cleaned.

The feed supply should be kept clean, and the feed bunks and waterers should also be cleaned and sanitized. Pens, pails, nipple buckets, bottles, and automated feeders used for feeding milk or similar formulas should be cleaned and sanitized after each use. Scrubbing these utensils with detergents or chemical disinfectants is recommended.

The maintenance of lactating animals may require certain specialized equipment. If surplus milk is to be sold through commercial channels, an area of sufficient size should be provided in which the cooling, handling, and storing of milk, as well as the washing, sanitizing, and storing of milk containers and utensils can be conducted. A wash vat with two compartments (for washing and sanitization) of sufficient size to accommodate the largest utensils used and adequate hot-water facilities are desirable. Larger installations involving pipeline systems for collection and transport of milk must conform to local and state requirements for the production of market milk. Waste cans should be washed each time they are emptied. Personnel should wear appropriate clothing, including footwear that can be readily disinfected. Highly infectious waste and materials should be sterilized before disposal.

Decontamination

Selection of a decontamination procedure should include the consideration of effects on the animal and research, as well as the surface and ma-

terial to be decontaminated. An ideal disinfectant must have a broad germicidal spectrum, be stable, and not deteriorate in the presence of organic matter. The disinfectant should be soluble or emulsifiable, noncorrosive, and it should not bleach, rot, or stain fabrics. It should be harmless to humans and animals. No *single* disinfectant meets the aforementioned criteria; therefore, selection should be made from several so that the most criteria are met.

Some of the more commonly used disinfectants are:

- *Hot water* removes organic matter and disinfects but does not kill spore-forming organisms. Steam is effective only in a closed container where the flowing steam is maintained near the boiling point, and the steaming process must continue for 1 hour. In the presence of a detergent, such cleansing and disinfecting does an adequate job for most surfaces, including feeding and milking equipment.
- *Sodium carbonate* (washing soda) is usually used in a 4 percent solution and is readily effective for cleansing and decontaminating when used in a hot solution.
- *Sodium hydroxide*, also known as household lye, is used in 2 percent concentrations and is an inexpensive, widely available compound. It has been found to be effective against most of the common bacterial pathogens.

Since lye is caustic, it must be used with caution. Persons applying lye solutions should protect their eyes and wear rubber boots, gloves, and clothing. Lye will damage painted surfaces if allowed to remain for prolonged periods. However, bare wood and most metals—with the exception of aluminum and galvanized steel—are not affected.

Lye is dispensed in solution as 13 oz to 5 gal of water. It is advisable to have an acid solution, such as vinegar, available to neutralize any sodium hydroxide that may come in contact with body surfaces.

- *Calcium hydroxide* (slaked lime) is irritating and caustic, although less so than sodium and potassium hydrate. Its disinfecting action is due to the alkaline pH. Whitewash is composed of a mixture of 17.3 kg (38 lb) of slaked lime and 6.8 kg (15 lb) of salt dissolved in sufficient water to yield a paint of a consistency that can readily be applied with a brush or sprayer. This material is usually applied to wooden walls. The addition of 4 percent soapy cresol or 0.5 kg (1 lb) lye to 2.3 kg (5 lb) lime improves the disinfection quality of lime.

Commercial whitewash preparations containing insecticides are also available. Often, this form of lime is used to cover dead animals before burying to prevent spread of disease by scavenger animals. Where there is a problem of foot rot in animals moving in from wet, muddy fields, the mixture of lime and 5 percent copper sulfate is a useful foot dust.

- *Chlorinated lime* in a 20 percent solution is used mainly to sanitize and deodorize. The powder is irritating to nose and throat.
- *Cresol* (lysol), a phenolic compound, is effective at 2–4 percent solutions (about 1 cup to 2 gal of water to make a 4 percent solution). It is useful for washing and disinfecting pens, barns, and other buildings. Its stability makes it useful for foot baths and cleaning of trucks, especially following studies of brucellosis, shipping fever, or tuberculosis. Cresol may be used to disinfect instruments.
- *Quaternary ammonium compounds*, cationic detergent disinfectants, are effective against many disease organisms including bacteria and fungi but have limited activity against most viruses and spores. Their antimicrobial action is enhanced by surface cleaning resulting from detergent properties. Quaternary ammonium compounds are not entirely nontoxic, and high concentrations will cause severe irritation and even death when taken internally.
- *Chlorine and iodine* disinfection effectiveness is dependent on the acidity of water and the temperature at which it is used. Chlorine is more active in acid water than in alkaline. There are different forms of chlorine. Sodium hypochlorite is active as a disinfectant but has little residual bactericidal action. In contrast, calcium hypochlorite acts more slowly and disinfection properties persist. Chlorine compounds are irritating to the skin and are corrosive to metal. They should not be used on steel for long contact periods and, if left in contact with aluminum chlorine, compounds will cause pitting.
- *Formaldehyde gas* disinfecting properties are dependent on a humidity of 75 percent or greater. The gas has little penetrating power and is immediately dissipated on surfaces of walls and fomites. It is irritating and pungent. High temperatures enhance the disinfecting action of this gas.
- *Ethylene oxide gas* is highly active and will penetrate porous surfaces without loss of its disinfecting power. However, it is explosive and care should be exercised when it is used. Specialized equipment and formulations are available that increase its usefulness and decrease the explosive hazard. The expense of such equipment makes it generally less useful except for decontaminating expensive articles that will not withstand sterilization by more conventional methods.
- *Propylene oxide gas* is less effective than ethylene oxide gas. It is not explosive. It is more active than formaldehyde in penetrating porous surfaces.

Disease Prevention

Many infectious and parasitic disease agents can be transmitted by fomites; therefore, introduction of materials or equipment from other areas into re-

search animal holding, feed, or equipment storage areas should be minimized or prevented. Visitation by personnel other than those directly involved with the care and use of experimental animals should be minimized and carefully controlled. Where indicated, visitors should be provided protective clothing and footwear and be properly escorted. Animal care and research personnel should carefully observe the personal hygiene procedures discussed below.

Similarly, wild birds, rodents, dogs, cats, insects, and other animals should be kept out of research animal holding areas and food and equipment storage areas, if practicable. Rodent control by trapping and baiting and insect control by spraying, baiting, and dusting should be vigorously pursued.

If a transmissible disease other than one induced in the experiment is diagnosed, all animals should be quarantined and consideration given to the elimination of the affected and exposed animals from the test. The area from which these animals have been eliminated should be cleaned and decontaminated using appropriate detergents and disinfectants. Where indicated, appropriate immunizations should be administered to all animals held in the unit.

Organs and Tissues

Occasionally, it may be desirable to market large domestic animals that have been used in research and to obtain their organs and tissues at slaughter to complete the study. Researchers should be aware that a USDA permit is required to remove inedible animal organs or tissues from a federally inspected slaughtering establishment. Permits can be obtained from the Meat and Poultry Inspection Program Area Supervisor where the slaughtering establishment is located. A permit is not required for edible materials such as kidneys and livers.

