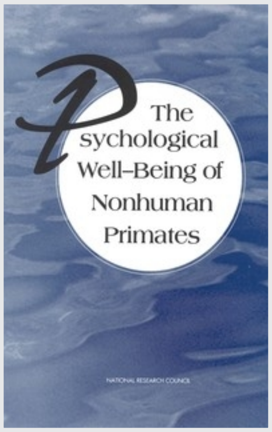

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Preface

Research with nonhuman primates leads to improvements in the health of humans and other animals. Because of their physiological and structural similarity to humans, nonhuman primates often constitute valuable models of human disease, provide conclusive evidence of safety and efficacy of new products and procedures, and serve biomedicine as surrogates for humans in many other important ways. In addition, they are a resource for learning about the order Primates and its many ecological adaptations through their exhibition, study, and enjoyment in the nation's zoos. For many years, attention has been given to their contribution to the health and well-being of humans; but little attention has been given to *their* well-being. Recently, behavioral scientists, investigators, veterinarians, and technicians have been studying the psychological well-being of nonhuman primates; this has resulted in a growing understanding of what is known about their well-being.

The task of the Committee on Well-Being of Nonhuman Primates, in the National Research Council's Institute for Laboratory Animal Research (ILAR), originated in a 1985 amendment to the Animal Welfare Act (P.L. 99-198, the Food Security Act). The law states that standards shall be promulgated to include minimal requirements "for a physical environment adequate to promote the psychological well-being of primates," and that wording is incorporated into later Animal Welfare Regulations, Title 9, Animals and Animal Products, Subchapter A (Animal Welfare), Parts 1-4 (9 CFR 1-4). The period since publication of the standards has seen a great deal of activity seeking to provide and assess strategies that would address the psychological well-being of some 40 species of nonhuman primates used in biomedical research and of many more held in zoos. During this time, some funding became available for research into these issues. Although many called the language anthropomorphic and few, if any, methods existed for understanding and assessing the *psychological* well-being of other animals, the U.S.

Department of Agriculture (USDA) wisely left important details of implementation to be negotiated between the institutions and their animal-welfare inspectors.

Not unexpectedly, about as many different strategies emerged as there are institutions that have nonhuman primates. That is seen as highly desirable by scientists, for it will provide a range of beneficial options; but it has produced some confusion and lack of understanding among some members of Congress, the public, and animal protectionists. Whereas placing the responsibility on individual research institutions and zoos for providing psychological well-being necessarily stimulates inquiry, it also creates unease among those who would prefer that specific methods be spelled out, rather than leaving it up to the regulated community to achieve the desired goal. The committee agrees with the current approach and feels that to have written engineering or prescriptive specifications to accommodate the psychological well-being and individual needs of each type of nonhuman primate would have been short-sighted and would have risked compromising the welfare of many animals in the process of achieving easily administered regulations. Moreover, well-being can be achieved by a variety of techniques. For those reasons, this report supports performance-based standards but stresses the need for a scientific approach in establishing such standards so that the results can be measured and assessed. The use of *professional judgment* in interpreting and applying the recommendations in this report is crucial. Rote applications of the recommendations provided here, prescriptive translations of these recommendations, anthropomorphic interpretations of the needs of nonhuman primates, and generation of "cookbook" recipes for broad application across multiple colonies are unwarranted and likely to produce outcomes contrary to the intended goals. The ability to develop, apply, evaluate, and inspect institutional well-being plans depends, first and foremost, on the specific knowledge and skills of the personnel involved.

The sponsors of this report asked that guidelines be developed that would assist institutions and inspectors alike. They requested recommendations regarding species-specific strategies for psychological well-being and an indication of the methods by which these strategies could be assessed. Specifically, the committee was asked to evaluate the environmental variables that are the most influential in affecting the well-being of nonhuman primates, evaluate behavioral and physiological measures that are objective indexes of the effects of these environmental variables, produce recommendations and procedures for use by institutions in developing plans consistent with federal law, and suggest priorities for future research.

We anticipate that these guidelines will be of interest to institutions that house nonhuman primates; to the institutional animal care and use committees that oversee all programs in which such animals are used; to the researchers, veterinarians, and technicians that work with the animals; to federal inspectors that enforce the law from which this report derives; to private consultants that evaluate animal care and use programs and facilities; and to the public, which holds researchers and exhibitors accountable for the care and treatment of these highly evolved species. We also hope that it will be seen by critics of the present regulations as an honest attempt to ensure the well-being of primates.

This report is not the final word. Because it is intended for use by large and small biomedical research facilities and institutions ranging from state-of-the-art zoos to roadside exhibits, some will be disappointed by the length of some sections and the brevity of others and by the lack of concrete recommendations applicable to species of interest. The committee recognizes these deficiencies but feels that they reflect the state of the art: much is known about some species, very little about others. Where definitive recommendations are lacking, readers are encouraged to learn about closely related species, talk to other primatologists, and use their best professional judgment. With a clear focus on enhancing the well-being of each individual animal, we believe that the technologies and attitudes expressed in this report will provide a sound beginning.

Throughout its deliberations and public forums, the assistance of numerous invited participants, and the vigorous peer-review process, the committee held tenaciously to one goal: to develop recommendations that would be good for the animals. To the extent that that goal was achieved, many people deserve recognition. The report's character grew from the discussions at two public meetings. The participants were Elizabeth Baldwin, American Psychological Association; Patricia Feeser, Duke University Primate Center; Roger Fouts, Central Washington University; Mary Geibe, Regulatory Enforcement and Animal Care, USDA; Heather Lange, representing Adelle Douglass, American Humane Association; Scott Line, Bowman Gray School of Medicine; Cathy Liss, Animal Welfare Institute; former senator John Melcher; Jan Moor-Jankowski, Laboratory for Experimental Medicine and Surgery in Primates, New York University Medical Center; Adrian Morrison, consultant to the Department of Health and Human Services (DHHS); Peggy O'Neill, National Institutes of Health; Martin Stephens, The Humane Society of the United States; Christine Stevens, Animal Welfare Institute (also representing Jane Goodall, Goodall Institute); and Betty Willis, American Psychological Society.

Many others expressed an interest in the committee's work. The committee appreciates the written comments provided by Ursula Bartecki, University of Göttingen; John Boyce, American Veterinary Medical Association; Carolyn Crockett, Washington Regional Primate Research Center; Jo Fritz, Primate Foundation of Arizona; Frederick Goodwin, DHHS; Ronald Hunt, New England Regional Primate Research Center; Frank Loew, Tufts University; LaVonne Meunier and Sarah Campbell, SmithKline Beecham Pharmaceuticals; Charles Middleton, State University of New York at Stonybrook; Viktor Reinhardt, University of Wisconsin; Phillip Robinson, University of California, San Diego; Raye Rooney, The Gorilla Foundation; David Valerio, Hazleton Research Products, Inc.; and David Washburn, Georgia State University.

As the committee delved into its task and reflected on the written and oral comments of contributors, it saw that additional expertise would be needed. We

express our gratitude to the following, who graciously responded to the committee's request and submitted materials on a wide variety of topics in the text: Nancy Ator, Johns Hopkins Medical Institutions; Bruce Ewald, Ciba-Geigy Corporation; Tine Griede, National Foundation for Research in Zoological Gardens, Netherlands; James Woods, University of Michigan Medical School; and William Woolverton, University of Chicago.

In recognition of the need for expertise from zoological institutions, we requested assistance from Benjamin Beck of the National Zoological Park in Washington, D.C. The committee appreciates Dr. Beck's outstanding assistance in expressing the views of public exhibitors and their recommendations. He and his colleague Lisa Stevens provided the committee with an informative visit to the National Zoological Park. We hope that those who keep nonhuman primates in zoos will find much of value in this report. If they do, it will be largely because of the input of their colleagues Ben and Lisa.

This report has been reviewed by persons chosen for their diverse perspectives and technical expertise in accordance with procedures approved by the National Research Council's Report Review Committee. The purposes of this independent review are to provide candid and critical comments that will assist the authors and the National Research Council in making the published report as sound as possible and to ensure that the report meets institutional standards of objectivity, evidence, and responsiveness to the study charge. The content of the review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following persons for their participation in the review of this report:

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Irwin S. Bernstein, *Chair*
Committee on Well-Being of
Nonhuman Primates

Contents

Executive Summary

Psychological well-being refers to mental state. It cannot be defined in terms of the environment, although environments certainly influence individual well-being. It cannot be equated with an activity or behavioral profile, although individual status influences behavior. It is not synonymous with any physiological state, although physiological condition and psychological well-being interact. Psychological well-being is influenced by meeting the needs of an individual animal that are based on its species, sex, age, and developmental experiences. Its assessment must be based on multiple indexes:

- The animal's ability to cope effectively with day-to-day changes in its social and physical environment (with reference to meeting its own needs).
- The animal's ability to engage in beneficial species-typical activities.
- The absence of maladaptive or pathological behavior that results in self-injury or other undesirable consequences (see Bayne 1996 for a discussion of the normal and abnormal behaviors).
- The presence of a balanced temperament (appropriate balance of aggression and passivity) and absence of chronic signs of distress as indexed by the presence of affiliative versus distress vocalizations, facial expressions, postures, and physiological responses (e.g., labored breathing, excessive cardiac response, and abnormal hormonal concentrations).

The assessment should be based on the behavior of an individual animal and not simply on normative physical and behavioral profiles of the species. Although behavior that deviates from species-typical patterns warrants further exploration, the expression of atypical behavior in an animal might not be sufficient evidence to infer a serious detriment in psychological well-being. The first sign of any abnormality is often a change in behavior. If the atypical behavior of an animal can be attributed to its age and sex, the behavior might be persistent and acceptable for that animal. Whereas it might be argued that rearing conditions and treatments that lead to atypical behavioral profiles should be avoided as undesirable, animals already reared under such conditions can be maintained in ways that are supportive of their individual psychological well-being as an amelioration of unusual behavior patterns caused by their earlier life experiences.

Assessment of psychological well-being should be based on the factors listed above. For example, the brief occurrence of symptoms associated with stress is not evidence of a chronic state of distress. The entrance of an unfamiliar person into an animal colony room might provoke expressions of acute fear from animals that do not ordinarily exhibit such symptoms. Furthermore, the absence of all environmental stressors is not required to prevent distress; in fact, the elicitation of normal effective coping responses to the minor stressors of life can be beneficial.

Nevertheless, in the assessment of a program designed to provide for the psychological well-being of nonhuman primates, all recognizable instances of behavior and physiology that deviate from the species normative pattern warrant further inquiry. Such instances should be noted, and colony records should indicate that an appropriately trained person offered a provisional diagnosis and instructions for disposition of the case. Once an appropriate person has assumed responsibility for remediation or has prescribed for the psychological well-being of the animals in question, this should be regarded as an appropriate clinical response.

A well-designed plan to provide for the psychological well-being of nonhuman primates must also provide for their physical well-being. Providing for psychological well-being, however, might require some compromise with standards for maximizing sanitation and isolating individual animals from all sources of potential contaminants. Beyond reasonable physical well-being, psychological well-being is enhanced by

- Appropriate social companionship.
- Opportunities to engage in behavior related to foraging, exploration, and other activities appropriate to the species, age, sex, and condition of the animal.
- Housing that provides for suitable postural and locomotor expression.
- Interactions with personnel that are generally positive and not a source of unnecessary stress.

Absolute standards or minimums are neither possible nor desirable for each of those four characteristics, because of the great variability of each animal's previous history and needs and the variability among the institutions holding them. No single solution will always be best, and at present the research required to substantiate recommendations is still in the future. We know that the needed social companionship depends on species, age, sex, and rearing history and ranges from sensory contact to direct association with multiple other animals. We know that the utility of devices designed to provide opportunities for foraging and exploration depends on the same variables. We know that housing requirements depend on bodily dimensions, normal postures, and locomotor patterns (e.g., arm swinging versus bipedal leaping versus quadrupedal striding or climbing). We know that some animals rarely tolerate close human contacts, whereas others seem to respond positively to familiar humans. Quantitative specification of minimums for each characteristic might be considered desirable by some, but it is important that standards be validated against performance; that is, do the specified characteristics actually improve the psychological well-being of the affected animals?

Nevertheless, a comprehensive program to improve the psychological well-being of nonhuman primates will attend to each of the variables and include a means to test and assess the influence of each. The benefits of providing a cage companion, an enrichment device, a cage of design and dimensions that appeal to a human's aesthetic sense, and a sensitive caregiver to interact with the animals should be validated and documented. A performance standard should be used to show whether the provided features increase the diversity and amount of normal behavior and decrease the frequency and duration of behavior that results in self-injury or other undesirable consequences. Social companions must be conducive to positive affiliation rather than be a source of stress and a cause of avoidance; an inappropriate companion can be worse than no companion at all. Enrichment devices do their job when they provide otherwise-absent opportunities to engage in species-typical foraging and exploratory activities, but a device that requires excessive time for foraging at the expense of social or other species-typical activities is not an enrichment. Likewise, enrichment devices can be used by multiple animals, but they should not become a source of competitive conflicts. Cage dimensions and furnishings are suitable if they allow for expression of normal postures and locomotor expression, as opposed to open unused spaces and furnishings that do not allow for normal postural positions. Human interactions should provide for activities that the animals appreciate, rather than simply provoke animal activity.

The four bulleted items listed above are related. Whereas spatial requirements are based on individual needs, social housing need not mean that spatial requirements for one animal are multiplied by the number of animals housed. If housing provides sufficient space for one animal to express a normal locomotor pattern, a second animal has access to the same space for locomotor expression minus only the volume of space actually occupied by the first animal. For example, if housing needs to be 2 m high to provide sufficient vertical space for an animal's postural and locomotor needs, two animals do not need vertical space 4 m high. Floor areas likewise need not be simple multiples; in fact, for arboreal animals that normally flee upward and spend much of their locomotor time climbing, floor areas might be secondary to vertical space in providing for postural and locomotor expression. The volume of space available, rather than floor area, might be critical for nonhuman primates. Guidelines for minimal space for primates should be reassessed on the basis of such considerations (NRC 1996).

Whereas we know some of the relevant dimensions that influence psychological well-being in nonhuman primates and some of the outcomes that we hope to attain by proper specification of such characteristics, we cannot specify the exact measurements required for each of the many species and for individual animals of every age, sex, and life history. But we can expect institutions to monitor and assess the conditions of animals in their charge and to make appropriate efforts to improve conditions that do not meet the criteria of psychological well-being.

In sum, whereas a great deal is known about the natural history and behavior of nonhuman primates held in captivity, much more information is required. While some research areas are discussed in Chapter 10, the use to which this information is to be put should be unequivocal—the furtherance of performance goals through the enhancement of knowledge. Even with substantially greater information, the development of prescriptive recipes for primate well-being would not be desirable. A variety of solutions might achieve the same general goal: animals that are maintained under conditions that promote their physical and psychological well-being. The aim of research in this area should be to find means by which to assess psychological and physical well-being and to provide the knowledge necessary to develop programs to achieve this general goal. Animals maintained for research, exhibition, or education can all be maintained under conditions that are consistent with this goal and that will provide for their well-being. It is the responsibility of all who keep nonhuman primates to ensure that personnel are appropriately trained to develop procedures consistent with the goals of the institution and the psychological and physical well-being of the animals in their charge.

Introduction

The debate over the use of animals in research and exhibition involves issues of morality and ethics, as well as questions of scientific merit and appropriate husbandry. In recent years, public concern about the use of animals has been conveyed with increasing frequency to members of Congress. In 1985, Congress responded to the concern by amending the Animal Welfare Act of 1966 and 1978 to include a provision that was to have a substantial impact on all those who use primates, whether for research, for exhibition, or for other purposes. The new provision promulgated by the U.S. Department of Agriculture (USDA) as regulations in 1991 states that "dealers, exhibitors, and research facilities must develop, document, and follow an appropriate plan for environmental enhancement adequate to promote the psychological well-being of nonhuman primates." Consequently, it is incumbent on all those who care for, use, or regulate the use of primates to grapple with the problem of how to evaluate the "psychological well-being" of these animals. Because of the great variety of needs of the many nonhuman primate species and the lack of understanding of their mental states, the sponsors of this report asked the National Research Council (NRC) to recommend ways in which to assess and promote psychological well-being. In response, NRC asked a committee of experts to develop such recommendations, which constitute this report. The purpose of this volume is to help scientists, veterinarians, curators, inspectors, duly appointed committees, and others concerned with the psychological well-being of nonhuman primates to deal more effectively with this complex issue.

Because verbal instruments are not suitable to assess psychological well-being in animals, some people have advocated the use of engineering standards, which focus on easily measured aspects of the physical environment. Others have argued that the performance of the animals should be used to assess psychological well-being. There has been considerable debate over the use of engineering versus performance standards (Novak and Drewson 1989; Sackett 1991).

The USDA, the agency with primary authority for enforcing the Animal Welfare Act, initially preferred engineering standards, which had been the cornerstone of all previous regulations. In the absence of performance measures to validate the efficacy of physical manipulations, however, it proved very difficult to identify the environmental features that promoted psychological well-being. For example, USDA initially proposed to alter cage sizes, assuming that larger cages would promote psychological well-being.

However, results of studies of the effects of cage expansion did not indicate that the change reduced abnormal behavior (Bayne and McCully 1989; Line and others 1990c); tension and aggression actually increased in some cases in which group-housed monkeys were given more floor space (Erwin 1979; Novak and Drewsen 1989). USDA also suggested that captive primates be given access to enrichment devices. However, it is often not clear what specific benefits enrichment devices provide or which devices actually provide enrichment, inasmuch as there are enormous individual and species differences in responses to such devices.

As a consequence of the inadequacy of an engineering approach to psychological well-being, the committee believes that the focus should be on the primates themselves and on their reactions to various features of life in captivity. This emphasis on performance standards presupposes that explicit criteria are available for the evaluation of psychological well-being. Although psychological well-being implies a subjective mental state or private experience, the practical need for observable criteria as a basis for assessment is imperative. As a first step toward developing such criteria, assessments of psychological well-being should look for signs of chronic distress as manifested in maladaptive or pathological behavior.