Vermin Control

Vermin (wild birds, cockroaches, grain-infesting insects, flies, and rodents) constitute a hazard to animal health. A control program is essential (Mallis, 1964). A year-round rodent control program should be conducted by using bait stations and removing outside shelter or hiding places. The area surrounding the facility should be free of excess waste materials. Grain storage areas should be rodent proof to deny rodents a food source, thus driving them to bait stations.

A pest control program initiated before buildings are occupied is essential. Breeding sites for insect pests should be eliminated. Every pesticide

application program should be carefully evaluated before implementation to ensure that the pesticide at the recommended rate and frequency of application will not have an adverse effect on the animals placed on experiment.

Fumigation can be used in buildings and in feed and bedding storage areas to destroy vermin. Electrified screens have been used at the entrances to indoor housing units, as well as air curtains or blowers that act as a barrier to the entrance of insects.

Personal Hygiene

A high standard of personal cleanliness must be maintained and facilities provided so that this can be accomplished. Special clothing and footwear, head covering, face masks, and other materials should be provided for specific experiments or as needed and should be regularly laundered and kept in good condition. Clothing should be changed daily or as often as needed to prevent the spread of disease and to maintain a clean and neat appearance. Street clothing should be stored in locker rooms. Toilet facilities and showers with towels and soap or disinfectant soap, as appropriate, should be provided.

Personnel should have a physical examination prior to employment. They should receive appropriate inoculations and vaccinations for tetanus and, depending upon the nature of the work, for other disease entities. Diagnostic tests for tuberculosis and brucellosis are recommended.

In situations where employees are exposed or may be exposed to zoonoses, specific and detailed instruction should be given all employees on the dangers and methods of prevention of infection.

IDENTIFICATION MARKINGS

Individual identification of experimental animals, whether in breeding herds or in laboratory situations, is essential.

Temporary Identification

Marking Crayons These are especially useful in temporarily sorting animals into various treatment groups, using either different colors or a different location for the mark.

Ear Tags Plastic and metal ear tags of many sorts are available from livestock supply houses. All tags require some type of plier or pincer to attach the tags to the ear. The pliers or pincers must be designed for the specific

tags used. Several commercially available, flexible, one-piece tags seem satisfactory. Most can be obtained either blank or pre-numbered.

Clipping Hair or Wool Different areas of the body can be clipped to identify animals for short-term studies.

Paper Tags Such tags with glue or other adhesive on one side can be applied to cattle, but these are not satisfactory on sheep. Ordinary sale-barn tags are economical and readily available. However, they are effective for only a few days.

Paint Brands Nonpermanent paints are available that can be used to spot-brand cattle or sheep for sorting. Number brands can be applied with regular branding irons or with numbers fashioned out of No. 9 smooth wire. These numbers should be applied away from the animal's tail, preferably high on the sides of the rump or in the loin region to prevent the numbers from being rubbed off before drying and so they can be easily read when the animals are crowded.

Neck Chains Removable neck chains with plastic or copper numbered plates for cattle and goats are easily applied. They have the disadvantages, however, of being easily lost and may be dangerous to the animal, in that the neck chain may get caught and suffocate the animal. Also, adjustments of the neck chains are often necessary.

Permanent Identification

Hot Iron Branding Such brands are used both for legal establishment of ownership and for numbering cattle. Copper or steel irons, which are heated either by fire or electricity, are applied at various locations on the body but preferably on the upper hind quarters for easy reading. Brands should be at least 101.6 mm (4 in.) high and the iron should be not less than 12.7 mm (0.5 in.) thick. Numbers should not be applied to cattle that weigh less than about 182 kg (400 lb), but ownership brands can be applied earlier. When buying hot-iron-branded cattle in a state with brand inspection laws, permits must be obtained to move such cattle off a farm or ranch, even when disposing of them.

Tattoo Permanent ink tattoo numbers or letters can be placed in ears, sheep flanks, or under the tails of goats. Black ink will work on all but black-skinned animals, in which case green ink is more satisfactory.

Ear Marking Various ear cropping and notching systems are used as an ownership identification or to divide the sexes, but such systems are not satisfactory for individual identification.

Freeze Branding A painless method of branding a smoothly clipped area of skin with copper irons chilled in dry ice and alcohol to -70.0 °C (-158 °F) destroys the pigmentation hair cells in the skin. Freeze branding works well for permanently numbering pigmented cattle when performed by an experienced person. Time of application is critical and will vary with animal age, breed, and season. Such brands are not considered legal in establishing ownership in states with brand inspection laws. At least 2-3 months is required for the nonpigmented or white hairs to grow in after branding. Such brands are not satisfactory for sheep, goats, or white-haired cattle.

BREEDING AND MATING SYSTEMS

General Statements

Cattle Young heifers reach sexual maturity at an average age of 12-14 months, although some may begin cycling as early as 6 months of age. Large breeds such as some of the European exotic breeds and those with Zebu breeding tend to develop more slowly and may not begin cycling until they are over 24 months. Plane of nutrition during development can influence sexual maturity. Normally, heifers of most breeds should weigh about 272 kg (600 lb) before they are bred. Pastures or rations fed in drylot should contain enough protein and energy to promote some gain in weight during the breeding season. This "flushing" effect will ensure earlier cycling and higher conception rates. Lactating cows normally begin cycling in 8-10 weeks after calving and because of the approximate 9-month gestation period, cows should be rebred to ensure a 12-month calving interval. Young bulls can service a few cows at 12-15 months, but such bulls should not be expected to serve over 15 cows in a 75-day breeding season. More mature bulls can serve 35-50 cows per season.

Artificial insemination can be successfully used in either dairy or beef cows. Estrous detection requires skill and close attention. Use of marker devices on either cows or bulls or a vasectomized male will facilitate detection. The estrous cycle is approximately 3 weeks in length and estrus itself averages about 18 hours. Ovulation occurs about 15 hours after cessation of estrus. Cows will stand for natural service only for 1 day, but since ovulation occurs after estrus, artificial insemination can be delayed until the morning after the onset of estrus. Highest conception occurs from two

services, one insemination late in the day of estrus and the second the following morning.

Sheep Well-fed ewe lambs that are born in the spring are usually sexually mature and will show estrus during the first fall. Ram lambs are also fertile by fall and can breed a few ewes, whereas mature rams can breed from 35 to 50 ewes. There are breed or type differences regarding this trait, with the fine-wool sheep being slower to develop. Since most sheep of this type are found in areas where the plane of nutrition is often suboptimal, the tendency to develop more slowly could be overcome by supplemental feeding.

Conception rate in sheep is generally higher if flock mating is practiced, as contrasted to hand mating. Heat detection is possible by using color-marking harnesses on rams or vasectomized males. The estrous cycle averages 17 days with estrus itself lasting for 1–2 days. Ovulation occurs near the end of estrus and the gestation period is about 5 months or slightly less. If experimental lambs of a certain age are desired throughout the year, only those breeds such as either the Dorset or the fine-wool type of sheep should be used. These tend to breed over a longer period than other breeds that are seasonally polyestrous and breed in fall and winter to lamb in spring.