The essential next step is to decide on the signs of distress and on what constitutes maladaptive or pathological behavior (see also discussions of causes and signs of distress in NRC 1992). Meaningful judgments will involve some subjective component based on the observer's perceptions, experiences, and values, as well as reflect knowledge about the animal whose psychological state is being evaluated—ideally, knowledge based on experience with the species. Human perceptions and values, unless tempered by an understanding of the other species, can be a poor basis for judgments about psychological well-being. Many animals not only live their everyday lives under conditions that humans would find unendurable, but prosper in these circumstances. The natural lives of rats, lions, alligators, and giraffes differ from each other and from ours in myriad ways. So do the requirements of those species when they are maintained in captivity. Clearly, the criteria used to assess the psychological well-being of any species should be based on the best available information about that species.

That is also the case when the animals are primates. The need for information about particular species might be less widely recognized, however, when the animals are monkeys or apes. Resemblance of those animals to humans in appearance and behavior encourages the assumption that they have identical needs and abilities. But that cannot be accepted uncritically. Nonhuman primates are a highly diverse group. They not only differ from humans in many respects, but also differ widely from each other. Their normal behavior, needs, and abilities differ from one taxonomic group to another.

Their diversity is easier to accept when one considers that there are more than 200 species of primates. In addition to humans, primates include apes, New World and Old World monkeys, and an assortment of other forms collectively referred to as prosimians, such as tarsiers, lemurs, aye ayes, and bushbabies. Nonhuman primates range in size from the diminutive mouse lemur, weighing only a few grams, to the gigantic mountain gorilla, weighing more than 180 kg. Species also differ in habitat, diet, activity patterns, use of space, reproductive physiology, growth rates, social relationships, and cognitive abilities. Few of the species are used extensively in research. Although more are maintained in zoos, some are rarely or never found in captivity. Information is lacking on the natural history, biology, and behavior of many species (Fleagle 1988; Smuts and others 1987).

All primates are placed taxonomically in a single group called an order. The order Primates is subdivided into the traditional taxonomic categories, such as suborders, infraorders, superfamilies, families, subfamilies, genera, and species. The informal scheme that follows is consistent with the accepted system of classifying primate species (for example, see Fleagle 1988; Napier and Napier 1967, 1985) and will be adequate for our purposes.

The *prosimians* include tarsiers, lemurs, sifakas, indris, aye ayes, lorises, pottos, and bushbabies or galagos (Fleagle 1988). Tree shrews, once considered in this group, have now been removed from the Primate order on the basis of structural considerations, most notably in the ear, and by early fossil differentiation. Most prosimians have pointed muzzles, a naked rhinarium (a moist patch of bare skin around the nose), and claws instead of nails on some fingers and toes. Many species of prosimians are nocturnal. Few institutions maintain them in captivity, but some lemurs, especially the ring-tailed lemur *L. catta*, and some species of *Galago* are found in exhibits.

The *anthropoids* include all other species in the Primate order. These animals conform to the popular view of what a monkey or ape should look like. A popular distinction between monkeys and apes is that monkeys have tails. It is true that apes are tailless, but some monkeys are also virtually tailless. A more basic distinction within the anthropoids is between New World and Old World forms. New World anthropoids are distinguished from Old World anthropoids by having three rather than two premolars (bicuspids) and by having a broader septum between the nostrils.

New World primates are found in Central and South America. They are known collectively as Platyrrhines and include marmosets, tamarins, howler monkeys, spider monkeys, capuchin monkeys, woolly monkeys, squirrel monkeys, night monkeys, titi monkeys, sakis, and uacaris. Some species of marmosets (genus *Callithrix*), tamarins (genus *Saguinus*) and squirrel monkeys (genus *Saimiri*) are often used in laboratory research (Bennett and others 1995; UFAW 1987) capuchins (genus *Cebus*) and night (or owl) monkeys (genus *Aotus*) are used less often. Other species of New World monkeys are used little or not at all for research but can be found in zoos.

Old World primates in their natural habitat are found mainly in Africa and Asia, although some species exist as introduced populations throughout the world. Old World primates include humans, apes (chimpanzees, gorillas, orangutans, and gibbons), and many monkey species. Because of their close phylogenetic relationship to humans, chimpanzees (genus *Pan*) are the subjects of choice for some kinds of biomedical research and for investigations of cognitive abilities, including the acquisition of language (NRC 1997b; Savage-Rumbaugh and others 1998). The monkeys most often encountered in laboratories are the macaques (genus *Macaca*), especially rhesus monkeys (M. *mulatta*). Pigtail monkeys (*M. nemestrina*), crab-eating monkeys (*M. fascicularis*), baboons (genus *Papio*), and vervets or green monkeys (*Cercopithecus aethiops*) are also relatively common in laboratory research, whereas other forms—such as mangabeys, talapoins, guenons, and patas—are seldom used and are generally found only in exhibits. The leaf-eating monkeys (*Colobus, Presbytis*, and related genera) are also less commonly seen, even in exhibits.

There is no one correct taxonomic list of primates, and no comprehensive list is attempted in this report. Each of the taxonomic chapters (Chapter 5-9) includes an introduction to the major groupings in its taxon and the common and scientific names of species most likely to be found in captivity. In addition, lists of the generally accepted scientific names and typical common names that are used in referring to the primates mentioned in this report are provided in the front of Chapters 5-9.

In spite of the many important variations among primate species, these animals share several features that, in combination, set them apart from most other biological groups. The primates are characterized by developmental periods that are long for mammals of their size (especially the periods of gestation and infant dependence), exceptional ability to modify behavior (intelligence, learning capacity, and behavioral flexibility), and prominent and consistent sociality associated with highly differentiated social relationships.

Both the qualities common to all primates and the attributes peculiar to particular species must be considered in establishing standards for promoting and assessing psychological well-being. That requirement is reflected in the organization of this volume. The first four chapters deal with general issues. Chapter 1 is concerned with principles and criteria of psychological well-being that apply to all primates—and indeed to many nonprimates. Chapter 2 deals with the essential elements of an effective institutional program designed to ensure well-being. Chapter 3 reviews basic institutional procedures and routines from the standpoint of their impact on psychological well-being. Chapter 4 considers the challenges to well-being created by special conditions and procedures that might be required by research protocols. Each of the next five chapters deals with the particular attributes and requirements of a specific biological group in the Primate order.

The recommendations presented in this volume are based on the collective experience of the committee and the information available to it. It should be emphasized, however, that many gaps exist in our knowledge of psychological well-being in nonhuman primates. The problems are multifaceted and cannot be wholly divorced from broader concerns regarding conservation, primatology, the effective and judicious use of primates in research, and other uniquely human enterprises. Even apart from those complex issues, research directly focused on psychological well-being is in its infancy. Chapter 10 suggests some of the pressing research needs. It is hoped that the contents of this volume will be reviewed within the next 5 years and that new information on psychological well-being will yield revisions and updates.

1

Principles of Psychological Well-Being of Nonhuman Primates

The use of the term *psychological well-being* in the development of legally mandated regulations has created concern and continuing controversy. Some have tried to equate psychological well-being with engineering standards that specify physical dimensions, such as square meters of floor space or types of cage furnishings. Others have argued that psychological well-being is a function of individual preferences and therefore cannot be defined broadly. Still others have suggested replacing *well-being* with such terms as *environmental enrichment*. Those views are problematic and in some cases inaccurate. Indeed, attempts to relate psychological well-being strictly to physical features, such as cage size, have been largely unsuccessful and unproductive (Crockett and others 1993a). In contrast, the view that psychological well-being is so variable among animals that it cannot be defined might be unnecessarily pessimistic.

Replacement terms, such as *environmental enrichment*, are also problematic because they refer to different processes. *Environmental enrichment*, although sometimes used interchangeably with *psychological well-being*, is an independent variable that refers to manipulations to improve the environments of captive primates to enhance psychological well-being. *Enrichment* is used in the sense of providing for species-appropriate activities in an otherwise restrictive and limited environment. In contrast, psychological well-being is an abstraction that is inferred by measuring behavioral and physiological variables in the affected primates to determine whether a manipulation had the desired effect.

The assessment of psychological well-being is based on the responses of animals to their environment. Multiple measures will be required in this assessment (Novak and Suomi 1988, 1991; Snowdon and Savage 1989). An emerging consensus suggests that in addition to physical health the following criteria are important in assessing psychological well-being:

- The animal's ability to cope effectively with day-to-day changes in its social and physical environment (with reference to meeting its own needs).
- The animal's ability to engage in beneficial species-typical activities.
- The absence of maladaptive or pathological behavior that results in self-injury or other undesirable consequences (see Bayne 1996 for a discussion of the normal and abnormal behaviors).
- The presence of a balanced temperament (appropriate balance of aggression and passivity) and absence of chronic signs of distress as indexed by the presence of affiliative verses distress vocalizations, facial expressions, postures, and physiological responses (e.g., labored breathing, excessive cardiac response, and abnormal hormonal concentrations).

None of those criteria can stand alone as the defining measure of psychological well-being in captive primates. However, when used together, they might provide a detailed picture of a primate's psychological health.

In assessing general well-being, physical health is probably the easiest to assess on the basis of established veterinary procedures for captive nonhuman primates (Bennett and others 1995; Keeling and Wolf 1975). Routine health examinations given at specified intervals are usually supplemented with daily inspections of an animal to monitor for such variables as hair condition, alertness, gait, appetite, body weight, and injury. The inspections can be used to identify potential problems in both psychological and physical well-being. Good physical health, however, is not synonymous with good psychological health. Psychologically disturbed animals might appear to be in good physical condition, and evidence of poor physical condition does not preclude psychological well-being. For example, elderly monkeys can show signs of clinical disease, such as arthritis, but maintain social ties, breed successfully, and appear alert and responsive to environmental stimuli.

Two general principles are important in assessing behavioral indicators of psychological well-being. First, there should be behavioral diversity; animals should exhibit a broad range of species-typical patterns of behavior. That does not mean that every species-typical behavior described for a given species in nature need be exhibited by captive members of that species; this is neither possible in all cases (e.g., providing space equivalent to an animal's daily movements in nature) nor necessarily desirable (e.g., recreating intertroop conflicts, predator attacks, weather extremes, droughts, and environmental hardships). But captive primates should be provided with suitable opportunities to express a variety of species-typical behavior.

The second principle is that some kinds of species-typical behavior might be better indicators of psychological well-being than others. For example, reproductive success (including reproductive behavior, fertility, prenatal adequacy, birth, and parental care) is often considered to be a good indicator of psychological well-being, but not all captive primates are of breeding age (they might be too young or too old), and some might be deliberately maintained in nonbreeding situations; furthermore, some types of reproductive failure (e.g., infertility) are not necessarily linked to poor psychological well-being. It could be argued that we should focus on searching for evidence of ill-being as represented by self-biting or bizarre, idiosyncratic activities, such as back-flips, eye-pokes, and hair-plucking. Although behavioral stereotypies might represent psychological disturbance brought about by environmental factors (Draper and Bernstein 1963), similar behavioral symptoms could result from atypical developmental processes and not be eliminated by manipulating housing. Nonhuman primates reared in deprived social environments during the first year of life often develop idiosyncratic behavior—such as rocking, self-clasping, and self-mouthing—as a replacement for maternal activities (Fritz 1986; Fritz and Howell, 1993a). Such patterns might persist for the life of the animal, and their appearance can reflect early rearing experience, rather than distress in the present environment (Mason and Berkson 1975). Some physical ailments can also be manifest in such symptoms as self-biting. Monkeys that develop reactive arthritis after shigella infections sometimes bite the affected limb, but in this case medical treatment will improve limb mobility and eliminate self-biting.

Thus it is extremely important to determine the etiology of atypical behavioral patterns before recommending any form of intervention. In some cases, medical treatment will be required; in others, environmental manipulations might be effective. Developmentally induced stereotypies are less amenable to treatment, but they can generally be avoided by rearing infant primates in a species-typical social environment. The severity of developmental abnormalities varies with the degree of early social deprivation. The most extensive data available come from rhesus monkeys (*Macaca mulatta*) and indicate that physical contact with social companions is essential for normal development (Mason 1991). If such contact is restricted to the mother alone or peers alone, some social deficits can persist for life (Mason 1991). Whereas limiting access to peers in a playroom situation seems to be less damaging than other forms of social restriction, the full range of species-typical behavior, including effective reproductive behavior, is more likely in animals given a sufficient amount of species-typical social experience. Only in a common enclosure can monkeys learn the consequences of their own actions on the behavior of social partners. It is that dimension of responsiveness that distinguishes social partners from inanimate objects.

When research protocols demand restrictions on early social experience, the institution should be prepared to deal with the long-term husbandry problems associated with such rearing practices. The atypical behavior exhibited by monkeys so restricted might reflect idiosyncratic devices to cope with early environmental deprivation, and in such cases direct intervention to disrupt the atypical behavior could be harmful. In cases documented to result from early rearing conditions, the atypical behavior cannot be taken to mean that the animal is not being well cared for, given its early rearing experience.

Reducing stress is often considered the best way to promote the psychological well-being of captive primates, the assumption being that stress is the antithesis of well-being (Moberg 1985). However, stress occurs in many forms, both positive and negative, as noted by Selye (1974), who divided stressful stimuli into "eustress" and distress. It might be more useful to look for signs of distress in captive primates, such as chronic or excessive fear, grimacing, withdrawal, altered breathing, distress vocalizations, anorexia, or unusual postures (Morton and Griffiths 1985; NRC 1992).

The manner in which an animal adapts to environmental changes or brief environmental disruptions (e.g., cage-cleaning) can provide information about its psychological state (Mineka and Kihlstrom 1978; Mineka and others 1986). At issue are the appropriateness of the reaction, given the particular kind of disruption, and the time that it takes an animal to adjust to the temporary or new situation. One can examine adaptation in monkeys by evaluating their reactions to temporary but routine husbandry events, such as being removed from their home cage, or to more permanent events, such as a change in cage location.

The ability to adapt to change is a manifestation of a broader capability: to exhibit behavior appropriate to the environmental context. For example, it is expected that socially reared nonhuman primates will display a broad range of species-typical behavior and express the behavior patterns in relevant contexts. Such animals should interact in a socially competent, species-characteristic manner with cagemates (if present). They should not limit their movement through space to a small part of the environment or to a single repetitive pattern, such as pacing, but rather should display a variety of species-typical locomotor patterns.

Identification of species-typical patterns of behavior has depended heavily on studies of behavior in the natural environment. Some of the characteristics of wild populations that are thought to be relevant to captive primate well-being are the nature of social organization, mating system (e.g., monogamous), group size, group composition, spacing patterns, patterns of emigration and immigration, nature of habitat (e.g., open grassland or dense foliage), range of locomotor patterns (e.g., terrestrial or arboreal), food availability and dietary selection, sleeping places, nocturnality or diurnality, sedentary or mobile activity, feeding patterns, reproduction, age at sexual maturity, seasonality of breeding, parental care, communication, movement patterns, and normal postures of resting and sleeping. A plan for psychological well-being should take such characteristics into account. It should be noted, however, that there is a tremendous disparity in the amount of information available on the various species of primates held in captivity.

Even very closely related species (i.e., members of a genus) can differ substantially in behavior. For example, bonnet macaques (*Macaca radiata*) typically exhibit little intragroup aggression and show considerable group cohesion.

Female bonnet macaques display aunting behavior to the extent that infants develop close attachment bonds with adult females other than their own mothers; loss of a mother does not greatly alter the behavior and physiology of infant bonnets, because they are generally adopted by other females (Reite and others 1989). In contrast, pigtail macaques (*M. nemestrina*) typically exhibit greater intragroup aggression and less social cohesion than bonnet macaques (Kaufman and Rosenblum 1967). Mothers are highly protective of their infants, restricting their activity to the extent that the infants do not form social bonds with other unrelated adults in the social group; loss of a mother can result in profound behavioral and physiological changes in infants (Reite and others 1981) and can have adverse long-term behavioral consequences (Capitanio and Reite 1984) and immunological consequences (Laudenslager and others 1986, 1996).

Even within a species, substantial individual differences in behavior can influence our interpretation of psychological well-being. Nonhuman primates are known to exhibit marked individual differences in "personality" (Caine and others 1983; Stevenson-Hinde and Zunz 1978; Suomi and Novak 1991). Macaques, for example, display relatively stable differences in temperament that have behavioral and physiological analogues. Both genetic mechanisms (Boccia and others 1994) and experience (Capitanio and others 1986) are probably involved.

A sudden change in the appearance or behavior of an animal might indicate a problem. For example, a shift from normal to unusual behavior might indicate a deterioration of the animal's well-being and warrant attention. Conversely, alterations of behavior in response to environmental manipulations (e.g., enrichment attempts) can be used to validate an intervention if undesirable behavior (e.g., self-biting) declines and normal behavior increases.

In summary, we expect animals in a state of psychological well-being to engage in species-typical behavior if given the opportunity to do so, to be capable of coping with minor disruptions in routine, and to display a balanced affect (as opposed to behavior that is indicative of chronic distress) and a behavioral repertoire that does not include maladaptive or pathological behavior. The best ways to fulfill such expectations are discussed in the next three chapters: programs to promote psychological well-being, general considerations of animal care, and special conditions related to research requirements.

2

Essentials of a Program to Provide Psychological Well-Being

> We should emphasize the following points: freedom or reasonably spacious quarters, fresh air and sunshine, preferably coupled with marked variations in temperature, cleanliness of surroundings as well as in the body; clean and carefully prepared food in proper variety and quantity; a sufficient and regular supply of pure water; congenial species companionship and intelligent and sympathetic human companionship, and finally, adequate resources, both in company and in isolation, for work and play (Yerkes 1925).