Fall-shearing of rams is a recommended practice to ensure a high conception rate. Excessive weight or high condition in rams is sometimes detrimental to high conception rate.

Lambing paralysis or pregnancy disease (ketosis) is a problem in sheep and especially in flocks maintained for experimental purposes. The cause is a disturbed metabolism near the end of gestation. It can normally be controlled by reducing the roughage portion of the diet a few weeks prior to parturition and substituting a high-energy carbohydrate source such as corn. In place of roughage, 170 to 340 g (6–12 oz) of grain plus forced exercise will generally reduce this problem to a minimum. The problem is similar to the same condition often noticed in heavy-milking dairy cows and dairy goats.

Goats The reproductive process in goats is similar to that in sheep, although goats have slightly longer estrus and gestation periods and seem to be more variable in this respect. Management practices should take this latter point into account. Few goats are bred as yearlings even though they sexually mature early enough to do so. Like most mutton breeds of sheep, goats are fall-season breeders.

One special problem with Angora goats is that they must be protected

from cold rainstorms or snow for a few weeks after shearing. Simple, open-front sheds will accomplish this purpose.

Care of the Newborn and Neonate

At birth of young, experimental females of all ruminant species need individual attention on a 24-hour basis. In some studies, such as cases wherein the treatments may affect reproduction, judgment must be used as to how much assistance should be applied. The necessity of assistance during birth will be minimal but since experimental numbers are usually small and the expense incurred up to this time will be large, living offspring are essential. The avoidance of extremely heavy or large males as sires can reduce dystocia or birth difficulties, especially when experimental treatments may impose stress or when young females have not developed at an optimal rate.

Under most ordinary circumstances, beef calves are weaned at 6–8 months of age, but beef calves can be early weaned from their dams at 1–3 days as can dairy calves. In these circumstances, calves usually are provided whole milk or milk replacer for 4–8 weeks, fed from pails or other containers, some of which are equipped with nipples. A starter (dry concentrate) comprised principally of grains and protein supplement should be offered from the first week after birth. This, plus limited feeding of milk replacers, encourages early development of ruminoreticular function and the transition to the ruminating state.

Lambs and Angora kids normally nurse their dams for 3–5 months, although they can be early weaned just as calves. Milk goat kids are normally handled the same as dairy calves, i.e., they are not nursed by their dams.

It is generally more desirable to remove the young from their mothers abruptly, rather than over a period of days. The mother stops pining and fretting sooner and fewer udder problems result. Removal of excessive milk accumulation by hand milking may be indicated in very heavy-milking beef breed cows or ewes; however, it is seldom required. Dairy cows and goats normally are milked after their young are removed.

Necessity of Colostrum for Newborn

Except where the experimental procedure dictates that the young receive no colostrum, all young ruminants should receive colostrum, with its protective antibodies and special nutrients, by nursing the dam or by hand feeding for at least 1 day after birth. Should the mother be lost at birth,

colostrum from another dam will usually serve as well. Excess colostrum can be stored in the frozen state for emergency use. If no colostrum is available, young animals can sometimes be saved by the addition of suitable antibiotics and vitamins to their milk.

Care of Dam at Parturition

Ketosis and parturient paresis or "milk fever" in heavy-milking dairy cows and lambing paralysis or pregnancy disease in sheep are problems that require special attention and consideration at the time of parturition. Space in this publication is too limited for a complete discussion of the subject, but researchers should be aware of the potential problem and consult with persons informed on the subject.

Buying Pregnant Females

Reproductive diseases and uncertainty of pregnancy are the two problems most often encountered in buying or acquiring pregnant females. Ordinarily, if health papers certified by a veterinarian accompany the purchased females, one can be reasonably certain that disease will not be a problem. Sometimes the tests applied do not cover the complete spectrum of possible diseases, and this should be taken into account. The diseases of most concern are brucellosis, leptospirosis, vibriosis, and Johne's disease (especially in goats).

Pregnancy in cattle can be confirmed with reasonable accuracy 2 months after breeding or later by a person experienced in rectal palpation. Confirmation of early pregnancy in sheep or goats is more difficult and guarantees of pregnancy are ordinarily not made by suppliers of sheep.

Much time can be saved in certain studies by purchasing bred or pregnant females but uncertainty of parentage, uneven birth dates, and the possibility of buying open or unbred females make this procedure a questionable one for most laboratories. The extreme danger of introducing disease is an added consideration. Most bred females for sale through commercial channels will be relatively old and will have a short productive life ahead of them.

Size and Facilities for Housing Newborn

Cows and ewes or does used in nutrition or disease studies in which individual feeding or treatment is indicated should be provided an individual pen or stall, at least for a few days before and after parturition. A 3.05 X 3.05-m (10 X 10-ft) box stall for each cow and a 1.22 X 1.83-m

(4 X 6-ft) pen for each ewe and doe provides adequate space. These may be built in permanent form or with portable panels. Such individual penning assures closer attention to the feeding program and at parturition and reduces the chances of the mother not claiming and nursing her young. The attendant can also save time if parturition occurs in nearby quarters, which facilitates checking females in the normal off-work hours.

Foot Care

Ordinarily, feeder animals to be used in experiments less than 1 year will not require foot trimming. However, infectious foot rot can be a problem in animals in muddy lots and should not go unattended if it occurs. Sheep and goats require foot trimming three to four times yearly, even when housed on concrete. Cattle housed on concrete require very little trimming. Long toes of cattle should be cut back to normal lengths by removing the excess growth from the underside of the foot and the dewclaws should be clipped. Some type of restraining table or chute needs to be provided to work with cattle. Injury to both cattle and attendants is a possibility unless prior planning for such work is done and unless some type of restraining equipment is provided. Throwing cattle for foot trimming is possible but generally not recommended for valuable experimental animals, especially for cows and bulls because of the possibility of serious injury. Sheep and goat feet are easily trimmed with a pocket knife, pruning shears, or foot-rot shears while the animals are held in a sitting position or fastened in a trough on their back or side.

FEEDING MATURE RUMINANTS

The ingredients and nutrient composition of rations for ruminants vary widely, depending on cost and availability of ingredients, age, rate of growth, pregnancy, lactation, and physical activity. Usually, the most economical ration can be formulated from locally available roughages and grains, with appropriate supplements. The composition of the supplement must be adapted to the available roughages and grains; thus, no standard supplement for all situations can be recommended (see Chapter 3, p. 41). The National Research Council publications give specific recommendations for nutrient requirements of the mature ruminant. For example, the 1971 Committee on Animal Nutrition publication *Nutrient Requirements of Dairy Cattle* includes the following information:

- Maintenance requirements of mature breeding bulls
- Maintenance requirements of mature lactating cows

- Milk production requirements, in addition to maintenance and pregnancy
- Recommended nutrient content of rations of lactating cows, dry cows, and mature bulls, in units per kilogram of dry ration
- Composition of feeds commonly used in dairy rations
- Examples of formulated rations for high producing lactating cows, listing amounts of specific ingredients. Somewhat similar information is also provided in the publications *Nutrient Requirements of Beef Cattle* and *Nutrient Requirements of Sheep* of the Committee on Animal Nutrition, National Research Council.

The requirements for reproduction are not extensive, except during the last 2 months of gestation in cattle and during approximately the last 5–6 weeks in sheep and goats. Even then, however, the increased requirements are relatively small in comparison to the needs during heavy lactation. For example, the energy needs of a high-producing dairy cow can be four to five times the maintenance (nonpregnant, nonlactating) requirements, whereas total requirements during the last 2 months of gestation are only about one third greater than maintenance needs. During high milk production, it is almost impossible for the cow to consume feed in excess of her energy needs. When the ruminant is not lactating or is lactating at a low level, the ration must be restricted to prevent overfattening (unless fattening is the objective). Thus, the nature of the most appropriate ration varies greatly with the level of lactation and other physiological conditions. Also, there are many acceptable feed combinations and the availability and cost of ingredients varies greatly for various geographic locations. Consequently, recommended rations for the anticipated conditions should be requested from the state's animal science department where the laboratory is located (or from a neighboring state). This will permit consideration of the most appropriate feed combinations for that locality and for the specific type of experimental conditions involved. Most agricultural experiment stations have bulletins or other publications that contain recommended formula rations for various types of animals under various conditions.

Although group feeding of mature ruminants sometimes is appropriate, under many experimental circumstances, provision for individual feeding is needed. This permits measurement (and control) of feed intake, which sometimes is necessary and provides a means of more closely tailoring the diet to the needs of the animal. Individual feeding, on the other hand, requires more elaborate facilities and more labor. The nature of the particular experiment usually will dictate the feeding procedure to be employed. In any case, great care must be taken to provide appropriate feeds,

containing all the necessary nutrients, in proper amounts and in appropriate physical form to maintain a healthy animal.

BLOOD COLLECTION

It is frequently desirable in studies with laboratory animals to collect samples of blood. Blood sampling is so commonplace that numerous techniques can be used. The method will depend upon the individual investigator (Farrell *et al.*, 1970). In the case of sheep, goats, and cattle it is easy to obtain blood samples from the jugular vein. By applying pressure over the jugular and thus enlarging the area, it is then easy to insert the needle and withdraw blood into a syringe or other collection device. Prior to insertion of the needle, the hair or wool should be clipped and the area shaved and thoroughly cleaned. Swab the area with an antiseptic prior to the insertion of a sterile needle.

It is possible to collect blood samples continuously by the insertion of an indwelling catheter. The catheter may be inserted into the carotid artery, the ruminal vein, the portal vein, or other specialized area (McGilliard, Thorp, 1971; McGilliard, 1971, 1972). However, these are quite specialized techniques and a veterinarian should be consulted prior to performing this operation. Other possibilities are to exteriorize by surgery the carotid artery or other areas that are to be sampled (Sterzing *et al.*, 1971; Romsos *et al.*, 1970).

PHYSIOLOGICAL DATA

Some of the physiological data for cattle, sheep, and goats are summarized in Table 4. The parameters summarized include blood volume, rectal temperatures, milk composition, blood pH, heart rates, blood pressure, respiration rates, and blood composition.

ANESTHESIA OF CATTLE, SHEEP, AND GOATS

The majority of surgical procedures performed on these ruminants are done with local anesthesia. Field blocks are the simplest to perform once the anatomical locations are known. These have been adequately described for the bovine by Evans (Soma, 1971). A technique for retrograde regional anesthesia of the forelimb has also been described (Manahan *et al.*, 1971). With the animal properly restrained by ropes or barriers, abdominal surgery can be conducted under field blocks.

TABLE 4 Physiological Data for Cattle, Sheep, and Goats[a]

Parameter	Units	Adult Cattle	Goats	Sheep
Blood volume	ml/kg body wt.	57–62	70–70.6	57–66.4
Blood pH (arterial)	pH	7.38(7.27–7.49)	–	–
Blood pH (venous)	pH	–	–	7.44(7.32–7.54)
Blood pressure				
Right ventricular				
Systolic	mm Hg	42–56	24.5(24–32)	26.3(18–37)
Diastolic	mm Hg	0–1	-1.5(-3–0)	-3.1(-6–0)
Pulmonary artery				
Systolic	mm Hg	33–46	–	–
Diastolic	mm Hg	19–21	–	–
Mean	mm Hg	24–31	–	9
Relative capacity of gastrointestinal tract				
Stomach	%	71	67	67
Small intestine	%	18	21	21
Cecum	%	3	2	2
Colon and rectum	%	8	10	10
Heart rates	Beats/min	60–70	90(70–135)	75(60–120)
Respiration rates	Breaths/min	30	19	–
Body temperature (rectal)	°C	38.3(36.7–39)	39.1(38.3–39.9)	39.1(38.5–39.7)

		Holstein	Jersey		
Milk composition					
Fat	%	3.5	5.5	3.5	10.4
Protein	%	3.1	3.9	3.1	6.8
Lactose	%	4.9	4.9	4.6	3.7
Ash	%	0.7	0.7	0.8	0.9
Blood composition					
Glucose	mg/100 ml whole blood	40–70		45–60	30–50
Total nonprotein nitrogen	whole blood	20–40		30–44	20–38
Urea nitrogen	whole blood	6–27		13–28	8–70
Uric acid	whole blood	0.05–2		0.3–1	0.05–2
Creatinine	whole blood	1–2		1–2	1–2
Amino acid nitrogen	whole blood	4–8		–	5–8
Lactic acid	whole blood	5–20		–	9–2
Total cholesterol	mg/100 ml serum	50–230		55–200	100–150
Calcium	mEq/1 serum	4.5–6		4.5–6	4.5–6
Inorganic phosphorous	mEq/1 serum	2–5.2		2–5.2	2–5.2
Chloride	mEq/1 serum	80–100		100–125	95–110
Blood specific gravity		1.052		1.042	1.051
Erythrocytes/cu mm blood	millions/cu mm	6–8		13–14	10–13
Leukocytes/cu mm blood	no./cu mm	7,000–10,000		8,000–12,000	7,000–10,000

[a]Swenson, 1970.

Epidural anesthesia is more difficult to accomplish than field blocks but the techniques can be mastered quickly. Needles with matching stylets are recommended for ease and safety. Care must be taken to prevent subarachnoid injection as unexpectedly high levels of paralysis can occur. The techniques and complications have been described (Soma, 1971).