Current regulations require that facilities develop, document, and follow a plan for promoting the psychological well-being of captive nonhuman primates (9 CFR, Subchapter A). The plan must address the social needs of the primates housed in a facility and provide some form of environmental enrichment, that is, opportunities for the expression of species-typical activity. Beyond those general requirements, however, the specifics are left to individual institutions. This strategy is a direct acknowledgment of the impossibility of developing a single, overarching plan that can promote psychological well-being in all individual members of every species of nonhuman primates in all possible housing conditions.

Psychological well-being is directly related to life history and to the unique adaptations of each species to its ecological niche (Novak and Suomi 1991). Psychological health is also a function of the unique life experiences of individual animals. Thus, the environmental conditions that promote the psychological well-being of primates will necessarily differ as a function of developmental experiences, species, sex, and individual differences (Lehman and Lessnau 1992;

Line and others 1991; Novak and Suomi 1988; Novak and others 1993; O'Neill and Price 1991; Suomi and Novak 1991).

Nevertheless, it is possible to identify the important elements that should be considered in designing a program to promote the psychological well-being of captive nonhuman primates. The maxims presented by Yerkes (1925) many years ago concerning the husbandry and well-being of apes still serve as useful guidelines as we move beyond taking care of only the physical needs of nonhuman primates to try to provide for their psychological needs. Yerkes's views on social housing, the importance of work and play, the need for congenial and capable caregivers—all presaged contemporary views about primate psychological needs. We believe that a well-designed plan to provide for psychological well-being should promote balanced or positive temperament as defined in the previous chapter. To achieve these goals, the plan should include

- Appropriate social companionship.
- Opportunities to engage in behavior related to foraging, exploration, and other activities appropriate to the species, age, sex, and condition of the animals.
- Housing that permits suitable postural and locomotor expression.
- Interactions with personnel that are generally positive and not a source of unnecessary stress.
- Freedom from unnecessary pain and distress.

SOCIAL COMPANIONSHIP

Social interactions are considered to be one of the most important factors influencing the psychological well-being of most nonhuman primates. A social environment enables nonhuman primates to perform many species-appropriate activities, including grooming, play, sleeping huddles, and sexual behavior. Moreover, partners contribute to meeting other psychological needs by providing variation (e.g., social interactions that are not completely predictable), challenge (e.g., competition for access to objects), and opportunity for control (e.g., play bouts) (Mineka and Kihlstrom 1978; Mineka and others 1986). Most primates normally live in social groups, and they should be socially housed if they are to express many aspects of their normal behaviors. However, the introduction of strange cagemates should be done gradually under conditions that minimize the likelihood of injurious aggression. For example, compatibility might be assessed by observing animals while they occupy adjacent cages, before allowing them to interact (Reinhardt 1989a).

Knowing that most primates benefit from social interactions, it should be obvious that they can be harmed by a lack of social interaction. Harlow and Suomi (1971), Harlow and others (1971), Novak (1979), and numerous others have elicited profound behavioral problems by rearing infant and young macaques without mothers or peers. Davenport and others (1973) and Fritz (1986) reported on problems encountered in the resocialization of chimpanzees that had been maintained without appropriate social conspecific interaction. The manifestations of inadequate early rearing include a broad range of species-inappropriate behaviors, such as the inability to cope with stress as evidenced by self-biting; lack of appropriate breeding and parental skills; rocking, eye-poking, and other stereotypic behaviors; coprophagy; and inability to interact appropriately in social situations. Many of these behaviors are refractory to change and persist for life; at best remediation programs are labor intensive and expensive. Clearly, the goal of housing nonhuman primates is to avoid the development of behavior problems through the careful planning, execution, and assessment of an institutional strategy, or plan, for ensuring the psychological well-being of the animals.

Although social housing is a critical component of psychological well-being, careful consideration is required in developing the procedures to achieve this objective. Because of the xenophobic reactions of many primate species, which can result in severe aggression to strangers, attempts to pair monkeys or create social groups must be handled with care (Clarke and others 1995). A number of different strategies—which vary according to the species, age, sex, and social experience—are possible for forming pairs or groups of primates (Coe 1991; Cooper and others 1997; Crockett and others 1997; Fritz 1986, 1989, 1994; Reinhardt 1988, 1989a, 1991a; Vermeer 1997). It should be remembered, however, that many species of primates express social dominance, and fighting between animals can occur (Bayne and others 1995). Although unfamiliar rhesus monkeys can be introduced to one another and become compatible pairs (Reinhardt 1989a), it is not so easy to introduce a rhesus monkey into a previously established group, because of the likelihood of a severe group attack. Rhesus groups are best formed with total strangers so that individuals are protected by the “organized chaos” of the group (Bernstein 1964). Other species, with different social dynamics, such as capuchins, present different challenges (Fragaszy and others 1994).

As with all close human-nonhuman primate interactions, personnel safety should receive the utmost consideration when forming pairs or groups of primates. The ability to separate incompatible animals should be well planned before new introductions.

Although a social living situation is important, there can be practical and scientific reasons for using individual housing, such as research protocols, medical conditions, the possibility of disease transmission, hyperaggressiveness, and hypersubmissiveness. When experimental protocols require individual housing, nonhuman primates should, whenever it is possible, have visual, auditory, or olfactory contact with each other. Animals that have been individually housed, even for long periods, have been successfully resocialized when efforts have been made to find compatible companions.

OPPORTUNITIES TO ENGAGE IN SPECIES-TYPICAL ACTIVITIES

The ideal environment for a nonhuman primate fosters the expression of desirable species-typical activities and does not distort the expression of normal behavior. In order to discuss the environment, however, one should first have an understanding of what species-typical activities will support a conclusion that the environment is achieving the goal of enabling individual well-being. Several factors should be considered, and knowledgeable judgment should be used in applying them:

Species-typical activities in the wild. A basic understanding of the behavior of a species in the wild is essential if that species is to be maintained in captivity. That is, does the species live in large groups like squirrel monkeys, or is it relatively solitary like orangutans? *What type* of social group does it have; do either young males or females emigrate from the parent group? Are social groups stable, or are they loosely connected and do they come together primarily for mating? Does the species locomote and sleep in trees, or on the ground? Does it make nests? Does it eat a variety of foods, including some meat, like macaques, or is it more limited to leaves and other plant parts like the colobus? There are many other similar questions one might ask, each varying in importance among the species. These are discussed in more detail in Chapters 5 through 9.

In addition to knowing what each species does, an understanding of the "time budget" devoted to its principal activities (i.e., foraging, eating, locomoting, grooming, and sleeping) is desirable (Marriott 1988), but an absolute mirroring of this time budget in captivity is neither practical nor necessary. Some animals might devote the majority of their waking time to foraging, but in the process they might cover many miles. Providing the same time budget for foraging in captivity, without the associated exercise-related activity of locomotion, will likely produce obesity. This suggests the need to provide other types of activities and to reexamine diets. Other behaviors adapted for the wild, such as alarm calls for snakes or hawks should be recognized as alarm calls for unexpected occurrences (such as a broken water pipe, escaping steam, or an animal escaped from its cage) in the captive environment. On the other hand, captive environments that are created without a reasonable appreciation for how animals spend their time in the wild can result in expressions of qualitatively normal behaviors that are quantitatively harmful. Grooming of self or others to the point of baldness is a common example.

Knowledge of individual animal's previous history. As important as understanding "normal" species-typical activities in the wild is an appreciation for how an animal has been raised in captivity. A normally social animal raised for years in a semisocial environment (e.g., a room with multiple animals all in single cages) *might* not readily adapt to a normal social grouping, although studies have shown that this is not invariably the case. Some become adapted to people and develop close bonds with them, whereas others are highly stressed when people are near.

Nature of the research. Some research requires housing conditions that restrict the movement or social interactions of animals. In such cases, efforts should be redoubled for these animals, *when it is compatible with the protocol*, to compensate for their well-being in other ways, e.g., provision of food treats and "toys" with which they will interact.

Types of research facility and housing opportunity. Metropolitan medical centers have less space for holding animals than suburban settings. Not all facilities can have the option of large multi-acre outdoor facilities, but that does not make indoor or indoor-outdoor settings less capable of providing for the well-being of the animals. Each has its strengths and limitations—animals in a large paddock are more difficult to treat when they are hurt than are those in smaller environments—but each has the potential to provide all aspects of the well-being of most species.

Each of those considerations—behaviors in the wild, rearing conditions, nature of the research, and type of housing—should be addressed in answering the question, What is meant by a suitable expression of species-typical activities with which an animal's well-being can be assessed? The answer to that question is what this book is all about.

Many captive environments do not allow for the expression of the full range of desirable species-typical activities, such as foraging and exploration, unless they are enhanced by providing devices that foster such activities. Key to the establishment of environmental enrichment and the enabling of species-typical behaviors are the concepts of habituation and interest. Objects that retain their interest for the animal have a higher probability of contributing to the well-being of an animal, whereas objects that lose interest for the animal or to which the animal becomes habituated contribute little to well-being. Assessment of interest should be a continuing aspect of all environmental enrichment programs.

Throughout this text we use the terms *species-typical* and *species-appropriate* to refer to behavior that knowledgeable observers might consider normal and desirable. The most reasonable interpretation of what behaviors are normal and appropriate should take into account behavior of the species in the wild; time budgets, or quantity of time devoted to each behavior; and the quality of the behavior as exhibited in captivity. For example, social grooming is commonly seen in the wild and is considered a desirable species-typical activity in captivity. But when grooming is exhibited at the expense of other normal behavior, it becomes an undesirable excess of a species-typical behavior. Whereas grooming is desirable, overgrooming is not, and it represents a time budget out of balance and a warping of the quality of the behavior that results in a distortion of the numerous behaviors that the species commonly exhibits. (See also Erwin and Deni 1979.)

Providing animals with opportunities to engage in species-typical activities includes providing opportunities for them to control and predict environmental changes. Providing suitable opportunities for self-initiated activities (e.g., wood chips to permit foraging, and social companions with which to groom or play) allows animals some degree of control. When a routine is under human control (e.g., cleaning, feeding, and experimental manipulations), clear signals of the nature of the activity allow animals to anticipate and adapt to events. When a routine is essentially innocuous to the animal, clear signals that identify an environmental change as part of a familiar routine can be beneficial. On the other hand, pleasant surprises, such as treats and favored activities, need not be so routinized. Similarly, when procedures involve some level of discomfort to an animal, long anticipatory periods signaling the impending event can be a source of distress.

Individual animals can control some features of their environment through self-initiated activity if opportunities are provided. Even though an activity might be repetitive and the material familiar, animals can control some of the changes in their environment. This control, or "work," is a common feature of the activity of animals in natural settings and can take many forms (Reinhardt 1993, 1994a).

A degree of environmental control and challenge and the opportunities to engage in species-typical activities can be provided through enrichment techniques that provide opportunities for voluntary interaction. Such opportunities should be oriented to the animals' physical and cognitive capabilities, rather than aesthetic appearance. Enrichment devices should be carefully selected on the basis of the behavior that needs opportunities for expression. An enrichment program should be customized to the animals and the institution; what is successful in one facility might not work in another (Bayne and others 1993b). Enrichment devices can be used for both individually and socially housed primates; in the latter case, the devices should stimulate social interest and play, not competition that leads to fighting.

Environmental enrichment is a broad classification that encompasses various methods. For example, such cage furnishings as perches, shelves, and tunnels have been used to increase the comfort of animals by allowing them to get off the cage floor, assume a variety of physical postures, engage in various physical activities, and escape the attention of others when socially housed (Neveu and Deputte 1996). Methods to increase species-typical behaviors, such as foraging activities, include hiding food in wood shavings or wood wool spread on the enclosure floor (Chamove and others 1982), using foraging puzzles that require an animal to discover the presence of food in a container and implement a strategy to obtain it (Hayes 1990; Murchison 1995), spreading particulate food on foraging boards to increase the time spent in collecting it (Bayne and others 1992b), and placing food in different locations within the primary enclosure and so requiring an animal to move around its home to obtain food. The use of such devices can vary widely, and provision should be made to ensure that every animal receives its daily ration of food. Devices suitable for animals of some ages and species might not be suitable for all ages and species.

Manipulable objects should be sanitizable or replaceable and not harmful to animals or the caging and physical-plant utility systems. Objects (often durable toys) that animals can explore visually, orally, and tactually are often used because they are inexpensive and easy to sanitize. Some metal and plastic pieces can become ingested or entangled over the head and limbs and cause considerable harm to the animals (Murchison 1993). Small objects can go down the drains and clog sewer systems or damage sewage lift pumps. Moreover, these objects might be of little value if the species in question is not particularly manipulative or if animals readily lose interest in them. In general, a combined strategy of risk assessment and cost-benefit analysis should be used for the selection of these objects. Clearly, not all devices that present some risk should be avoided if they are thought to benefit the animals. Straw and burlap bedding, cargo nets, and destructible (and edible) objects can be injurious to animals, but if they are carefully selected and the animals are frequently observed, we believe that the benefits of many of these types of objects outweigh their potential harm.

A number of devices and toys have been reported on in the literature. None appear to be universally suited to all animals. A toy that appears to be beneficial for one rhesus might be ignored by another in the same colony. We do not believe it possible to recommend which toys are best for any species, but we do believe that some general guidelines can be developed. Several categories of devices have been used for nonsocial enrichment. An exhaustive list is not possible, and some of the best are noncommercial products, such as recycled cardboard, telephone directories, and plastic bottles alone or filled with frozen juice or food.

For the sake of simplicity, we think of these devices in three categories: manipulable objects (toys), foraging situations or apparatuses (Line and others 1990a), and furniture for climbing, resting, perching, or locomoting above the floor. Toys consist of commercial or home-made manipulable objects of plastic, hard rubber (e.g., Kong® toys, see Crockett and others 1989), paper (such as telephone directories), or wood (Reinhardt 1997b). In general, they consist of man-made objects not used by the animals in the wild but of some possible benefit for some animals through handling, mouthing, and use as “tools,” which often result in the destruction of the items. The novelty of the items seems to wear off rapidly for many animals, and new and different toys are needed to restimulate animals to use them (Lutz and Farrow 1996; Paquette and Prescott 1988; Taylor and others 1997a). Toys might be rotated through the colony on the basis of such characteristics as texture, shape, and color to help sustain interest. Foraging boards and puzzles stimulate foraging activity and are discussed in many sections of this report. In the furniture category are ropes, swings, perches, and climbing structures; deep bedding with or without browse, such as grains and popcorn; nest boxes and other structures to permit privacy and escape; and mirrors and video monitors. The list is limited only by the imagination of each person who has some responsibility for the welfare of animals. The type of enrichment selected is often based on whether an animal is singly housed or pair or group housed. Toys have been used most commonly for singly housed animals, but might show promise for group-housed animals (Brent and Belik 1997; Novak and others 1993). Other variables are involved in the selection and evaluation of these devices, including the species for which they are used. Additional discussion of this topic is provided in Chapters 5-9.

Technologically more complex enrichment devices, such as joystick-operated computer games that challenge cognitive and motor capabilities, have proved of interest to chimpanzees and several species of monkeys for long periods. Unfortunately, they are relatively expensive and require considerable maintenance. Some single-housed primates will watch television that depicts activities of their own species (Brent and others 1989; Rumbaugh and others 1989) and a recent report suggests that rhesus monkeys watch television if the scenes change rapidly (Platt and Novak 1997).

In addition to the properties of an enriching device itself, other factors affect whether and to what extent an animal might find it "enriching." These factors include the mode of presentation, such as the spacing of puzzle feeders to avoid competition (Maki and others 1989); order of presentation and time of exposure to minimize declining interest (Cardinal and Kent 1998; Crockett and others 1989; Leming and Henderson 1996; Paquette and Prescott 1988); visibility; and ease of access. Other authors have discussed these issues as well (Bayne 1991; Fritz and Howell 1993a; Bloomsmith and others 1991).

Some foods provide both nutrition and opportunity for manipulation, such as scattering corn, popcorn, or other items in the bedding (Beirise and Reinhardt 1992; Grief and others 1992). Food treats can also be given in the form of unprocessed fruits and vegetables. Unpeeled bananas, artichokes, potatoes, and coconuts increase animals' processing time of the food and can provide entertaining moments for the animals and care staff (Bloomsmith 1989; Nadler and others 1992). Fruit juices, as liquid or frozen into cubes, are also enjoyed by many animals (Goodwin 1997). Even increasing the frequency of feeding seems beneficial (Nadler and others 1989; Taylor and others 1997b). There are many opportunities for creativity in the use of food treats and presentation of food as part of well-being programs. The diet should be nutritionally balanced and raw food treated to decrease the likelihood of infection (NRC 1996, p. 40).

HOUSING DESIGN

Housing should permit the expression of species-typical postures and locomotion. Species, age, sex, and individual histories are important factors to consider when evaluating housing designs. Performance standards based on postural adjustments and locomotor activities preclude specification of dimensions on the basis of any single criterion, such as body weight or dimension. Use of legal cage sizes will not always meet an animal's behavioral requirements. Species that normally move by brachiation (swinging from hand to hand while hanging from supports) or vertical leaping and clinging require substantially different cage designs from conventional quadrupedal striders even if all are of similar body weight. Cage design should reflect units of usable space, that is, space in the cage through which the animal can move. For example, a high glass-walled cage with no vertical perches or climbing structures might look like a two-dimensional environment to its inhabitants whereas a smaller cage, with a smaller floor area and multiple climbing surfaces, might provide more usable space for many nonhuman primates.

Species-typical behavior can be promoted by various aspects of cage design. There should be sufficient space and furnishings, and they should be allocated and placed in a manner that supports basic locomotor patterns and postural adjustments. Special additions to a cage, such as feeding devices, can be placed so as to foster species-typical posture and locomotion. Features of the environment that appeal to humans (such as vertical smooth walls, tidy floors, minimal odors, and soft toys) are not necessarily conducive to the well-being of all nonhuman primates. For example, soft toys might be suitable for infants of some species but dangerous to adults that might try to eat the toys.

When animals are housed socially, the committee believes the spatial requirements of the group need not be calculated by assessing the spatial requirements for one animal to express normal postures and locomotion and multiplying by the number of animals. For example, if housing needs to be 2 m high to permit brachiation, a cage for two animals does not need to be 4 m high. Likewise, floor areas need not be simple multiples. In fact, for arboreal species that normally flee up and spend most of their time climbing, floor area might be secondary to vertical space in providing for postural and locomotor opportunities. The volume of usable space could be the appropriate dimension to consider, and individual animals must have sufficient usable space to express normal postures and locomotion when the space occupied by each cage companion is taken into account. When two animals are housed together by interconnecting their cages, greater spatial opportunities exist for both than when each is housed in its separate cage. Thus, modification of current cage-size regulations ought to be considered. Ten animals might not require 10 times the floor space of a single animal to ensure adequate space for normal postures and locomotion, but some animals might need more space than others (NRC 1996), for example, for fleeing from the aggresion of dominant animals (old, sedentary, or infirm animals might use less space than younger animals).

We agree strongly with Subpart D, paragraph 3.80(c) of the Animal Welfare Standards, which states that "innovative primary enclosures not precisely meeting the floor area and height requirements provided in paragraphs (b)(1) and (b)(2) of this section, but that do provide nonhuman primates with a sufficient volume of space and opportunity to express species-typical behavior, may be used . . ." That statement and paragraph 3.81(a) (Social Groupings) properly encourage social groupings and *behaviorally* defined cage space. However, many nonhuman primates are now singly housed because of paragraph (b)(2)(iv) which states that: "when more than one nonhuman primate is housed in a primary enclosure, the minimum space requirement for the enclosure is the sum of the minimum floor area space required for each individual nonhuman primate. . . ." We believe that the latter statement is indefensible and that cage design (volume and furnishing) should result from a thoughtful understanding of the needs of the animals, not from multiples of body weight of the inhabitants. We further believe that many nonhuman primates in single cages today would benefit from a compatible cagemate, *even if the cage sizes do not precisely meet the letter of the law* (Eaton and others 1994; Reinhardt and Hurwitz 1993); such is the strength of our belief in the value of social housing. This attitude is also expressed in the *Guide for the Care and Use of Laboratory Animals* (NRC 1996).

Providing housing environments with materials, surfaces, and structures that support species-normal activities might make them more difficult to sanitize. For example, the use of wood shavings and wooden structures has often been discouraged in primate enclosures for sanitation reasons. However, at least one study (Chamove and others 1982) has found a decrease in bacterial content over time in wooden shavings placed on the cage floor and an increase in behavior classified as desirable in five of six species of nonhuman primates studied. Some natural-wood products contain bactericidal compounds that provide self-sanitation (D.O. Cliver, University of Wisconsin-Madison, unpublished data, 1993). Straw or woodchip bedding, ropes of natural materials, branches, and cardboard products can all increase the variety of surfaces and objects in a cage. When these materials have been replaced because of wear or soiling, they have not been found to constitute a health hazard. The colony manager, veterinarian, and institutional animal care and use committee (IACUC) should monitor the effectiveness of these cage modifications to ensure they enhance well-being consistent with good sanitation and the requirements of the research project. (See also NRC 1996.)

Although chewed wooden structures might not be aesthetic, some species need to chew wood or other suitable material to keep their teeth and gums in good condition. Other species require wooden or porous surfaces for scent-marking (Epple 1986). The use of wooden structures and objects to support locomotor and manipulative activity should require only that appropriate schedules be developed for replacement to meet valid sanitation concerns. Likewise, open water in streams, pans, or puddles supports varied activities in many species and should be acceptable, given reasonable procedures to maintain sanitation. The frequency of changing soiled or worn materials and access to streams or puddles requires reasonable care to ensure that they do not present a health hazard. Access to streams or puddles need not be routinely prevented (NRC 1996, p. 41).

Those who develop plans for psychological well-being and those evaluating and inspecting such plans should be aware of the benefits of using natural objects that support varied natural activities (Reinhardt 1997b). Thinking about the nature of suitable caging material in absolutes should be discouraged in favor of carefully crafted plans that take into account the housed animals' psychological needs to engage in species-typical activities.

PERSONNEL INTERACTIONS

It is essential that both the providers of animal care and those overseeing the animal-care program receive training regarding the physical and behavioral needs of each species in a facility (9 CFR Ch. 1 (Animal Welfare Regulations) paragraph 3.85; CCAC 1993; NRC 1991, 1996). Training should be part of all technicians' jobs and should be supplemented with institution-sponsored discussions and training programs and with reference materials applicable to their work and to the species with which they are engaged (Kreger 1995). Coordinators of institutional training programs can seek assistance from the Animal Welfare Information Center (AWIC), Beltsville, Md., U.S. Department of Agriculture, Agricultural Research Service, National Agricultural Library (see also NRC 1991).

Relevant personnel should be skilled in procedures, such as capture and cage sanitation, both to minimize animal distress and to maximize caregiver safety. They should learn to identify individual animals and to recognize normal and abnormal behavior of individual animals. They should also know about species-typical patterns of social organization so that they can form appropriate social groups and understand which animals in a social group are most vulnerable to aggressive attacks and injuries. Finally, it is important to be aware that social interactions with familiar human caregivers can have marked positive effects (Baker 1997; Bayne and others 1993a; Wolfle 1985, 1987) and, conversely, that an animal can behave quite differently, even somewhat abnormally, toward unfamiliar persons, such as new animal technicians or visitors (Chamove and others 1988; Miller and others 1986). Chapter 3 presents some detailed comments on training personnel and animals in necessary routines that involve human-animal interactions.

A good program for animal care should include plans for monitoring, intervention, remediation, and appropriate documentation. Observations of animals, especially of large outdoor nonhuman primate colonies, is a shared responsibility that varies greatly among facilities and includes the animal-care staff, behavioral scientists and technicians, and other investigators. The key is that each animal should be observed daily (although we recognize that this might not be possible in island colonies and similar situations) by people appropriately trained to do so in a manner consistent with the constraints of the facility and welfare of the animals. Records should include identification of unusual behavior, provisional diagnoses (including assessment of the current condition and aspects of an animal's history that are necessary for its interpretation), and attempted remediation and its effectiveness (NRC 1996).

DOCUMENTATION

In order to "develop, document, and follow an appropriate plan for environmental enhancement adequate to promote the psychological well-being of nonhuman primates" (9 CFR 3.81), each institution's plan should contain a statement of goals, specify the methods that will be used to achieve the goals, and describe the criteria that will be used to evaluate the effectiveness of the program. A guiding principle is that the program should be based on an understanding of the natural history of a species and its traits and, where necessary, should take into account the histories of individual animals. It is important to recognize that programs to promote the psychological well-being of nonhuman primates are living documents subject to change and updating as new information is acquired.

Each facility should have protocols for diagnosing the cause of physical impairments and abnormal behavior, determining when remediation is necessary, developing remediation plans, assessing effectiveness of remediation, and maintaining appropriate records; they should specify who will be responsible for each aspect of diagnosis, remediation, assessment, and documentation. Personnel making the decisions should have training in the aspects of veterinary medicine and primate behavior necessary to ensure that diagnoses and treatments are developed in a knowledgeable manner. It is recognized that there might be no known methods for remediating some physical impairments and abnormal behavior (Novak and others, in press) and that for some individual animals all known methods of remediation might prove ineffective. In those cases, it is important that personnel responsible for animal care document good-faith efforts to use all currently available information in attempting remediation.

The well-being of research animals is not just a consideration of the animal-care staff. In many cases, it begins with the research protocols. Research methods should be evaluated regularly; as less stressful or less invasive methods are developed, their adoption should be considered. Methods of enhancing animal well-being must be consistent with the requirements and goals of the research (NRC 1996).

CHECKLIST FOR A PLAN TO PROMOTE THE PSYCHOLOGICAL WELL-BEING OF NONHUMAN PRIMATES

This outline constitutes a sample checklist of points to consider in the development of institutional plans to provide for the psychological well-being of nonhuman primates. The institutional plan should clearly reflect species variations. However, few plans can be expected to be equally beneficial for all individuals of a species, and professional judgment should be exercised to address the needs of individual animals. It should be remembered that, as with the *Guide* (NRC 1996) itself, this checklist provides the goals but *implementing standards* should be developed by individual institutions to achieve the goals in *their* settings, with *their* personnel, and for the *individuals* and *species* being considered. The authors of this report believe that no single plan developed here or by a particular facility, can be entirely adequate for all facilities. We also understand that the initial development of a plan by an institution that has not previously developed one, can be daunting. We have therefore referenced items in the following checklist to the discussion in the text, which should enable construction of a plan suitable to each institution's goals and species. Additional information about the construction of plans can be found in Appendix A. Also, institutions designing enrichment plans for nonhuman primates are encouraged to take advantage of the periodic bibliographies on related subjects provided by the U. S. Department of Agriculture's Animal Welfare Information Center (AWIC 1992). (See also AWI 1998.)

I. Statements of Goals
   A. The plan should contain a statement of the goals of the facility in terms of the following topics that apply:
      1. Research. (p. 19)
      2. Breeding. (pp. 12, 17, 42-43)
      3. Sales.
      4. Education. (p. 25)
      5. Exhibition.
      6. Other.
   B. The plan should contain a statement of the aims of the well-being program in terms of the following topics that apply:
      1. Providing opportunities for the expression of a broad range of species-typical behaviors. (pp. 18-22)
      2. Providing cognitive stimulation. (pp. 21-22)
      3. Decreasing self-injurious behavior. (pp. 11, 17, 19, 21, 33-35)
      4. Decreasing stereotypies (such patterns as pacing and eye poking). (pp. 12-14, 17)
      5. Providing predictability of routine procedures and events. (p. 20)
      6. Providing opportunities for animals to alter their environment. (pp. 20, 33)
      7. Training personnel and animals for husbandry and biomedical routines. (pp. 25, 37, 40-42)
      8. Other.

II. Pertinent Information

A. The plan should contain a brief summary of relevant information on the natural history and behavioral ecology of each species of nonhuman primate in the facility in the context of scientific justification for the enrichment strategies implemented. The clinical records should indicate both the medical and behavioral status of the animals and treatment(s) to be administered. Environmental or behavioral enrichments might include such treatments as the following:

1. Habitat diversity.
2. Feeding habits. (pp. 18, 20, 39-40)
3. Social organization. (pp. 13-14, 16-17, 25, 42-43)
4. Manipulable objects and toys. (pp. 21-22)
5. Other

B. The plan should provide a mechanism for maintaining and using animal records if such a plan is not already part of the facility program, including the following types of information, if known:

1. Source of animal (born at facility or acquired from person and/or institutional source). (pp. 13, 19)
2. Rearing history (wild-born, reared at facility in mixed-sex groups, peer-reared, etc.). (p. 19)
3. Housing history (type of cage and types of partners). (p. 12)
4. Health and behavior records and miscellaneous observations. (pp. 26, 38-39)
5. Other.

III. Social Interactions (pp. 13-14)

The plan should contain a discussion of how social interactions are to be provided, including one or more of the following:

A. Continuous housing in pairs or groups. (pp. 16-17)

B. Intermittent housing in pairs or groups, e.g., 1 hr or more several times a week (a standard procedure for social-unit formation should take into account the risks in group formation). (p. 17)

C. Visual, auditory, and olfactory contact with conspecifics. (pp. 17, 33)

D. Positive interaction with animal-care technicians. (p. 25)

E. Interactions with other species (e.g., chimpanzees with dogs). (p. 108)

IV. Environmental Enrichment

The plan should contain a discussion of techniques used to provide opportunities for foraging and exploration, such as those in the following list. It is recommended that techniques from the categories given below be combined so that enrichment might accomplish multiple objectives.

A. Techniques to promote foraging, including "processing" of raw vegetables and fruits. (pp. 20-22)
B. Techniques to promote manipulation. (pp. 20-22, 34)
C. Techniques that allow animals to control aspects of the environment (opening doors and peep holes, influencing temperature and light, etc.). (p. 20)
D. Techniques to promote other species-typical activity, including locomotion. (pp. 18-22)
E. Techniques to reduce self-injurious behavior. (pp. 11, 17, 19, 21, 33-35)
F. Techniques that require learning of novel responses for appetitive reward. (pp. 20-22, 40-42)
G. Techniques that provide varied sensory stimuli (e.g., texture, density, shape, size, color, taste, and smell). (pp. 21-22)
H. Other.

V. Special Considerations

The plan should make specific provisions for unusual situations and develop strategies for considering psychological well-being in these contexts, including one or more of the following:

A. Strategies for hyperaggressive animals. (pp. 17, 33)
B. Strategies for animals exhibiting injurious behavior. (pp. 34-38)
C. Strategies for individual housing required because of veterinary care or research protocols. (pp. 17, 19-22, 33)
D. Strategies for animals tethered or under restraint. (pp. 19, 40-42)
E. Strategies for young (infant or juvenile) primates. (pp. 16-17, 22-23, 45)
F. Strategies for very old primates. (p. 23)
G. Other.

VI. Monitoring

A. Various measures can be used to assess the well-being of nonhuman primates, including the following:
   1. Daily physical health checks by caregivers to assess
      a. Activity. (pp. 25, 45-46)
      b. Physical signs (eye and nose discharges, feces, urine production, menses, food ingestion, etc.). (pp. 11, 45-46)
   2. Daily monitoring of behavioral state by caregivers to identify
      a. Atypical behavior patterns. (p. 25)

   b. Changes in proportion of normal behavioral activity. (pp. 18-19)
3. Recording reactions to routine husbandry events. (pp. 26, 45)
4. Recording ability to respond to training. (pp. 40-42)
5. Recording responses indicative of distress. (pp. 11, 13, 26)
6. Other.

B. The plan should discuss various elements of remediation (p. 21), including
   1. Means of documenting successful and unsuccessful attempts at remediating diagnosed animals. (pp. 12-13, 17)
   2. Protocols for followup of remediation efforts. (pp. 25-26)
   3. Steps taken to accommodate animals that do not respond to remediation. (p. 26)
   4. Establishment of end-point criteria (e.g., serious self-biter). (p. 35)

C. The plan is considered to be effective and properly implemented if one of the following conditions is satisfied:
   1. Individual animals are judged to be in a state of well-being, or
   2. The cause of distress or atypical behavior in any animal can be shown to be derived from antecedent conditions of abnormal development, inappropriate rearing conditions, or an approved research protocol; practices are identified and implemented for the benefit of future generations of animals; and facility records exist for the presence, etiology, and remediation or accommodation of observed cases of lack of well-being.

3

General Care and Psychological Well-Being

The amount and type of care required to promote the psychological well-being of nonhuman primates in captivity depend on a great number of variables, including individual animal characteristics, species, opportunities for natural social interaction, degree of confinement, purpose or goal of confinement, and projected length of confinement. All those variables will affect decisions regarding type of housing, degree of human contact, types and delivery of food, and health care. Each circumstance presents a challenge to animal-care technicians, researchers, and veterinary medical staff to provide a level of care necessary both to meet the needs of the animals and to make the animals available for the intended purpose.

This chapter presents information that is applicable to any primate-care program. Chapter 4 considers the special needs of primates used for particular research purposes. Detailed information on the husbandry, nutrition, and medical care of nonhuman primates has already been published elsewhere (Bennett and others 1995; NRC 1978, 1996). The present chapter focuses on aspects of care especially pertinent to psychological well-being.

It is important to recognize the great diversity, not only among major taxa but among species within a single genus, and to acknowledge that diversity in designing animal-care programs. Once the species characteristics have been identified, consideration should be given to individual differences in temperament, developmental history, sex, and age and to the fact that behavioral competence of many nonhuman primate adults depends on early experience. Pertinent aspects of those issues are discussed in the chapters that cover specific taxa.

HOUSING

Nonhuman primates in captivity have been maintained in varied housing conditions. Animals have been housed for many years in research facilities in individual cages that can be easily sanitized and placed in climate-controlled rooms. Indoor-outdoor runs have been used as primary housing, usually with the indoor portion engineered to protect the animals from environmental extremes (NRC 1996). Heavy-wire units originally built to store corn and often referred to as corn cribs and corrals with areas of 0.1-3.0 hectares (0.2-7.4 acres) have been used as outdoor housing. Some corrals contain structures to protect the animals from the elements; others are connected to structures that provide shelter and are used to capture the animals. Nonhuman primates have also been maintained on islands, some with areas of over 175 hectares (430 acres). Each form of housing has advantages and disadvantages.

The acceptable temperature range for primates adapted to the outdoors varies greatly. Some species, such as savanna baboons, when properly acclimated can tolerate temperatures from near freezing to over 39°C (102.2°F), whereas other species, such as pygmy marmosets, can survive only in relatively narrow temperature ranges. Regardless, primates housed outdoors should be protected from environmental extremes in ways that are appropriate to their species, age, disease status, and acclimatization. Indoor-housing temperature fluctuations should be kept within the range of 18-29°C (64-84°F) (NRC 1996; see Chapters 5-9 for species-specific information).

Efforts to provide cage-size recommendations according to animal size have been frustrated by the enormous diversity of nonhuman-primate lifestyles and locomotor activities. No single factor, such as body weight or size, is sufficient to specify cage designs for captive primates. A matrix of factors should be considered, including species-typical behavior, postures, locomotor activity, age of the animals, required duration of caging, and number and sex of animals to be housed in each cage. However, housing should allow the animals to exist in a state of physical and psychological well-being.