Safe intravenous anesthesia with pentobarbital is difficult. In inexperienced hands, a high rate of complications and mortality occurs. Short-acting thiobarbiturates have also been used with mixed results. Intravenous chloralose is commonly used in nonsurvival experimental surgery of sheep and goats. Indications and dosage schedules have been published in the *Federation Proceedings on Laboratory Animal Anesthesia* (1969). Complications from bloat and inhalation pneumonia can be minimized by withholding feed and water before surgery. Halothane and methoxyflurane are the most common inhalation anesthetic agents used for general anesthesia. The development of circle absorption systems leads to the practical administration of these agents but their physical properties dictate the use of specialized equipment and training (Soma, 1971; Weaver, 1966). The continued use of calves and other large domestic animals as models for surgical techniques in the field of experimental cardiovascular research has greatly increased our knowledge in the anesthetic management of these animals (Short *et al.*, 1968). Steps must be taken to provide mechanical assistance to respiration whenever thoracic surgery is performed. Proper ventilation of the bovine has proved to be a formidable obstacle in the anesthetic management of these animals (Soma, 1971). The user of anesthetic, analgesic, and tranquilizing agents in conjunction with research studies must comply with federal regulations applying to the use and reporting of these substances under the provisions of Public Law 91-579, the Animal Welfare Act.

SURGERY

The most frequently performed surgical procedures in management of ruminants are castration, dehorning, foot trimming, and docking (shortening the tail).

Castration

This procedure is performed with the least risk and pain in very young animals (calves 4–10 weeks, lambs and kids 4–8 weeks). With increasing age, risk of severe hemorrhage is high. Only skilled personnel should undertake this procedure. Basically, it is accomplished by incision into the scrotum with subsequent sectioning of the spermatic cord and removal of the

testicle or by crushing or severing the spermatic cord without incision by use of an emasculatome or "Burdizzo."

Dehorning

Dehorning should be carried out when animals are very young. When possible, local anesthesia should be applied by blocking the cornual nerve. In older animals, after horn development has occurred, considerable arterial hemorrhage will occur following dehorning. This may be arrested by grasping the cut end of the artery with hemostat forceps and twisting, thus breaking the vessel. Clot formation quickly ensues and bleeding stops. Basically, dehorning is accomplished by cautious application of caustic chemicals to the horn button that destroys the matrix or root of the horn; cautery of horn buttons by use of heated irons; or removal of the horn and associated epidermis around the horn base by use of clippers, saws, gougers, or dehorning spoons. Veterinary assistance should be obtained to properly conduct regional or cornual anesthesia and ligation of arteries severed by any of the above methods of dehorning as this is a surgical procedure.

Foot Trimming

Animals housed in close confinement frequently develop uneven hooves, apparently due to lack of abrasive action, which does occur on range or pasture. These uneven growths must be trimmed away or lameness may result. A variety of tools such as knives, chisels, and shears can be used for trimming. Electric hoof grinders have been used for this purpose. Caution should be exercised not to invade the innervated or "pink" area of the foot (Leach, 1943).

Docking

Removal of a portion of the tail is routinely practiced with young lambs. Usually it is accomplished at the same time as the castration of young males; however, the younger the animal, the more innocuous the procedure. It is usually performed either by surgical incision through the skin followed by section between coccygeal vertebrae or use of a "Burdizzo" or emasculatome (Ensminger, 1970).

Deodorizing Male Goats

A procedure for rendering buck goats scentless has been described and might prove useful with goats used in laboratory research (Ford, 1965).

EUTHANASIA

The term euthanasia implies that painless death has been induced. Animal welfare and humane considerations make it imperative that every effort be exerted to achieve a painless death in an animal that must be killed.

Factors that must be considered are capacity of the agent or method to produce death without causing pain, time required to produce loss of consciousness and death, reliability of the method, safety to personnel, potential of the method for minimizing undesirable psychologic stress, compatibility with requirement and purpose, emotional effect on observers or operators, economic feasibility of the method, and potential environmental impact (Smith, 1972).

Intravenous administration of a combination solution of chloral hydrate, magnesium sulfate, and pentobarbital sodium (30 g, 15 g, and 6.6 g, respectively, in 1000 ml water) until respiration and heartbeat cease is a highly acceptable euthanasia method for cattle, sheep, and goats. This combination has been shown to be an effective anesthetic and overdose produces euthanasia (Jones, 1954; Millenbruck *et al.*, 1946). It is available commercially from veterinary pharmaceutical companies. In general, if anesthetics are used in overdosage they will produce euthanasia.

Shooting and Captive Bolt Pistol are recommended euthanasia procedures if the projectile is accurately placed to enter the brain and adequate precautions are taken to assure safety of personnel. This method of euthanasia obviously would not be indicated where examination of the brain was necessary as part of the necropsy procedure.

Electrocution produces euthanasia if electrodes are placed so that the appropriate level of current flows through the brain to produce immediate unconsciousness. Due to difficulties in accomplishing this and because of the hazard of attending personnel, this method probably should not be considered. Caution should be exercised that death has occurred before final disposal of the carcass is carried out.

NECROPSY

The techniques to be followed in conducting recommended necropsy procedures on ruminants are described by Jones and Gleiser (1954).

Necropsy should be conducted as soon as possible after death. When environmental temperatures are high, necropsy should be performed as soon as possible since bloating and other postmortem changes will occur very rapidly. If necropsy cannot be performed soon after death, the carcass should be quickly chilled but not frozen. If several animals in a group have died, these and any other moribund animals should be necropsied.

Before proceeding with the necropsy, a detailed history should be obtained as to signs exhibited by the animals before death, duration of the condition, age of animal, ration fed, and response to any treatment administered. Attention must also be given to herd management practices, type of housing used, and the possible introduction of disease by the recent addition of animals to the group. A complete history can be as valuable as the necropsy itself in arriving at an accurate diagnosis.

Careful physical or external examination of the carcass may disclose disease signs that will substantiate internal lesions. Veterinary assistance should be obtained to conduct a necropsy as soon as possible on animals which show extensive body swellings, abnormal discharges from body openings, and vesicles and ulcers on the mucous membranes of the gums or tongue. While poor body condition is often indicative of internal parasitism, examination of the gastrointestinal tract must be conducted to determine the degree and type of parasitism. The degree of asepsis to be followed in the conduct of the necropsy procedure will be determined by the intended use of the tissues collected for examination. Undue delay in performing necropsy may render tissues unsuitable for recovery of microbiological culture or histopathological examination.

ANIMAL DISPOSAL

Normal

Meat-producing animals that have been used for experimental purposes may be sold for slaughter if they meet USDA and state meat inspection requirements. These animals must be free of infectious diseases and toxic substances and must have been subjected to a prescribed withdrawal period as verified by a certification when used in experiments involving antibiotics, hormones, or similar substances. Specific requests for clearance for unusual substances, or extended withdrawal time following high-level dosage of drugs, should be arranged in advance with the USDA Meat Inspection Service.

Contaminated

Any animal carcass that has been exposed to an infectious disease, or that contains a toxic or deleterious substance, or has been in direct contact with a toxic substance which may render it injurious to human health is considered contaminated. These carcasses should be disposed of in such a manner as to prevent spread of infectious diseases or human contamination with toxic materials.