Cages should be designed to permit normal postures and locomotor activity. When not stressful (e.g., with breeding pairs of marmosets), walls should be as open as possible—e.g., consisting of mesh, glass or clear plastic, or bars—because the ability to monitor their environment visually is very important to some primates. A nest box or shelter with opaque walls will allow an animal to "hide" when it wants to be out of direct view. Cage design should minimize discomfort and risk of injury to the animals. For example, some species have anatomical features, such as long tails, that might require a taller cage than other species of the same body weight. An animal maintained for an extended period might require a larger cage so that it can partake of its normal locomotor activity. Smaller quarters might be justified case by case for quarantine, veterinary, or experimental requirements.

Individual Housing. There are both advantages and disadvantages to individual caging. The physical health of a primate might be best protected when it is maintained in a cage that can be completely sanitized. Proper sanitation has virtually eliminated many endemic diseases, such as shigellosis and salmonellosis. Individual caging also minimizes wounding due to fighting. However, some animals that previously exhibited normal behavior in social settings develop atypical patterns of activity, including self-wounding, when kept in individual cages for an extended period (Bryant and others 1988), although this period has not been defined. Similarly, some physiological measures appear to be altered in individually housed primates (Coelho and others 1991; Gonzalez and others 1982; Mendoza and Mason 1994; Mendoza and others 1991; Saltzman and others 1991; Shively and others 1989). Reinhardt and others (1991) found no differences in cortisol levels with single vs. social housing.

The ability to see, hear, and smell other primates and even touch them to a limited degree by reaching through the cage walls does not preclude the development of abnormal patterns. Extensive tactile contact with conspecifics, at times of the animals' choosing, seems to contribute substantially to psychological well-being. Other factors associated with single caging—such as reduced mobility, restricted visual field, inability to get out of sight of a nearby animal, low environmental diversity, and minimal control over or predictability of a given environment—also might influence an animal's psychological well-being. Variation by species, age, and sex and even between individual animals of the same age-sex classification in the same environment has also been reported (Suomi and Novak 1991).

Most primates are social creatures and should not be housed in a room alone except for short periods. Whenever possible, social species should be socially housed. Even in individual cages, however, nonhuman primates interact with one another, so cages should be arranged to ensure that animals within visual range are compatible. Primates that continually threaten each other should be moved out of direct visual contact. Some individual primates also appear to experience stress if they are housed close to the animal-room door or a window that exposes them to human traffic. Such animals can be moved to the back of the room away from doors and windows. Husbandry practices can also be a source of stress and should be conducted in a smooth, predictable manner that minimizes disruption and decreases extraneous noise. Cages should be cleaned in a manner that does not wet the animals (NRC 1996, pp. 42-43).

Where social opportunities are limited, environmental enrichment can take on increased importance. Environmental-enrichment programs attempt to increase environmental diversity by providing manipulable objects (Bayne 1989, 1991; Brent and Belik 1997; Cardinal and Kent 1998; Line and Morgan 1991); social stimulation through interaction with known humans (Bayne and others 1993a; Wolfle 1985, 1987) through the use of mirrors (Collinge 1989; Eglash and Snowdon 1983; O'Neill-Wagner and others 1997; Platt and Thompson 1985) or video monitors (Brent and others 1989; Rumbaugh and others 1989); increased visual stimulation (Fritz and others 1997; Reinhardt 1997c) and auditory stimulation (Morgan and others 1998); and additional foraging opportunities (Bayne and others 1992b; Murchison 1994; Reinhardt 1994a). But not all stimuli elicit interest on the part of all species or ages of animals (Line and others 1991), and some stimuli might evoke negative reactions in some species or individuals; e.g., mirrors elicit aggressive behavior in some animals, such as chimpanzees (Lambeth and Bloomsmith 1992). Furthermore, some primates rapidly habituate to many kinds of stimulation. To complicate matters, rapid habituation to manipulable objects has been noted in individually housed rhesus monkeys, whereas socially housed animals continued to manipulate objects for months after initial exposure (Novak and others 1993). Thus, environmental enrichment, although of greater importance to singly caged animals, might be more difficult to achieve in these circumstances.

Aggression directed toward the physical environment or toward the aggressor's own body is greater in small single cages than in enriched cages or social settings (Bryant and others 1988; Chamove and others 1984; Line and others 1990b; Reinhardt 1990b.) Such aggression is apparently rare in free-ranging animals, although the use of branches and other objects in aggressive displays occurs in some species of free-ranging New World and Old World monkeys and in apes. In captivity, these forms of aggression are more common in some species than others. They might be examples of what has been called *redirection*, which is characterized by the direction of an act toward a different target from the one that elicited it. In a singly caged animal, of course, the eliciting stimulus is generally out of reach.

Chronic self-injurious behavior that causes tissue damage is particularly troubling. Although this behavior has long been labeled "self-directed aggression," the association between aggression and self-directed biting is probably not absolute (Novak and others, in press). We therefore prefer to call it self-injurious behavior or self-directed biting. It has been most frequently reported among adult male macaque monkeys housed individually (Bayne and others 1995; Chamove and others 1984; Gilbert and Wrenshall 1989; Line and others 1990b); if it is a firmly established pattern, it is resistant to treatment. Although the causes of severe self-directed biting are poorly understood (Pond and Rush 1983), prolonged individual housing is probably an influential contributing factor. The handling of self-directed biting is an example of how the *overall* program or plan for the psychological well-being of an institution's nonhuman primates relates to the procedures adopted for intervention in a *specific* situation. As in the institution's occupational health and safety, veterinary care, and sanitation programs, there need to be standard operating procedures (SOPs) for each aspect of the program. When single housing is required and an animal exhibits self-directed biting, the SOP should detail the steps to be taken. These steps need to be based on current scientific information but accommodate flexibility in adaptation to an individual animal, housing situation, and possible antecedent conditions that are at the root of the behavior. Alleviation of self-injurious behavior is frequently achieved through enrichment of the environment (Chamove and others 1984; see also the other discussions and references on this topic throughout this report) or introduction of the animal to compatible cagemates or social groups (Bernstein 1991; Line and others 1990b; Vermeer 1997; Williams and Abee 1988). If well-being cannot be achieved, euthanasia is a compassionate final option (AVMA 1993, AWIC 1990).

Group Housing. Group housing generally promotes behavioral health; primates typically exhibit a broad range of species-typical behavior when housed with other primates. But group housing increases risks of disease transmission, aggression, wounding, and food deprivation because of competition.

Various steps can be taken to minimize the risks. Food and water should be available from several locations to prevent individual animals from dominating a single source (Bloomsmith and others 1994; Maki and others 1989) and the food and water should be available in quantities sufficient to ensure that all animals receive an adequate ration. Also, shade, ancillary heat sources, and shelter should be provided so that some animals do not prohibit others from gaining access to critical resources. Likewise, environmental enrichment techniques should not incite aggressive competition over a device intended to enhance well-being (Maki and others 1989).

Disease transmission can be minimized by keeping social groups intact and introducing new animals only when necessary. (Some introductions of new animals are required in almost every colony for genetic diversity and replacement; it is critical that such introductions be handled carefully.) (See Chapter 2, "Social Companionship.") Equipment, such as transport cages, should either be dedicated to particular groups or be sanitized after use with a particular group of animals.

The risk of serious injuries caused by aggression to other animals is considerably greater in socially housed animals than in those living alone (Erwin 1979; Rolland 1991). No matter how carefully animals are selected for group living and no matter how well they have gotten along in the past, sudden outbreaks of aggression can occur and result in serious injuries (Ehardt and Bernstein 1986). Such spontaneous occurrences might be an important source of scientific information about the causes and consequences of social aggression. In any case, the facility staff has the obligation to monitor these events closely and to intervene in order to prevent serious injury to the participants. Decisions as to when and how to intervene require a considerable knowledge of the species, the particular social group, and effective techniques for dealing with serious aggression. Premature separation (e.g., before the social structure and dominance hierarchy are established) can invite renewed aggression when an animal is reintroduced.

Close observation of animals will often detect the onset of social instability long before aggression leads to injuries. For example, chasing, threatening, and avoidance can increase before the first physical attack. Changes in established feeding orders and social relationships can also serve as warning signs. Excessive time hiding in physical structures—such as visual blinds, tunnels, barrels, and boxes—can also indicate that active intervention is required.

Social instability might be an indication that the environment lacks stimulation needed for species-specific behaviors and that enrichment is needed. Enriching the environment with perches (Bayne and others 1989, 1992a; Crockett and Bowden 1994; Shimoji and others 1993), visual breaks and hiding areas (if none exist), and foraging tasks (Bayne and others 1991; Boccia 1989; Chamove and Anderson 1979) might be successful in reducing hostility.

If combative behaviors continue after environmental complexity has been assessed and changed, various other techniques for restoring social stability should be considered. In some species, stability can be restored by removing the victim (Vermeer 1997); in other species, a new victim replaces the old. Likewise, removing an aggressor might restore harmony in one case and increase social instability in another. A victim that is removed and treated can be safely returned to some groups but not all. In some species, the longer the victim has been away, the riskier is the return. Clearly, no simple formula describes the most effective procedure for all species.

When animals repeatedly initiate biting attacks or when biting presents a potential for serious injury to personnel or other animals, dental modification should be considered. In many species, severe puncture and slashing injuries can be caused by elongated canine teeth. Extraction of canines is not advisable; these teeth are deeply rooted, and extraction places the animal at risk of structural damage to the maxillary sinuses, dental malocclusions, and periodontal disease. A better procedure is to blunt the canines (Carter and Houghton 1987; Coman and others, in press). In considering this procedure, it is well to remember that in Old World monkeys, the trailing edges of the upper canines are honed on the lower first bicuspid or premolar. Only when the canines are reduced so that they no longer project beyond the occlusal surface do they lose their potential to inflict slash and puncture injuries. The procedure is not without risk and might expose the tooth pulp chamber and result in an abscess. When required, a pulpectomy should be performed by a qualified professional and the tooth filled with dental amalgam or acrylic (Carter and Houghton 1987). That procedure, of course, does not preclude inflicting serious crushing injuries.

Aggression can be minimized by keeping social groups intact, but this is not always possible. If animals used in research protocols, or sick or injured animals, require removal for treatment, efforts should be made eventually to reintroduce them to their social group. Reintroductions often become riskier with the passage of time, although they are generally easier when an entire group is separated into single cages than when only one or two animals have been removed. All reintroductions, however, should be monitored continuously for the first hour and periodically thereafter. Introductions or reintroductions generally involve housing unfamiliar animals nearby for a few days and observing them for the presence of combative behavior. Many descriptions of this procedure are available (for chimpanzees, Fritz 1986, 1989, 1994; for macaques, Coe 1991, Bernstein 1969, Bernstein and others 1974a, b, Crockett and others 1997, Reinhardt 1988, 1989a, 1991a; for capuchins, Cooper and others 1997; and for squirrel monkeys, Vermeer 1997).

Group housing can pose a problem in gaining access to individual subjects for testing or biomedical sampling. At least three solutions have been used: training of individual animals to enter small transfer cages, movement of animals to smaller gang cages and then to transfer cages, and the inclusion of tunnels within group enclosures so that animals can be herded into the tunnels and then moved one at a time into transfer cages (Clarke and others 1988; Knowles and others 1995; Phillippi-Falkenstein and Clarke 1992; Reinhardt 1992a; see also “Restraint and Training” later in this chapter). Those techniques are superior to techniques that require personnel to enter group pens with nets and gloves to capture specific animals. The latter procedures are stressful and dangerous to technician and animal alike. Although the limited use of nets is recommended in Chapter 6 for some small New World monkeys, we do not recommend it in general or especially for macaques, for which training to enter a transfer cage is much preferred, because it reduces the risk to personnel of exposure to bites, *Circopithecine herpesvirus*, and other zoonoses.

Before a social group is established, the social organization of the species under free-ranging conditions should be examined. For example, young male rhesus monkeys form associations, so pair housing of males might be successful (Reinhardt 1989a, 1994b, 1995). Adults of other species are often intolerant of members of their own sex (Coe and Rosenblum 1984; Crockett and others 1994), especially in the presence of adults of the other sex; for example, because of the natural social affiliations of squirrel monkeys, females are more readily housed together than males (see Saltzman and others 1991). Knowledge of natural sex or age-class affinities can aid in the planning of social units.

Several key elements of the housing area for social units should be addressed in either cage design or SOPs. Provision of refuges might be beneficial to prevent fighting in some species. Provision should be made for easy removal of individual animals if fighting occurs and for ready access to animals for protocol purposes or husbandry routines. The safety of facility personnel should also be a driving force behind SOPs or enclosure design for routine husbandry procedures. For example, the use of a shift or transfer cage or run might be necessary when staff enter an enclosure to perform routine tasks. Flexibility in converting social to individual housing of animals might be desirable to control feeding and to treat or examine an individual animal. The ability to partition a larger cage for short periods greatly facilitates cleaning and maintenance.

Although social housing of primates can enhance reproductive capability and development of species-typical behavior, some animals cannot be successfully paired or incorporated into social groups (see also Coe 1991). It might therefore be more humane to house some animals alone; these animals could find a solitary life less stressful. The forced pairing or grouping of *every* primate is not recommended.

SANITATION

Sanitation must be provided, but the procedures used to accomplish good sanitation depend on cage type and species. *Sanitation*, as used in this report, indicates the maintenance of conditions conducive to health and involves bedding changes, cleaning, and disinfection. Cleaning removes excessive amounts of dirt and debris, and disinfection reduces or eliminates unacceptable concentrations of microorganisms (NRC 1996, p. 42). Portable cages can be taken to a mechanical cage-washer, but built-in cages require hand washing with either brushes or high-pressure sprayers. Corrals might require spot cleaning of feces if heavily populated; otherwise, the sun should desiccate the waste products sufficiently. Wooden structures, such as perches and tree limbs, introduced into a cage need to be replaced as they become worn. Primates have a tendency to lick cage surfaces; therefore, a clean-water rinse should be used to ensure that no trace of detergents or disinfectants remains on these surfaces. Enrichment devices should be sanitized or replaced as appropriate (Bayne and others 1993a; NRC 1996).

When primates are housed outdoors, vermin control in the area is essential. Wild rodents can transmit diseases, and wild animals have been known to attack primates. The ground inside corrals should be graded to permit rainwater runoff and steps should be taken to prevent the formation of stagnant pools of water, such as placing gravel or concrete under waterers. Continuously running streams of water might provide not only drinking water but enrichment, inasmuch as some species enjoy playing in water.

Cage cleaners should always be mindful of the important role of pheromonal communication, especially for callitrichids and prosimians (Epple 1986; Epple and others 1993). Complete sanitizing of a cage can be undesirable for species in which chemical communication is important. At the very least, a few perches or a nest box should be left with odors intact when cages are cleaned. These items should be cleaned at times other than when the entire cage is to be cleaned. Because of the strong role of scents in the lives of many nonhuman primates, one should not be overconcerned about the elimination of odors in a primate room but regular cleaning of surfaces contaminated with urine and feces should be maintained.

DAILY CARE

The daily observation of all primates in a colony is an important part of a program to provide animal well-being. Caregivers should note deviations from physical and behavioral norms for an animal, in addition to evidence of illness or injury. Lethargy in a normally active animal might be the only readily notable indication of a life-threatening condition. Unless a special diet has been prescribed to control excessive weight, caregivers should be certain that at least some food remains each day. Old food should be removed when new food is provided. It is especially important that caregivers ensure daily that all watering systems are functioning. If any animal shows less interest than usual in eating when fresh food is provided, that should be noted. A special effort should be made to check each animal in a social group, although this might not always be possible in some situations, such as in island colonies. The minimal requirements for daily care include the provision of food that is adequate in nutritional value and presented in a form that is easily consumed, the availability of potable water at all times during normal housing, and cleaning of cages in a manner and with a frequency that ensure control of disease (NRC 1996).

NUTRITION

A balanced diet is essential to maintain the physical health of primates. The dietary requirements of a few species of primates have been defined (Knapka and others 1995; NRC 1978) and several commercial manufacturers produce dry biscuits or moist products that meet these requirements. Some primates require a diet relatively high in protein, although excessive protein might lead to kidney problems in some night monkeys (*Aotus*). Diets can be purchased with different percentages of protein (15-25%) as appropriate to the colony. No diet can be considered appropriate for all primates. However, vitamin C is an essential component of the primate diet. Vitamin C added to commercial feed loses potency rather quickly, depending on storage conditions. If feed is refrigerated, the vitamin will be preserved longer, but commercial feed generally should be used within 90 days of milling. Supplementation with fruits that contain vitamin C provides food variety. Primates also require vitamin D in their diets, especially when housed indoors, and New World primates require vitamin D_3 supplementation (Bennett and others 1995). Because primates have diverse requirements for nutritional well-being, it might be difficult to form a balanced diet with only unprocessed natural foods. Most primates are omnivorous and cannot exist on a diet consisting only of grains, fruits, and vegetables.

All primates require regular access to water. Open watering pans or bowls can be used, but they are readily contaminated with feces, urine, and debris. If water is piped to primates housed outside, care should be taken to prevent freezing or excessive heating by the sun. Whereas most primates rapidly learn to use automatic watering devices, new animals need to learn how to use them.

Feeding can be used to provide positive behavioral stimulation as a means of enhancing primate well-being (Bayne and others 1992b; Fajzi and others 1989; NIH 1991). Variations in feeding strategies are particularly appealing because foraging under natural conditions accounts for a substantial portion of the diurnal activity budget (Herbers 1981; Malik and Southwick 1988; Marriott 1988; Milton 1980; Strier 1987). Several foraging devices are available commercially, and many are individually designed and constructed "in house"; these products offer a substantial range of price, ease of integration into husbandry procedures, sanitizability, and durability. Food can also be dropped into a substrate that partially obscures it from view. Feeding can present an opportunity for positive interaction between animals and caregivers (Bayne and others 1993a); however, hand feeding poses a potential hazard to personnel and therefore should be used selectively.

Earlier it was stated that routine practices minimize distress because they are predictable. But novel foods and feeding routines can be used for enrichment. They should be carefully monitored to ensure that animals are not so disturbed that they fail to consume their normal dietary intake. Novel foods, such as treats, can immediately be recognized as pleasant and need not be considered a potential source of stress.

RESTRAINT AND TRAINING

Restraint of animals for examination and treatment might be unavoidable, but most primates resist handling. Restraint should be as brief as possible and carefully tailored to the species, training, and experience of the animals. Insufficient restraint can result in injury to handlers, and undue force can result in injury to an animal. Injuries due to excessive force are of particular concern in the handling of small animals such as squirrel monkeys and marmosets.

To reduce the stress of physical or chemical restraint, many primates can be trained for routine procedures (Reinhardt 1997d). Rhesus monkeys have been trained to enter transport cages to present a limb for injection or venipuncture (Bunyak and others 1982; Heath 1989; Reinhardt 1991b, 1997a) to cooperate in the use of vascular access ports (McCully and Godwin 1992), and to present their perineum for examination and swabbing (Bunyak and others 1982). Even singly housed savanna baboons (Turkkan and others 1989), chimpanzees (Bloomsmith and others 1994; Byrd 1977; Laule and others 1992, 1996), and group-housed monkeys (Goodwin 1997; Knowles and others 1995; Phillippi-Falkenstein and Clarke 1992; Reinhardt 1990a; Williams and Bernstein 1995) have been trained to assist with clinical procedures, such as blood collection and injections, and to move into holding pens. Such training eliminates the need to anesthetize an animal for a procedure that lasts only a few seconds, reduces the time required to obtain a sample, reduces the use of pharmacological restraint agents, and, more important, gives the animal a degree of control in the situation.

Several basic principles are common to all training procedures. First, the appropriate response needs to be apparent to the subject. For example, if an animal is required to enter a compartment from the home cage, it should have seen and inspected the door. Experienced technicians wait until an animal visually fixates on the escape door before encouraging it to leave its home cage. Second, training should proceed in steps with attainable goals established. Once begun, it should continue until an animal has accomplished the goal for that session.

In avoidance training, an animal is encouraged to escape from or avoid something that it considers undesirable. The animal should be allowed to "escape" the threat of a net, gloved hand, or cage squeeze no matter how easily it might be caught at the time. The threat of noxious stimuli is more effective than the actual use of such stimuli. Escape from threat of restraint by a gloved hand or net is more effective than escape from restraint. The animal should be able to control the perceived threat of noxious stimuli by using an effective means of escape. Avoidance-training procedures should discontinue the aversive stimulus immediately. For example, if a squeeze-back cage is used to immobilize an animal's arm or leg for examination, the squeeze back should be released as soon as the limb is obtained; maintaining the squeeze while one examines the limb is counterproductive, in that no connection is established between presenting the limb and having restraint removed. Similarly, if resistance is rewarded by the technician's giving up, it will become even harder to overcome later the "reward" of the first experience. For example, an animal can learn that racing around a cage aimlessly can lead to withdrawal of the technician, net, or hand. Training should continue until the session's goal is achieved.

That principle also applies to positive reinforcement. If a favorite food is to be offered when an animal enters a new cage, giving the same food to a resisting animal rewards resistance rather than compliance. With patience, many animals can be trained to comply with laboratory requirements through the use of positive reinforcement alone. Reinforcement should be prompt. When an animal has complied with the desired activity, positive reinforcement (for example, food reward) should follow immediately. There should be no delay while notes are written or other activities performed.

Third, the procedure should be routine. When animals are to be handled or restrained, technicians and researchers should wear distinctive clothing, such as a different-colored laboratory coat or clothing other than what is worn for routine feeding and watering, behavioral observation, research, or any other daily activity. Although the animals might still recognize the individuals participating in the activity, the distinctive clothes separate this somewhat invasive situation from all other daily routines. Quiet, deliberate movements result in more effective cooperation than noisy, abrupt activity. Use of a routine can reduce overall stress. For example, capture of animals in a fixed order will allow animals to learn when their turn is coming and produce less stress than a varying order of capture and handling.

Fourth, animals should be allowed some latitude in performance. Each primate is an individual and can respond to a given situation idiosyncratically.

No matter how inefficient or awkward an animal's response might be, it should be accepted if it leads to the desired goal. It is futile to attempt to train all animals to a common standard. (For additional information on training of nonhuman primates to assist with routine procedures see Laule and others 1992, 1996.)

MATING PATTERNS

The committee does not advocate mating as a necessary component of psychological well-being, but it does recognize that many facilities breed primates. To promote the well-being of these animals, housing strategies should be based on naturally occurring mating systems. Mating patterns vary among the primates, and we summarize here what is known about the variations.

- *Solitary species*. Many nocturnal prosimians and orangutans (*Pongo pygmaeus*) lead largely solitary lives and engage in little physical contact with conspecifics other than maternal associations. Adults, however, often maintain overlapping home ranges and regularly exchange information with long-distance signals, including vocalizations and scent markings. The term *semisocial* might be appropriate in classifying these species. Chemical signals are particularly important in prosimian communication (Charles-Dominique 1974). Two patterns of mating have been described in the orangutan: forced copulation and consort relationships. We recommend that a captive female be given access to the male's quarters through a door too small for the male to pass through if she refuses to join him or withdraws from him.
- *Monogamous pairs*. A single male and a single female typically bond in some species, such as indris, mongoose lemurs, night monkeys, titis, gibbons, and siamangs. Most of the callitrichid monkeys also appear to be monogamous under captive conditions, but their social system in the wild is more flexible than that of the aforementioned species (see Chapter 6).
- *One-male groups*. A single mature male lives with several adult females in several species of forest guenons, many colobine monkeys, the patas monkey, and gelada and hamadryas baboons. Their societies vary in structure; under captive conditions, multiple one-male units of gelada and hamadryas can coexist in large enclosures (see Chapter 8). Aggressive takeover of a one-male unit by a new male is sometimes associated with infant deaths. In the Hanuman langur, for example, a successful challenger might kill young infants in the group; this has been observed in chimpanzees (Alford and others 1986). Obviously, that type of male reproductive strategy has to be taken into account in the captive husbandry of species that pursue it. It is probably unwise to replace a resident langur, chimpanzee, loris, or galago male with a new male while small infants are in the group.
- *Multimale groups*. Multiple males and females living in a single group without permanent associations between particular males and females is representative of all major taxa—e.g., the ring-tailed and black lemurs, the ruffed

lemur, most New World monkeys (cebids), many Old World monkeys, and the African apes—and has been used as a captive breeding strategy in some cases (Conlee and others 1996). But the details of the social organization of multimale groups vary widely. For example, in many groups, males disperse (e.g., rhesus monkeys); in others, the females transfer to other groups (e.g., chimpanzees); in some cases, both sexes disperse.

- *Hand rearing*. As a general rule, primates are good parents; however, as with other animals, including humans, some primates either reject their infants or encounter conditions that prevent proper infant care. Fostering or hand rearing is then possible, but providing for an infant's physical needs is far easier than providing for its social needs (Fritz and Fritz 1982, 1985). Substantial efforts will be required to provide the level of social stimulation necessary for the development of social skills in hand-reared animals. Frequent periods of interaction between young animals of similar age facilitate normal development, but continuous housing of hand-reared infants together is undesirable because it prolongs infantile behavior (Mason 1991) and might make the animals more susceptible to disease through alterations of the immune system (Gust and others 1992). Although some animals can be successfully placed with foster mothers of their own or closely-related species, many rejected infants are raised by humans. It is seldom possible under these circumstances to produce an infant with the same frequency and intensity of social contact and stimulation as provided by the natural mother and group, but every effort should be made to maximize the time that such infants are held, carried, and allowed to engage in social interactions. Inanimate surrogates and occasional contact with others will not ensure normal social development. (For additional reading on hand rearing, see Fritz and Howell 1993a; Fritz and others 1992a; Maki and others 1993; Meder 1985; O'Neill and others 1991; Reisen 1971.)

PERSONNEL

Appropriately trained and observant personnel are essential to maintaining primates in captivity. The caregivers should be knowledgeable not only about general husbandry procedures but also about the specific behavioral characteristics of the primate species for which they are responsible. Because of their contact with the animals in their care, they are often in the best position to note signs of illness, injury, or distress. Human interactions with primates can also have a profound impact on both physical and behavioral well-being (Baker 1997; Bayne and others 1993a; Miller and others 1986). For example, personnel can engage in activity that communicates negative messages to the animals, such as macaques and baboons, which can interpret a direct stare as a threat. Conversely, personnel can communicate messages that reduce animal stress, such as lip-smacking at chimpanzees or macaques.

For an enhancement program to succeed, those responsible for implementing and monitoring it should have knowledge of and experience with nonhuman primate behavior. They should attempt to predict and prevent harm to the animals caused by social partners, or even toys, on the basis of their knowledge of their animals. They should be alert to subtle changes in behavior, noting improvements due to enrichment or declines due to illness or other stressors. Periodic training of staff to acquaint them with advances in the field is essential.

Personnel should be aware of safety precautions needed to prevent physical injuries and disease transmission between themselves and the animals. Some enrichment techniques and devices that necessitate daily setup can place a caregiver at increased risk and are inappropriate with many animals. Good judgment in these cases requires individual knowledge of the animals, and caregivers should be encouraged to interact in positive and nonthreatening ways with their animals. Personnel practices that result in frequent exposure of primates to unfamiliar caregivers can also be stressful to animals and should be avoided.

Nonhuman primates and their caregivers must be protected from exposure to hazardous agents. Appropriate protective clothing is required to prevent transmission of disease to humans and to animals, particularly when infectious agents are involved (Bennett and others 1995; CDC-NIH 1993; NRC 1997a). Whereas protective clothing does not preclude forming individual relationships between animals and personnel, the use of a standard uniform , with minimal individual variation, hinders individual identification. It is sometimes advantageous to wear attire peculiar to individual caregivers or procedures (e.g., cleaning and feeding versus handling), rather than a standard uniform. It might convey useful cues to the animals and avoid undue alarm over a potential capture every time a person enters the room. Where possible, staff should avoid barriers that hinder the development of individual relationships between nonhuman primates and the people that care for them. The committee believes that the use of masks, face shields, gloves, and special uniforms should be based on specific needs to protect against identified hazards (NRC 1997a). The intense sociality of many primates is often expressed in forming social relationships with humans (Bayne and others 1993a; Hummer and others 1969; Wolfle 1985); these relationships not only might enhance the psychological well-being of the animals but also will facilitate many routine and even unusual procedures (see "Restraint and Training" earlier in this chapter). A familiar caregiver can often encourage an escaped animal to return to its usual housing or induce an animal to accept medicated food.

Interactions between humans and nonhuman primates can be made less stressful by adherence to routine schedules and procedures, familiarity with handlers and researchers through positive interactions outside the handling context, and the use of training procedures to elicit cooperation and thus minimize force or restraint (Chambers and others 1992; Phillippi-Falkenstein and Clarke 1992; Reinhardt 1990a, 1991b, 1992a, b; Reinhardt and Cowley 1992; Vertein and

Reinhardt 1989). Procedures that reduce reliance on forced restraint and that reduce invasiveness are less stressful for animals and staff, safer for both, and generally more efficient. Using cooperative methods of data collection can lead to higher-quality results. Therefore, training animals and staff to cooperate in routine procedures can be a valuable element of a well-being program.

VETERINARY CARE

Veterinary care should be the responsibility of a veterinarian who has training or experience in primate medicine. The veterinarian should be responsible for medical care and should have a leadership role, with investigators and other personnel, in establishing policies and procedures with respect to husbandry, animal well-being, hazard containment, nutrition, handling, occupational health, safety, and enrichment (CDC/NIH 1993; NRC 1996). The physical and, to a large degree, behavioral well-being of primates depends on a well-considered and comprehensive program of animal care and use.

An effective preventive-medicine program is the foundation on which a healthy, successful primate colony is built. Many factors contribute to a preventive-medicine program, including husbandry procedures, facility design, quarantine and isolation procedures, and clinical care. Primates usually do not show obvious signs of disease until they are seriously ill. In clinical terms, that means that animals identified as ill are often critically ill by the time they are discovered. Therefore, prevention of disease, rather than treatment, should be the primary focus of the veterinary care program.

Quarantine is a time when emphasis is placed on identification and treatment of disease. It is also a time of stabilization, permitting animals to adjust to changes in their physical and social environment, e.g., relocation from a native environment to sudden confinement or less-dramatic changes, as from one captive environment to another. Stresses associated with such moves are usually associated with various modes and distances of transportation, unfamiliar caregiver personnel, new surroundings and caging, different types and availability of food and water, and frequently repeated testing and sampling procedures.

Much of that is unavoidable, but it is helpful to give animals as much continuity with the familiar as is possible, including sensory contact with familiar conspecifics (Coe and others 1982; Coelho and others 1991; Gust and others 1994). Incoming animals that have previously lived together as a social group should be quarantined together as space permits. Infants should be kept with their mothers. Young juveniles will also likely benefit if kept in pairs or trios after arrival. The problems of medical treatment and control of disease should be balanced against the stress of separation and arousal. Such stresses can have profound consequences, especially in younger animals, and can lead not only to behavioral depression, but to changes in endocrine, physiological, immunological, and cognitive responses, which can exacerbate disease (Coe 1993; Gluck 1979; Goosen 1988; Gordon and others 1992; Laudenslager and others 1990).

The rigorous quarantine requirements for primates newly imported into the United States, as regulated by the Centers for Disease Control and Prevention (CDC), might limit but do not preclude attempts to provide enrichment. The relevant federal policies include foreign quarantine regulations (42 CFR Part 71.53), ebola-related filovirus infection and interim guidelines for handling nonhuman primates during transit and quarantine (CDC 1990), nonhuman-primate importation (CDC 1991), and tuberculosis in imported nonhuman primates (CDC 1993). Although the purpose of the CDC-imposed quarantine is to try to detect and prevent the introduction of diseased animals that could present a threat to humans or other nonhuman primates, quarantine is also a time of stabilization and routine disease monitoring. Programs for enriched, single-cage housing or various social groupings can be initiated during quarantine and continued after the quarantine and stabilization period.

Removal of an animal from its usual housing for treatment of an illness or injury can also prove stressful. Whereas such hospitalization is not as great a change as experienced by newly arrived quarantined animals, suggestions concerning maintaining ties in quarantined animals will still apply. Very young animals might need to be removed with their mothers or some familiar companion to reduce the stress of isolation, even if the second animal requires no treatment. Whenever possible, consideration should be given to ensuring that noninfectious animals under treatment can maintain at least some sensory contact with their usual companions.

4

Effect of Special Research Conditions on Psychological Well-Being

Research on nonhuman primates includes a wide array of activities. Much of it involves study of human diseases or conditions that can be studied only in living organisms and cannot be investigated experimentally in humans. Because of their many similarities to humans, nonhuman primates are often the subjects of choice for such research. Basic and applied knowledge gained from this research can improve the well-being of both humans and nonhuman primates.

Animals used in research sometimes experience unavoidable pain or discomfort and conditions that threaten their psychological well-being. Whereas every effort must be made to minimize those effects, it is the conditions that impair psychological well-being that sometimes are the subject of research themselves. Under all circumstances, however, negative effects on psychological well-being should be reduced to the greatest extent consistent with the research objectives. To help investigators to anticipate, mitigate, or avoid procedures that are likely to cause distress in research animals, many scientific organizations have drawn up codes of practice and ethical standards as guidelines for the care and use of animals. In addition, the *Guide for the Care and Use of Laboratory Animals* (the *Guide*) (NRC 1996) and the *U.S. Government Principles for the Utilization and Care of Vertebrate Animals Used in Testing, Research, and Training* (IRAC 1985) contain numerous specific recommendations that are observed by those whose research is supported by federal funds (see also NRC 1992) and by many in commercial and private institutions as well.

Among those recommendations, the *Guide,* the *Public Health Service (PHS) Policy on Humane Care and Use of Laboratory Animals* (OPRR 1996), and the

Animal Welfare Regulations state that institutions should appoint a committee (an institutional animal care and use committee, or IACUC) that is responsible for evaluating their animal care and use programs. Investigators have the obligation to assure review committees that animals will be treated humanely. Research on infectious diseases, effects of atypical rearing conditions, and pathological behavior pose special problems both for those establishing and maintaining enrichment programs and for those inspecting and reviewing such programs. Other circumstances in which experimental manipulations lead to changes in an animal's behavior—such as those related to surgery, drug or chemical treatment, or restriction of movement—also require special consideration to evaluate the animals appropriately and provide as well as possible for their psychological well-being. Investigators and IACUCs should periodically re-evaluate protocols in which animals experience special research conditions. They should be aware that knowledge about aspects of research procedures that cause distress and about methods to mitigate unwanted and unnecessary negative effects is changing continuously.

CONDITIONS INVOLVING INFECTIOUS DISEASES

Studies that use nonhuman primates for infectious-disease research of necessity invoke several precautionary measures, for example, specialized animal holding units for animal and personnel safety (CDC/NIH 1993; NRC 1997a), use of protective clothing, and restricted access to animal areas. A frequent result of such safety measures is an environment that lacks sensory input or challenge to the animal. This is a particular concern when animals are housed in biocontainment units.

It is the responsibility of the investigator, veterinarian, and IACUC to determine the type of biocontainment necessary for a particular research study. Topics that should form the basis of the assessment include the goals of biocontainment, the mode of transmission and biosafety level of the agent, and the object of protection (the personnel, subject animals, and other animals in the facility). For example, research animals might be maintained in biocontainment units to protect personnel from a hazardous agent, to protect the subject animals from adventitious agents in the environment that could interfere with the research, or to protect other animals in the facility from the agent by isolating the infected subject animals. The means of achieving biocontainment should also be carefully evaluated, especially considering the psychological well-being of the primates. For some hazardous agents, protective clothing can be a sufficient biosafety barrier; in other cases, both cage and room barriers with specialized ventilation equipment are necessary.