Incineration

The most satisfactory disposal procedure for contaminated carcasses is incineration of the total carcass. Competent engineering advice is mandatory to ensure correct design and operating techniques. When animals containing toxic residues are incinerated, special precautions may be needed to assure that these substances are confined within the incinerator and not vented through the flue system (see Chapter 2, pp. 25-26).

Sterilization and Rendering

Animal carcass material may be sterilized by autoclaving in suitable covered containers. These materials may then be transported to rendering plants for disposal. Materials disposed of in this manner should be free of radioactive materials or toxic substances that make them unsuitable for rendering and recycling for animal or plant foods.

Burial

Waste materials and animal carcasses that cannot be disposed of by the above methods may be subjected to burial. Precautions shall be taken to ensure that toxic or radioactive residues of these carcass materials do not enter a physical or biochemical environmental pathway for animals or plants. Safeguards shall be applied to provide adequate shielding from radioactive irradiation. Infectious materials and carcasses may be covered with slaked lime and buried if these areas do not contaminate food or water sources. All burial areas should conform to the standards of the USDA and the Atomic Energy Commission.

Glossary

BAREFACE Sheep without wool on their faces.

BUNKERS Feed mangers.

COMMERCIAL HERD A nonregistered herd (as opposed to purebred herd) or grade of cattle or sheep maintained for the production of meat, milk, or wool.

CREEP An enclosed feeding device that allows only the young animal access to supplemental feedstuffs.

CROSSBRED ANIMAL One whose parents are of distinctly different breeds.

CUTTING CHUTE A narrow passage equipped with gates at sides and rear used to separate animals into pens.

CYCLING A regularly recurrent state of sexual excitability, during which the female will accept the male and is capable of conceiving.

DROP To give birth to or deliver young.

DUMMY A simulated animal used in lieu of a live animal to encourage a male to mount for semen collection.

EAR CROPPING Notching or cutting the edge of the ear in a systematic manner to conform with a numbering system for animal identification.

EXOTIC BREEDS Animal breeds that are not common or indigenous to a country.

FLUSHING Increasing feed intake during breeding season to result in weight gain and to improve fertility and embryo survival.

FOUNDER A nutritional disorder usually resulting from excess consumption of feed. Animals refuse feed and may show other symptoms, such as inflammation of laminae.

GRADE ANIMAL An animal whose blood is essentially from one pure breed but cannot qualify as purebred because of lack of records of individual ancestors or because of other disqualifications.

HAND MATING Mating a dam with a known sire and knowledge of breeding time for female.

HEAT A period in the estrous cycle when the female will permit coitus.

KID GOATS Immature male or female goats.

MILK REPLACER A dry feed, reconstituted with water before feeding,

used as a substitute for whole milk in feeding young animals. It usually contains various nonfat milk solids and ingredients not of milk origin.

PINING To yearn for maternal care—calves will bawl and walk along fences.

PLANE OF NUTRITION Level of nutrition or amount of feed consumed in relation to nutritional requirements of an animal. It is common for a plane of nutrition to be expressed in terms of energy intake in relation to energy requirements for maintenance.

PROXIMATE ANALYSIS Analysis of feed for dry matter, crude protein, ash, crude fiber, ether extract, and nitrogen-free extract.

PUREBRED ANIMAL Offspring of animals of same breeds, with known ancestry. Usually eligible for registry by a purebred association for that breed.

THROWING CATTLE Forcing the animal to assume the prone position usually on its side or back.

TOP CROSSING A cross in which usually purebred or superior males are mated with stock of inferior breeding to improve the quality of the offspring.

TWINNING Delivery of twins.

Appendix: Housing and Equipment Sources for Ruminants

1. Free-Stall Housing for Dairy Cattle M-138
   D. W. Bates, Extension Agricultural Engineer. Agricultural Extension Service. University of Minnesota, St. Paul, Minnesota 55108
2. Beef Housing and Equipment Handbook MWPS-6
   Midwest Plan Service. Agricultural Extension Service. University of Minnesota, St. Paul, Minnesota 55108
3. Sheep Equipment and Plans MWPS-3
   Midwest Plan Service. Iowa State University, Ames, Iowa 50010
4. Planning Grain-Feed Handling for Livestock and Cash-Grain Farms MWSP-13
   Midwest Plan Service. Iowa State University, Ames, Iowa 50010
5. 31′ × 44′ Insulated Calf Barn with Individual and Group Pens M-149
   D. W. Bates, Extension Agricultural Engineer. Agricultural Extension Service. University of Minnesota, St. Paul, Minnesota 55108
6. Building Layouts for Confined Beef Finishing 1969
   Dennis M. Ryan, Extension Agricultural Engineer. Agricultural Extension Service. University of Minnesota, St. Paul, Minnesota 55108
7. How to Plan Your Stall Dairy Barn M-132
   D. W. Bates, Extension Agricultural Engineer. Agricultural Extension Service. University of Minnesota, St. Paul, Minnesota 55108
8. Beef Feedlot Layouts 1969
   Dennis M. Ryan, Extension Agricultural Engineer. Agricultural Extension Service. University of Minnesota, St. Paul, Minnesota 55108
9. Mounds for Beef Cattle
   Dennis M. Ryan, Extension Agricultural Engineer. Agricultural Extension Service. University of Minnesota, St. Paul, Minnesota 55108
10. How to Select and Install Electric Fans for Dairy Stable Ventilation M-128
    D. W. Bates, Extension Agricultural Engineer. Agricultural Extension Service. University of Minnesota, St. Paul, Minnesota 55108
11. Dairy Housing and Equipment Handbook MWPS-7
    Midwest Plan Service. Iowa State University, Ames, Iowa 50010
12. Manure Grate Design for Dairy Barns M-155
    D. W. Bates, J. A. Moore, G. D. Marx, and M. C. Jacobson. Agricultural Extension Service. University of Minnesota, St. Paul, Minnesota 55108
13. Design Tables for Reinforced Concrete Manure Tanks, Slats, and Beams TR-3
    Technical Resource. Midwest Plan Service. Iowa State University, Ames, Iowa 50010
14. Publications of Agricultural Engineers Digest
    AED-1 Anerobic Manure Lagoons. AED-8 Handling Liquid Manure. AED-13 Insulation and Heat Loss. Midwest Plan Service. Iowa State University, Ames, Iowa 50010

References

Abrams, J. T. and R. G. Linton, [eds.] 1962. Animal nutrition and veterinary dietetics, 4th ed. Williams & Wilkins Co., Baltimore, Md. 826 pp.

Balch, C. C., V. W. Johnson, and C. Machin. 1962. Housing and equipment for balance studies with cows. J. Agric. Sci. 59:335.

Blaxter, K. L. 1962. The energy metabolism of ruminants. Charles C Thomas, Springfield, Ill. 332 pp.

Bratzler, J. W. 1951. A metabolism crate for use with sheep. J. Anim. Sci. 10:592.

Brody, S. 1945. Bioenergetics and growth. Reinhold Publishing Corp., N. Y.

Canada Department of Agriculture 1957. The dairy goat. Publication 1023. Health of Animals Branch, Ottawa, Canada.

Committee on Animal Nutrition. 1968. Nutrient requirements of sheep. National Academy of Sciences-National Research Council, Washington, D.C. 64 pp.

Committee on Animal Nutrition. 1971a. Nutrient requirements of beef cattle. National Academy of Sciences-National Research Council, Washington, D.C. 55 pp.

Committee on Animal Nutrition. 1971b. Nutrient requirements of dairy cattle. National Academy of Sciences-National Research Council, Washington, D.C. 54 pp.

Committee on Revision of the Guide for Laboratory Animal Facilities and Care. 1972. Guide for the care and use of laboratory animals. Government Printing Office, Washington, D.C. 56 pp.

Dykstra, R. R. 1949. Animal sanitation and disease control. Interstate Printers and Publishers, Danville, Ill. 808 pp.

Dziuk, P. 1972. The importance of reproductive performance in efficient, intensified sheep production. Proceedings of a Symposium on Intensive Sheep Management, Paducah, Ky., 1972. 5 pp. (loose-leaf).

Ensminger, M. E. 1952. Sheep husbandry. Interstate Printers and Publishers, Danville, Ill. 404 pp.

Ensminger, M. E. 1968. Beef cattle science, 4th ed. Interstate Printers and Publishers, Danville, Ill. 1020 pp.

Ensminger, M. E. 1970. Sheep and wool science, 4th ed. Interstate Printers and Publishers, Danville, Ill. 948 pp.

Erwin, E. W., I. A. Dyer, M. E. Ensminger, and W. Moore. 1952. A portable metabolism stall for beef steers. J. Anim. Sci. 15:435.

Farrell, D. J., J. L. Corbett, and R. A. Lang. 1970. Research in veterinary science. II(3):217-220.

Federation Proceedings. 1969. Comparative anesthesia in laboratory animals. 28(4): 1378-1586.

Flatt, W. P. 1969. Methods of calorimetry (B) indirect, pp. 491-520. *In* D. P. Cuthberton [ed.], The international encyclopedia of food and nutrition. Vol. 17. Pergamon Press, London.

Frederiksen, K. R. 1972. Artificial rearing of lambs. Proceedings of a Symposium on Intensive Sheep Production, Paducah, Ky., 1972. 19 pp. (loose-leaf).

Ford, R. S. 1965. Buck deodorizing possible now with new researched method. Dairy Goat J. 43(4):3, 9, 12, 14, and 15.

Glimp, H. A. 1972. Effect of diet composition on performance of lambs reared from birth on a milk replacer. J. Anim. Sci. 34(6):1085–1088.

Gorski, J., T. H. Blosser, F. R. Murdock, A. S. Hodgson, B. K. Soni, and R. E. Erb. 1957. A urine and feces collecting apparatus for heifers and cows. J. Anim. Sci. 16:100.

Grace, O. D., N. R. Underdahl, and G. A. Young. 1959. Procurement of lambs by hysterectomy and their isolation. Am. J. Vet. Res. 20:239.

Hobbs, C. S., S. L. Hansard, and E. R. Barrick. 1950. Simplified methods and equipment used in the separation of urine from feces eliminated by heifers and steers. J. Anim. Sci. 9:563.

Hulet, C. H. 1972. A rectal-abdominal palpation technique for diagnosing pregnancy in the ewe. J. Anim. Sci. 35(4):814–819.

Inskeep, E. K. 1972. Artificial insemination, semen handling and pregnancy diagnosis. Proceedings of a Symposium on Intensive Sheep Management, Paducah, Ky., 1972. 11 pp. (loose-leaf).

Jones, L. M. 1954. Pharmacology and therapeutics. Iowa State College Press, Ames. 132 pp.

Jones, T. C. and C. Gleiser. 1954. Veterinary necropsy procedures. Lippincott, Philadelphia, Pa. 136 pp.

Kleiber, M. 1961. The fire of life–an introduction to animal energetics. John Wiley and Sons, N. Y. 454 pp.

Leach, C. A. 1943. Aids to goatkeeping. Dairy Goat J. Columbia, Missouri. n.p.

Lindahl, I. L. 1959. Techniques and procedures in animal production research. American Society of Animal Production, Oklahoma State University, Stillwater. n.p.

Lindahl, I. L. 1971. Pregnancy diagnosis in the ewe by intrarectal doppler. J. Anim. Sci. 32(5):922–925.

Lindsey, J. R., Chairman. 1969. Animal models for biomedical research II (a symposium). Institute of Laboratory Animal Resources, National Academy of Sciences–National Research Council, Washington, D.C. 53 pp.

Maijala, K. 1969. Finnish animal husbandry. Department of Finnish Animal Breeding Association, Helsinki. n.p.

Mallis, A. 1964. Handbook of pest control, 4th ed. MacNair-Dorland. New York. 1148 pp.

Manahan, M., R. Kumer, and R. P. S. Tyagi. 1971. Studies on intravenous retrograde regional anaesthesia of the forelimb on buffalo calves. Br. Vet. J. 127:401–407.

McGilliard, A. D. 1971. An implantable needle for sampling blood or infusion of the portal vein in calves. J. Appl. Physiol. 30(2):297–301.

McGilliard, A. D. 1972. Permanent implantation of arterial and venous catheters and lymphatic shunts. J. Dairy Sci. 55(8):1191–1199.

McGilliard, A. D. and J. W. Thorp. 1971. Catherization of the mesenteric and portal veins in calves. J. Dairy Sci. 54(1):129–132.

McPherson, C. W., Chairman. 1968. Animal models for biomedical research I (a symposium). Institute of Laboratory Animal Resources, National Academy of Sciences–National Research Council, Washington, D.C. 169 pp.

Metcalfe, J. and A. S. Hoversland. 1969. Biology of the pygmy goat. University of Oregon Medical School, Portland.

Middleton, C. C., Chairman. 1970. Animal models for biomedical research III (a symposium). Institute of Laboratory Animal Resources, National Academy of Sciences–National Research Council, Washington, D.C. 148 pp.

Millenbruck, E. W. and M. H. Wallinga. 1946. A newly developed anesthetic for horses. J. Am. Vet. Med. Assoc. 108:148.

Neumann, A. L. and R. R. Snapp. 1969. Beef cattle, 6th ed. John Wiley and Sons, N.Y. 767 pp.

Oxenrider, W. D., D. B. Purser, and W. G. Berger. 1971. A procedure to obtain germfree goats by hysterotomy. Am. J. Vet. Res. 32:1443.

Rogers, A. L., L. F. Erickson, A. S. Hoversland, J. Metcalfe, and P. L. Clary. 1969. Management of a colony of African pygmy goats for biomedical research. Lab. Anim. Care 19(2):181–185.