Regardless of the degree of biocontainment, it is the consensus of this committee that biosafety concerns alone do not justify sensory or behavioral isolation of subject animals. For example, the use of protective clothing does not have to keep personnel from interacting with the animals through appropriate postural and auditory cues, such as lip-smacking with many Old World species. Personnel should learn which human gestures and vocalizations are inappropriate and avoid the ones that stress the animals. Among the latter are threat faces, stares, threat vocalizations, imitations of alarm calls, and territorial calls. In some cases, physical contact between personnel and animal can be permitted, depending on the animal species and the hazardous agent. Likewise, social housing of animals used for infectious-disease research can be permitted in some studies. The use of biocontainment cage units with transparent walls, rather than solid or opaque walls, is preferred because they provide animals with visual contact with conspecifics. Recommendations provided in the *Guide* (NRC 1996) regarding acceptable ranges of illumination, cage size, temperature, humidity, ventilation, and noise level for conventional housing should be followed for biocontainment housing.

The enrichment program for animals in studies of infectious disease need not deviate substantially from that applied to conventionally housed animals. Typically, infected animals can receive the food treats used in the enrichment program for noninfected animals. Similarly, toys or other enrichment devices can be used with animals housed in biocontainment conditions if the devices are disposable or appropriately sanitized.

CONDITIONS INVOLVING ATYPICAL REARING ENVIRONMENTS

The source of nonhuman primates for research is steadily shifting from wild-born animals to subjects that are born and raised in captivity. Whereas the psychological well-being of an animal is best promoted in a social context that approximates the species-typical norm, sometimes this is not possible. Some mothers might reject or be unable to care for an infant, the infant might be ill and require special care, or an approved research protocol might preclude maintenance of normal social compositions. Under such conditions, every effort should be made to provide infants and other immature animals with appropriate social stimulation so as to minimize the adverse effects of rearing in socially restricted environments. In the case of macaques, daily, but not continuous, nontraumatic contact with age peers seems to prevent the worst symptoms of isolation rearing (Mason 1991). As outlined in Chapter 3, however, hand rearing will seldom succeed in producing a completely psychologically normal animal.

CONDITIONS INVOLVING PHYSICAL RESTRAINT OF ANIMALS

Some research protocols require that primates be physically restrained for various periods. In general, the least restraint that accomplishes the research objective should be used (NRC 1996). Restraint can be achieved by either pharmacological agents or special equipment. For purposes of this discussion, only nonpharmacological means of restraint are addressed.

The method of restraint chosen should reflect the purpose of restraint, the period and degree of restraint, maintenance requirements, and the degree of discomfort imposed on an animal. For example, if the research protocol requires that an animal be chronically restrained but does not require strict immobility of the animal, this might be achieved in the animal's home cage by using a jacket and tether system, rather than a more confining primate chair. Animal restraint for periodic weighing, examinations, or testing can be achieved by training the animal to enter a transfer cage, rather than be hand-captured, netted, or chemically immobilized. Pole and collar systems also avoid hand capture and close restraint (Reinhardt 1995).

To achieve the restraint objective best, a balance between maximizing the safety of the procedure and maximizing the comfort of the animals should be struck. If animals are to be chaired for long periods, careful attention should be paid to chair design. A chair that allows the animal to assume a natural sitting or perching posture is preferable to a chair that constrains an animal in an unnatural position. Appropriate use of padding and soft surfaces with restraint devices can also reduce the incidence of injuries, such as decubital ulcers.

The use of restraint equipment does not necessarily preclude an animal from participating in an enrichment program. Manipulable objects and foraging devices that will not become entangled with a tether can be provided to animals that are maintained on a tether. In fact, a tethered animal can be housed with visual, auditory, chemical, and even tactile contact with another without compromising its safety. Similarly, a subject restrained in a chair in a procedure room might profit by having its usual cagemate placed in a cage in its view. Chair-restrained animals can also be provided with enrichment devices attached to the chair. Group housing of animals that are caught daily is still possible if the animals are trained to enter a transfer box (Clarke and others 1988; Reinhardt 1992a) or present themselves for pole and collar capture (Reinhardt 1995).

When deciding on a mode of restraint, the investigator, veterinarian, and IACUC should consider multiple criteria. Does the device provide the minimal restraint required to achieve the research objective? Is it safe for animals and personnel? Are its design and construction appropriate to the age, size, behavior, and normal posture of the animal that will be restrained? Has due consideration been given in the design of the equipment to the animal's comfort, such as use of padding and wide straps and the elimination of sharp or abrasive surfaces? How long will the animal be required to remain in restraint on a single occasion? Will the period of restraint be supervised by trained personnel? Is the animal adapted to the method of restraint and thoroughly trained to the apparatus? Finally, what specific procedures will be used to accomplish these goals, and who will carry them out?

CONDITIONS INVOLVING MINIMALLY INVASIVE PROCEDURES

Precise application of physiological stimuli and accurate measurement of physiological effects might require invasive procedures. If several functionally equivalent procedures are available, a decision should be made as to which is least likely to have a negative effect on psychological well-being. For example, blood can be taken from indwelling catheters or by venipuncture. When samples need to be obtained with high frequency and minimal disturbance, a catheter or vascular access port might be preferred. Taking blood via catheter or vascular access port causes no pain, but the animal should be anesthetized while the equipment is being installed and should be prevented later from pulling it out. A primate chair can prevent the animal from removing the catheter, but it severely restricts the animal's mobility. Another method that might protect the catheter but cause less restriction of movement is a tether system that includes a protective cover on the catheter.

The stress involved in venipuncture lies primarily in the physical restraint necessary to obtain the sample. A variety of nonhuman primates have been successfully trained to extend a limb voluntarily to permit a sample to be collected if repeated brief sampling is required (Bernstein and others 1991; Laule and others 1996; Rose and others 1975). For some purposes, hormonal data can be obtained from samples of urine and feces, rather than blood samples (Crockett and others 1993b; Kelley and Bramblett 1981; Lopez-Anaya and others 1990; Lunn 1989). Baboons have also been trained to submit routinely for taking blood pressure (Turkkan and others 1989). In addition, a variety of devices are available, including commercial products, for telemetric recording of some physiological characteristics and for the delivery of stimuli or active substances. Personnel safety is paramount when people are working with and training nonhuman primates, and no single technique for gaining access to an animal's arm or leg safely is universally accepted. What is considered the best safe practice is to train the animal to extend its limb (and sometimes to hold a firmly attached bar with the fist), or place a limb or shoulder against the cage, but persons should NEVER reach into the cage of any but the smallest species. Macaques, chimpanzees, and other large species can do great damage to those who fail to heed this tenet. Readers should become very familiar with the training literature before initiating these programs (see "Restraint and Training" in Chapter 3 and Laule and others 1992).

Investigators should always be mindful of the effects of procedures on the well-being of the animals involved. If a choice is possible, instrumentation that appears least likely to cause a subject discomfort or distress should be chosen.

CONDITIONS INVOLVING SURGERY

Some research protocols require surgical procedures. Experimental surgery is often referred to as *major* or *minor*, depending on the nature of the procedure. Both major and minor surgical procedures are potentially painful and can have negative effects on the well-being of the subject animal. Surgical procedures should be carefully considered to determine the least-invasive and least-stressful method of accomplishing the research goal. Most minor procedures and all major procedures are carried out under general anesthesia. Therefore, the well-being of a subject animal is most likely to be compromised during the postoperative or healing period. Although humans can indicate when they do or do not wish to use analgesics to contend with temporary postsurgical pain, nonhuman primates cannot so indicate and so should be given analgesics to prevent distress and reduce pain. Appropriate use of analgesics should result in improved appetite and more interaction of an animal with its environment (NRC 1992), but care should be taken that sutures are not removed by the animal.

It should also be recognized that surgery performed with the goal of altering the normal function of a physiological system can affect the psychological well-being of animals in the postsurgical period. Such procedures include those which reduce a subject's ability to interact socially or with the environment. Examples are procedures that result in impaired sensory perception, limit an animal's movement capacities, and impair cognitive abilities. After those procedures, appropriate accommodations should be made in an animal's housing environment or access to enrichment devices to maximize the extent to which it can interact socially and with the environment. Such accommodations can include housing the animal in a social group where it will not be subject to aggressive attacks, giving it manipulable objects that can be used with a particular sensory or motor deficit, and giving increased personnel attention to an animal that can no longer be put in social housing.

MULTIPLE RESEARCH USE

Nonhuman primates are long-lived, expensive, and often threatened with extinction in nature. Animals maintained in a state of good health and well-being can contribute to research for many years. Facilities should assume that many nonhuman primates will participate in multiple studies and plan accordingly. This committee believes that appropriate multiple use of primates is in the best interest of conservation goals. Appropriate rest and recovery periods should be provided after each protocol that an animal participates in.

A subject of some controversy is the use of primates for multiple survival surgical projects. With most species, multiple survival surgery is not recommended; however, multiple survival surgery using nonhuman primates should be considered. To conserve as many animals as possible and maximize the long-range research contribution of each animal, it might be necessary to use animals in multiple protocols that involve surgery. IACUC participation in making these decisions is very important. The well-being of the animals is not necessarily compromised by this approach if careful attention is given to the use of analgesics and enough time is allowed for recovery between operations.[1]

CONDITIONS INVOLVING PAIN

Pain involves stimulation of physiological systems that process information about tissue damage (this process is called nociception) and systems that contribute to the perception of such events as painful. The two kinds of systems are not necessarily both active in all situations (Wall 1979). Nevertheless, the most conservative stance with respect to pain in nonhuman primates is to consider that both systems are operative. As stated in Principle IV of the *U.S. Government Principles for the Utilization and Care of Vertebrate Animals Used in Testing, Research, and Training,* "Unless the contrary is established, investigators should consider that procedures that cause pain or distress in human beings may cause pain and distress in other animals." (IRAC 1985; NRC 1992, 1996). Accordingly, we should assume that pain is potentially stressful for these animals and that severe or prolonged pain can threaten their psychological well-being.

Pain can occur in research animals for several reasons. It can be an unintended and unwanted byproduct of research. It can be an integral and explicit part of a research protocol, although not an objective (such as the use of electric shock in avoidance conditioning). It can occur as the principal focus of the research, as in experimental studies of pain itself and analgesia. Whatever its source, pain should be carefully monitored and controlled. Pain can occur as an unintended byproduct of research because of deficiencies in the design of equipment or as a postoperative response to surgery. In the first instance, equipment redesign is mandated; in the second, appropriate use of drugs is required (NRC 1992). When pain is used to motivate behavior or in experimental investigations of the nature and treatment of pain, the recommended procedure is to allow the animal to control the amount of pain it receives. For example, it might choose not to perform when the level of aversive stimulation is unacceptable or choose to avoid or escape from a painful stimulus. In any protocol involving the use of pain, the investigator should assess the pain by actually experiencing the maximal stimulus that would be delivered to the animal (NRC 1992).

[1] Before approving multiple major survival surgery on a single animal, readers should refer to the Animal Welfare Regulations, the Public Health Service Policy, and the *Guide*. Institutions are prohibited by federal law from conducting multiple major survival procedures on a single animal unless the procedures are components of a single approved protocol. Approval might be granted under exceptional circumstances.

ANIMAL MODELS OF SUBSTANCE ABUSE

Nonhuman primates (principally macaques, squirrel monkeys, and baboons) are used as subjects in behavioral and neuropharmacology experiments to study the effects of psychoactive drugs on specific types of behavior and to investigate the potential for abuse and drug dependence that such drugs present (e.g., Barrett 1985; Brady and Lukas 1984; Brady and others 1987; Meisch and Carroll 1987; Yanagita 1987). Some of the research conditions already considered—such as those involving restraint, invasive procedures, and aversive stimulation—are also used in research on psychoactive drugs, and the same concerns apply with respect to psychological well-being. In addition, the creation of physical or psychological drug dependence raises the possibility of intense withdrawal responses that might continue—or even become more severe—when an animal is no longer in the experimental setting. If such effects can be anticipated and are not part of the aims of the research, the IACUC and the investigator are obliged to consider them and if possible mitigate or eliminate them. Subjects in these studies present a special problem in providing for psychological well-being. They are often not compatible with social partners and might be unresponsive to other enrichment techniques, depending on the pharmacological agent being used and the degree of dependence. Their comfort and well-being require special attention and consideration.

CONDITIONS INVOLVING AGGRESSION

Aggression is a part of the lives of nonhuman primates. In its most extreme form, aggression can cause extensive injury or death, and even the milder forms of aggression—which are generally expressed as species-typical postures or facial expressions—can be a marked source of stress. Different types of aggression can be directed toward conspecifics or caregivers, or toward the physical environment. Self-injurious behavior is a special type of behavior of concern.

Although investigators can find many opportunities to study the mechanisms involved in the expression and control of aggression by observing spontaneous outbreaks of aggression, some forms of research into aggression might involve the use of methods that instigate aggression under controlled conditions. That aggression is the subject of an approved study does not relieve the investigator, veterinarian, and IACUC of the responsibility for ensuring that consequent injuries and stress are minimized. Aggressive episodes, whether fortuitously detected or instigated according to an applied protocol, should be carefully monitored and controlled. In both instances, investigators have an obligation to intervene to protect their subjects from harm. When aggression is studied as part of an approved protocol, there should be a clear statement of the criteria to be used in deciding when intervention is necessary and a protocol to follow to keep the risk of injury and the degree of stress to the minimum consistent with the aims of the research. For many research purposes, injury is an unnecessary and undesirable consequence of research on aggression.

5

Prosimians

Scientific Name[1]	**Common Name**
Lemurs	
LEMURIIDAE (lemurids)	
Lemur catta	ring-tailed lemur
Eulemur fulvus	brown lemur
Eulemur mongoz	mongoose lemur
Eulemur rubriventer	red-bellied lemur
Varecia variegatus	ruffed lemur
Hapalemur sp.	gentle lemur
CHEIROGALEIDAE (cheirogaleids)	
Cheriogaleus medius	fat-tailed dwarf lemur
Microcebus murinus	lesser mouse lemur
Mirza coquereli	Coquerel's mouse lemur
INDRIDAE (indrids)	
Indri sp.	indri
Propithecus sp.	sifaka
DAUBENTONIIDAE	
Daubentonia madagascariensis	aye-aye

[1] This is a list of scientific and common names of species discussed in this chapter, not a comprehensive taxonomic list.

Lorises and galagos	
LORISIDAE (lorisids)	
Galago crassicaudatus	thick-tailed galago
Galago senegalensis	dwarf galago, senegal galago
LORISINAE (Lorisines)	
Loris tardigradus	slender loris
Nycticebus coucang	slow loris
Tarsiers	
TARSIIDAE (tarsiids)	
Tarsius sp.	tarsier

This chapter is a brief summary of extensive published data. For more information and additional data on lemurs and other prosimians, consult Harcourt and others (1998); IUCN (1990); Segal (1989); Bennett and others (1995); and UFAW (1987).

The suborder Prosimii might constitute the most diversified set of living mammals. One major group, collectively referred to as lemurs, occurs in nature only in the Malagasy Islands. Its major taxonomic subgroups are the true lemurs (Lemuriidae), mouse and dwarf lemurs (Cheirogaleidae), indris and sifakas (Indridae), and perhaps the phylogenetically oddest of all primates, the aye-aye (Daubentonidae). Few are maintained in captivity; the most likely representatives to be seen in captivity are the Lemuriidae: the ring-tailed lemur (*Lemur catta*), the brown lemur (*Eulemur fulvus*), and the ruffed lemur (*Varecia variegatus*).

A second major group (Lorisidae) consists of lorises and galagos. All galagos in nature are from Africa; two members of the loris group are from Africa and two from Asia. Galagos are sometimes referred to as bushbabies, but this common name is sometimes applied to other animals as well. The thick-tailed galago (*Galago crassicaudatus*) and dwarf galago (*G. senegalensis*) are the only members of this group seen more than rarely in captivity.

A third major group consists of the tarsiers (*Tarsius*), from the islands of southeast Asia. The taxonomic position of tarsiers remains controversial; these animals are difficult to maintain in captivity, and few institutions attempt to do so.

Prosimii vary widely in size, dietary preferences, locomotor adaptations, social organization, and intelligence. Living prosimians range in size from the mouse lemur, with a body length of about 12 cm (5 in) and a weight less than 100 g (4 oz), to the tailless indri, with a body length of about 90 cm (3 ft). Different dietary adaptations in various genera and species are reflected in major differences in the alimentary tract. Differences in locomotor styles are reflected in major anatomical differences. All those contribute to the observed diversity in behavior and social organization. As body size and locomotor habits vary widely, so do requirements for housing and living space. There are agile leapers and slow climbers, predominantly arboreal and mainly terrestrial prosimians. There are insectivores, highly specialized leaf-eaters, bamboo-eaters, fruit-eaters, and omnivores. Some species occupy tree holes or build nests that are used as general sleeping quarters or primarily for the care of infants. Some prosimians give birth to twins or small litters, whereas the norm for most species is a single offspring. Some prosimians resemble bats in having ultrasonic calls, and some species have very complex vocal repertoires. A few species even exhibit periods of torpor resembling hibernation. Almost every prosimian species has its own distinctive life style. Some live in large groups, others in small groups; some travel alone, some in pairs. Most prosimians scent-mark and urine-mark their surroundings, others also mark with feces. There might be a greater diversity of scent glands on various body parts in prosimians than in any other mammal, and the ability to maintain scent marks in their environment appears to be important for the general well-being of prosimians.

Despite the enormous diversity of prosimians, a few general comparisons between prosimians and other primates can be made. Prosimians are less inquisitive, less restive, and less destructive to their environment than other primates; the only exception is the aye-aye, which will gnaw through structures. Prosimians are the primates farthest removed from humans, and there is much less likelihood of disease transmission between humans and prosimians than between humans and other primates. In fact, no case of a transmission of a zoonosis from prosimian to human could be found in a search of the literature.