Romsos, D. R. and A. D. McGilliard. 1970. Thoracic and intestinal lymph duct shunts in calves. J. Dairy Sci. 53(9):1275–1278.

Salisbury, G. W. and N. L. Vandemark. 1961. Physiology of reproduction and artificial insemination of cattle. W. H. Freeman and Co., San Francisco, Calif. 639 pp.

Schneider, B. H. The evaluation of feeds through digestability experiments. University of Georgia Press, Athens (in press).

Short, C. E., A. S. Keats, D. Kiotta, and W. Hall. 1968. Anaesthesia for cardiac surgery in calves. Am. J. Vet. Res. 29:2287–2294

Smith, C. K. 1961. Rearing gnotobiotic (germfree) goats and lambs. Conference on Application of Caesarean-Derived Animals to Disease Control in Livestock and Laboratory Animal Production. Michigan State University, East Lansing. 212 pp.

Smith, C. R., Chairman. 1972. Report of the AVMA Panel on Euthanasia. J. Am. Vet. Med. Assoc. 160(5):761–772.

Soma, L. R. [ed.]. 1971. Textbook of veterinary anaesthesia. Williams & Wilkins Co., Baltimore, Md. 633 pp.

Sterzing, P. R., A. D. McGilliard, and R. S. Allen. 1971. Application of a biopsy technique to the study of lipid absorption and transport by bovine small intestine. J. Anim. Sci. 32(4):774–777.

Sweat, R. L. and J. W. Dunn. 1965. Hysterectomy-derived, colostrum-deprived, isolation-raised calves for disease research. Am. J. Vet. Res. 26:1309.

Swenson, M. J. [ed.]. 1970. Dukes' physiology of domestic animals, 8th ed. Cornell University Press, Ithaca, N.Y. 1463 pp.

Terrill, C. E. 1972. Six lambs born to Finnsheep ewe. Sheep Breeder and Sheep Man 92(8):8.

Trexler, D. C. 1971. Microbiological isolation of large animals. Vet. Rec. 88:15.

Weaver, A. D. 1966. Recent developments in anaesthesia of large animals. Vet. Rec. 79, Clinical Supplement 3.

Williams, D. W. 1955. Beef cattle production in the south, 3rd ed. Interstate Printers and Publishers, Danville, Ill. 487 pp.

Bibliography

Briggs, H. M. 1969. Modern breeds of livestock, 3rd ed. MacMillan Co., N.Y. 714 pp.

Cole, H. H. [ed.]. 1966. Introduction to livestock production. W. H. Freeman and Co., San Francisco, Calif. 827 pp.

Hafez, E. S. E. and I. A. Dyer. 1969. Animal growth and nutrition. Lee and Febiger, Philadelphia, Pa. 402 pp.

Herrick, J. B. and H. L. Self. 1962. Evaluation of fertility in the bull and boar. Iowa State University Press, Ames. 148 pp.

Institute of Laboratory Animal Resources. 1971. Animals for research, 8th ed. National Academy of Sciences, Washington, D.C. 109 pp.

Kammalade, W. G., Sr., and W. G. Kammalade, Jr. 1955. Sheep science. J. B. Lippincott Co., N.Y. 536 pp.

Lasley, J. F. 1963. Genetics of livestock improvement. Prentice-Hall, Englewood Cliffs, N.J. 342 pp.

Mansfield, M. E., J. M. Lewis, and G. E. McKibben. 1967. Rearing lambs free of gastrointestinal nematodes. J. Am. Vet. Med. Assoc. 151:1182.

Maynard, L. A. and J. K. Loosli. 1969. Animal nutrition, 6th ed. McGraw-Hill Book Co., N.Y. 613 pp.

Merck Veterinary Manual, 3rd ed. 1967. Merck and Co., Rahway, N. J. 1674 pp.

Morrison, F. B. 1954. Feeds and feeding. Morrison Publishing Co., Ithaca, N.Y. n.p.

Perry, E. J. [ed.]. 1968. The artificial insemination of farm animals, 4th ed. Rutgers–The State University Press, New Brunswick, N.J. 473 pp.

Sainsbury, D. and P. Sainsbury 1967. Animal health and housing. Williams & Wilkins Co., Baltimore, Md. 329 pp.

Scott, G. E. 1970. Sheepmen's production handbook. Sheep Industry Development Program, Denver, Colo. n.p.

Swift, R. W. and C. French. 1954. Energy metabolism and nutrition. The Scarecrow Press, Washington, D.C. 264 pp.

Tavernor, W. D., P. C. Trexler, L. C. Vaughan, J. E. Cox, and D. G. C. Jones. 1971. The production of gnotobiotic piglets and calves by hysterectomy under general anesthesia. Vet. Rec. 88:10.

U.S. Department of Agriculture. 1917. The sheep tick and its eradication by dipping. Farmers Bulletin 798. Washington, D.C. n.p.

U.S. Department of Agriculture. 1942. Milk goats. Farmers Bulletin 920. Washington, D.C. n.p.

U.S. Department of Agriculture. 1944. The Angora goat. Farmers Bulletin 1203. Washington, D.C. n.p.

U.S. Department of Agriculture. 1950a. Cattle holding chute. Extension Service, Clemson Agricultural College, Circular 353. n.p.

U.S. Department of Agriculture. 1950b. Beef cattle in South Carolina. Extension Service, Clemson Agricultural College, Circular 356. n.p.

U.S. Department of Agriculture. 1966. A dairy goat for home milk production. Leaflet 538. Washington, D.C. n.p.

U.S. Department of Agriculture. 1968. Portable dipping vat for sheep. Misc. Publ. 1103. Washington, D.C. n.p.

U.S. Department of Agriculture. 1970. Beef cattle-dehorning, castrating, branding and marking. Farmers Bulletin 2141. Washington, D.C. n.p.

Universities Federation for Animal Welfare (in press). The UFAW handbook on the care and management of laboratory animals, 4th ed. Williams & Wilkins Co., Baltimore, Md.

Watson, D. F. 1962. An economical method for producing lambs practically free from parasites. J. Am. Vet. Med. Assoc. 140:58.

To assist ILAR in determining the usefulness of this guide, please complete and return this questionnaire to the Institute of Laboratory Animal Resources, National Academy of Sciences, 2101 Constitution Avenue, Washington, D.C. 20418.

QUESTIONNAIRE

Name _____ Institution _____

Department _____

1. Specific area of scientific interests?

2. What portions of the guide did you find particularly useful?

   a. Which sections did you find difficult to use?

   b. Were any sections contrary to your experience or misleading?

   c. Were any sections too vague or overly explicit?

3. Suggestions for the improvement of future issues:

   a. Format:

   b. Contents:

   c. Other:

4. Purpose for which guide was obtained:

   General reference _____
   Specific requirement for information _____
   Other (specify) _____

Ruminants: Cattle, Sheep, and Goats: Guidelines for the Breeding, Care, and Management of Laboratory An
http://www.nap.edu/catalog.php?record_id=20162

Copyright © National Academy of Sciences. All rights reserved.