In contrast with other primates, which (with the single exception of the night monkey, *Aotus*) are diurnal, prosimians are primarily nocturnal. Only among the lemurs are there some diurnal forms. Some are also crepuscular (active only at dawn and dusk), a few are cathemeral (being sporadically active throughout the 24-hour cycle), and a few display some flexibility in circadian rhythms. The captive maintenance of prosimians must take these patterns into account. Some institutions might wish to maintain reverse light cycles by using regular room lighting at night and low levels of red illumination during the day so that caregivers can observe them during their active period.

The Duke University Primate Center has had the most comprehensive experience in the care of prosimians of any institution in the United States and is the largest captive prosimian colony in the world (Bennett and others 1995). The committee's recommendations are based largely on successful experiences at Duke.

HOUSING

Prosimians can be kept safely in a wide variety of cages and enclosures, ranging from multihectare outdoor habitat enclosures, corrals, and large indoor rooms to complexes of small wire cages or even small single cages with a volume of 1 or 2 m^3. For monitoring and protection from hypothermia, the smaller, mainly nocturnal forms are best kept indoors on reversed lighting schedules.

Prosimians rarely attack cage structures. Perhaps as a consequence of their ability to leap and move rapidly through thorny scrub in their natural habitat, they are less likely than other primates to be injured by wire. Wire cages provide extensive climbing surfaces for small prosimians. Prosimians make good use of shelves, ropes, or swings and do well with natural substrates—such as vines, bamboo, and branches—to climb on or jump among. With regular cleaning and replacement of cage furniture, wooden objects have not been implicated as natural-disease vectors. Attempts to keep and breed prosimians under conditions that maximized sanitation and lacked nest boxes or appropriate substrates for climbing and jumping affected reproduction and survival adversely. In fact, the effects of long-term housing under these conditions were not readily reversed when the animals were provided more suitable housing in which other members of their species thrived.

True lemurs (*Lemur*, *Eulemur*, and *Varecia*) do well in large outdoor enclosures. Some success has been reported in smaller runs with a minimum of 5 m^3 (175 ft^3) per animal. Indoor rooms may also be used, although lights must be kept on a timer or on a manual light cycle designed to simulate seasonal photoperiod changes to ensure breeding. Concrete flooring of either indoor or outdoor enclosures is contraindicated because animals have been killed by falls onto concrete surfaces. Heated shelters larger than 60 cm square (2 ft square) should be provided with resting and feeding shelves. Under severe weather conditions, lemurs might need to be secured in sheltered housing because some will not use heated shelters regularly otherwise. Lemur housing should be furnished with vertical and horizontal natural substrates, such as vines, bamboo, and branches. Weekly sanitation of PVC “branches” has been associated with anogenital microabscesses in *Varecia.* Natural substrates sanitized less frequently do not produce such problems.

Large forested enclosures are suitable for lemurids, and one enclosure can hold species of all lemurid genera, inasmuch as these species are not hostile or competitive toward each other. The use of electric fencing is effective when groups are socially stable, but animals rejected by their social group will escape over such fences. Sand or grass flooring in enclosures can be maintained if spot-cleaned and raked daily. The Duke Primate Center has found weekly sanitation of shelter-box interiors and monthly sanitation of the cage furniture, nest boxes, and windows to be effective in maintaining sanitation and providing essential species odors.

In contrast with true lemurs, Cheirogaleidae (mouse and dwarf lemurs) seldom jump more than a meter and are conveniently housed in cages containing family groups of pairs or trios of animals plus the season’s juveniles. Cages as small as a 1.2-m cube (3.9-ft cube) appear to provide adequate space for such groups.[2] Cages constructed of coated wire are very light and can be hung from the walls in easily sanitized rooms. On the basis of the experience of the Duke center, we recommend that the cages themselves be sanitized no more than once a month—and less often when infants are present. Cage-washing seems to be stressful to these animals, and there are no reports of infectious-disease problems or spread of disease among captive mouse and dwarf lemurs housed in cages cleaned even less frequently. To protect against falls when they are kept in indoor rooms, floors can be coated with about 5 cm (2 in) of sand or wood chips, which should be spot cleaned daily. "Nest boxes" composed of plastic tubing of various diameters to accommodate larger and smaller cheirogaleids are recommended.

The Indridae (indris and sifakas) have highly developed leaping abilities—individual jumps can be up to 7 m (23 ft) laterally—and they need more space and more vertical supports than do other prosimians. Small families have been successfully maintained in indoor rooms of 5 × 7 × 6 m (16.4 × 23 × 19.7 ft). In warmer climates, these animals can be released into large outdoor enclosures, but they will need access to heated shelter boxes during colder weather. Indrids stop feeding and enter such warm quarters long before sunset. Heat lamps should be in more than one location because males are sometimes excluded from choice sleeping sites.

Aye-ayes (Daubentoniidae) will gnaw cage structures with their large chisel-like front incisors and require sturdier housing than other prosimians. They are adept at climbing and leaping and have been bred successfully in an indoor room of 5 × 5 × 5 m (16.4 × 16.4 × 16.4 ft) with extensive vertical and horizontal branches as well as ropes and vines for climbing and swinging. They require a nest box for short periods of rest and daytime sleeping. Aye-ayes stuff their nest boxes with branches, leaves, or straw as available. They normally live independently in the wild, but when provided with two or more nest boxes, mixed-sex pairs can live together after a period of adjustment. Floors should be covered with wood chips to prevent injury from falls and to absorb the normally dry fecal material and urine. Daily spot cleaning and monthly replacement of chips have proven sufficient.

Lorises and galagos tolerate few others in small cages. Large cages and cages partitioned into several chambers connected by wire tunnels that can variously be closed off can be used for breeding. Males should be separated from newborn infants with double-wired partitions because they sometimes attack

[2] Although the use of this size cage represents an exception to the size recommended in the Guide and required by the Animal Welfare Regulations, it has been found satisfactory for very small prosimians and approved for such use by the USDA at the Duke Primate Center. Other facilities are encouraged to seek similar approval if using caging not in compliance with the regulations.

infants. A nest box is required by all. The slow-moving lorises, as opposed to the more active galagos, require multiple horizontal branches and platforms for resting and marking. Because lorisines have a "dropping response" when startled (i.e., they fall to the floor), floors should be well cushioned with shavings or other suitable material.

Tarsiers are active jumpers, and a male and female will need an enclosure about 2 × 2 m (6.6 × 6.6 ft) and 3 m (9.8 ft) high to allow for leaping. In larger enclosures, they can be kept in groups. Rooms or cages should be furnished with multiple vertical bamboo poles, tree branches, and vines. Tarsiers will not use a nest box but do like to sit in tangles of vines. The substrate of cage furniture needs to provide ample climbing surfaces so that insects and lizards, introduced as food items, can be seen and hunted. High humidity is required by tarsiers; if it is not supplied through circulating air, the animals should be misted several times a day. Tarsiers prefer to drink droplets from the misting on their fur and cage furniture, rather than to drink from dishes. To prevent injury, cage floors should be covered with litter 5 cm (2 in) deep, such as shredded cypress bark, which is resistant to decomposition and retains moisture.

NUTRITION

Inasmuch as the prosimians are a highly diversified group of animals with extraordinary variation in dietary requirements, no general diet can be recommended. The group as a whole will not thrive on commercial diets standardized to meet the needs of New World or Old World monkeys. Many of their dietary needs are still not well understood. Therefore, maximizing dietary variety might prevent nutritional imbalance. The recommendations that follow are essentially descriptions of the most successful diets known at this time.

The true lemurs can be maintained on a diet of monkey chow mixed with alternating selections of chopped fruits and vegetables. The gentle lemur (*Hapalemur*) eats the leaves and stems of several bamboo species and seems to prefer only particular vegetables, such as cucumber and sweet potato. It appears to extract nutrients more efficiently than other lemurs, and browse should be carefully screened for potential toxicants (e.g., oxalates in Russian vine). The ruffed lemur (*Varecia*) is much more frugivorous and has a very short gut-passage time. Soft stools in these animals are firmed by the addition of browse to the diet. For the gentle lemur and mongoose lemur (*Eulemur mongoz*), monkey chow should be restricted lest they tend to become obese and develop hypercalcemia.

Mouse and dwarf lemurs (Cheirogaleidae) can be fed a combination of cracked monkey chow mixed with chopped fruit and vegetables and live crickets or mealworms. For the fat-tailed dwarf lemur (*Cheirogaleus medius*), the daily summer provision is a tablespoon each of the chow and vegetable-fruit mix with one or two crickets. The winter diet is reduced by one-fourth and crickets are eliminated. The lesser mouse lemur (*Microcebus murinus*) can be maintained on the same diet by adding a cricket to both the winter and summer diets. Obesity will result if winter diets are not reduced. *Mirza coquereli*, in contrast, does not enter torpor (a period of lethargy resembling hibernation), and no dietary change is required. It will consume about twice the amount in the summer as the lesser mouse lemur.

Indrids are obligatory folivores that have specialized in detoxifying various classes of leaf compounds, such as tannins. As a consequence, their captive diets require much more attention than that of other lemurs lest they quickly sicken and die. Sifakas pose particular problems in that they reject new items in their diet until they see and smell other conspecifics eating them. Leaf fiber (e.g., mango, sumac, mimosa, sweet gum, and tulip poplar) appears to be critically needed for their health. Deciduous leaves wrapped in plastic and frozen will be accepted after thawing. The seed pods and flowers of such plants as mimosa, redbud, and maple are also important food items, but they might cause diarrhea if introduced abruptly in large amounts. Browse is best presented by tying it to vertical supports. Peanuts and oak nuts should be limited because of their high fat content, but they are preferred foods, so they might help a sick (underweight) sifaka to recover from illness. Sifakas seem reluctant to drink water, and few will use a water bottle. Open bowls are more likely to be used, and browse can be sprayed with water.

Aye-ayes will reject monkey chow even if it is mixed with honey, coconut milk, milk, or fruit juice. They have been successfully maintained on commercially available foods, including a wide variety of fruits, cucumbers, coconuts, corn on the cob, sugarcane, raw eggs, and insect grubs, such as mealworms, waxworms, and various wood-boring larvae. Raw eggs should be limited to no more than three times a week because of the biotin-binding properties of avidin in the whites. Vitamins can be added to a gruel made of sweetened condensed milk, high-protein baby cereal, and eggs. Insect grubs appear to be the most-favored food items, as well as foodstuffs that are high in sugar or fat. Aye-ayes are not seen to drink often, but they will lick water from a bowl by using their specialized third digit (Napier and Napier 1985, pp. 93-94).

Lorises are adequately maintained on a diet of unsoftened, cracked monkey chow combined with chopped fruits and vegetables, crickets, and occasional mealworms. Separating feeding sites widely will reduce fighting over food. Yogurt and additional food should be provided to pregnant and lactating females. Lactation lasts for 6 months, but juveniles begin to eat solid food at 2-3 months.

Galagos—and in fact all lorisids—need hard elements in their diet to remove tartar or plaque from their tooth combs and canines. If they are not provided or if the teeth are not cleaned, these accumulations can cause severe gingivitis, tooth loss, and eventual death. The presence of too much protein in the diet of lorisids can promote kidney disease.

Tarsiers are strictly carnivorous and will not eat any kind of inanimate prepared food. In a typical night, a single tarsier will eat 30-40 crickets and perhaps one lizard. They will also accept mealworms, wild-caught insects, and laboratory-mouse pups. They also appear to need supplemental calcium, and crickets can be coated or dusted with powdered calcium or fed a diet rich in calcium before being introduced. Calcium paste can also be spread on tarsiers' thighs when they are sleeping, and they will later groom it off. Water should be supplied in bowls and as mist.

SOCIAL BEHAVIOR

Except for the relatively small number of species that do not consort as family groups (such as the mouse lemur, aye-aye, lorises, and some kinds of galago), prosimians do best when housed in social groups. All are highly sensitive to chemical stimuli (Schilling 1979). Scent glands often are sexually dimorphic and can undergo seasonal changes in activity (Epple 1986; Schilling 1979, 1980). There is great complexity in the scent-marking behavior of some prosimians, including elaborate mixing and dispersal of odorants from several sources (Evans and Goy 1968; Jolly 1966).

Behavioral observations and several experimental studies have shown that secretions yield detailed information about scent donors' species, subspecies, gender, individuality, and hormonal status, as well as the age of the scent mark (Clarke 1982a, b; Dugmore and others 1984; Epple 1986; Harrington 1976, 1977; Mertl 1975; Schilling 1979, 1980). This information is important in many contexts, such as territoriality, reproduction, and social hierarchies. In the solitary species, chemical signals seem to be the predominant means by which animals communicate and by which breeding activities are coordinated (Charles-Dominique 1974; Schilling 1980). Moreover, in at least one species, urinary odors have been shown to influence endocrine events. Odors from dominant male mouse lemurs decrease testosterone concentrations and increase cortisol concentrations in isolated, unfamiliar males (Schilling and Perret 1987; Schilling and others 1984). Such priming might not be limited to the mouse lemur, but might occur in males and females of some other prosimians as well (Epple 1986).

The high degree of reliance on chemical communication means that prosimians should be maintained in housing that permits them to engage in scent-marking activities, explore the scent of conspecifics, and maintain their own scent environment. Scent marks seem important to their well-being and might influence the reproductive physiology of conspecifics (Schilling 1979; Schilling and Perret 1987). Frequent and too-thorough cage-cleaning might be highly disruptive to their well-being. As with the callitrichids, cage-cleaning schedules should consider both the need for sanitation and maintenance of the animals' olfactory environment. During scheduled cleanings, it might be wise to leave at least some perches untouched until the next scheduled cleaning.

REPRODUCTION AND DEVELOPMENT

Unlike other primates, prosimians have a primitive bicornuate uterus and, with the exception of the tarsier, have diffuse rather than hemochorial placentation. Breeding patterns vary from extremely narrow seasonal to aseasonal breeding. Gestation varies from as short as 2 months in mouse lemurs to 6 months or more in lorises, indrids, and tarsiers.

True lemurs typically have brief, distinct breeding seasons. Males might fight one another during this time. Gestation lasts 4-4.5 months. Infants develop rapidly but might nurse for 4-6 months. Most mothers carry young infants, but gentle lemurs might "park" infants on a branch while feeding nearby. Whereas most species breed in social groups, the mongoose lemur (*Eulemur mongoz*) and red-bellied lemur (*E. rubriventer*) breed as single pairs.

Dwarf and mouse lemurs are usually found alone, but males seek out ovulating females. It is believed that males need olfactory or other contact with females to reach optimal breeding condition. Males constantly mark any clean surface during breeding, and excessive sanitation of cages interferes with breeding by the male. Females build nests where the young are born; *Mirza* builds a leafy nest, and the others nests in tree holes. As many as four infants can be born in a litter, but females abandon or cannibalize their young if cages are moved or cleaned while infants are in the nest. The vaginal openings of females often "seal" between estrus cycles. Gestation ranges from 2 to 3 months.

Obesity interferes with reproductive cycling in sifakas (*Propithecus*) and precautions to regulate calorie availability might be necessary with these animals. Singleton births are the rule, and care should be taken to keep periparturient females in warm environments because newborns have very thin hair and chill easily. Sifakas are the only lemurs whose birth period occurs in winter in the Northern Hemisphere. Other adult females and juveniles might interfere with newborns, so it is advisable to separate periparturient females for up to a week. It is, however, desirable to maintain visual and olfactory contact with other group members. After a week, mother sifakas will not allow other group members to steal or harm their infants. Fathers might at times carry infants but should be allowed to do so only if an infant can actively rejoin its mother. Weaning of infants occurs at 3-4 months. The gestation for *Propithecus* is 170 days.

An aye-aye male might join a female for a few days at the time of ovulation and even sleep on or near her nest, but he otherwise remains at a distance. After a 5.5-month gestation, an infant will remain in the nest for nearly 2 months unless its mother carries it in her mouth to a new nest location.

Galagos can take 2 or 3 years to resume breeding after being moved north of the equator. Galagos are less seasonal than lorises, but the vagina in both can seal until the week before estrus. Most can be kept as pairs for breeding, and even usually incompatible males can be safely placed with an estrous female. Males, however, should be removed from the room when females are ready to deliver and not returned until infants are well developed. If left with a female, a male will cannibalize infants and, if left in the same room, might so stress a female that she will attack her own infants. Gestation periods are 5.5-6 months in lorises and 4.5 months in galagos.

Although tarsiers will breed in captivity, they rarely survive the first week. Gestation is 6 months, and infants can weigh nearly 25% of the adult female's weight. It is thought that the failure of infants to thrive is due to dietary inadequacy.

COGNITION

Little work on lemur cognition has been published, and the general impression is that these animals are less ingenious than other primates. Nevertheless, they display similar abilities in reconciliation after fighting and have complex vocal repertoires. Housing of dwarf and mouse lemurs can be enriched by constructing cages with many internal branches and chambers that are connected by tunnels so that animals can range throughout considerable space and have both contact with conspecifics and the ability to avoid them. Enrichment devices in the form of puzzles excite little interest in lemurs. However, food puzzles that require efforts in foraging do seem to attract their interest.

The indrids will make use of swings and ropes and respond to food *extraction* puzzles. Although often passive, sifakas can be ingenious and manipulative when challenged in searching for food.

The aye-aye has a more convoluted brain than other prosimians and well-developed foraging capacities that involve coordination of the senses. Hearing is extremely acute, and the third digit on the forelimb is elongated and specialized for probing and percussive tapping. Enrichment can be provided through puzzle feeders, logs that contain grubs, and relatively frequent cage-furniture rearrangement.

Lorisids are inquisitive about their surroundings and seem to enjoy novel objects, such as wire mazes that contain fruit. Having live prey to hunt also greatly interests lorisids. Slender lorises will catch fish in water and stalk insects, birds, and small mammals. Gum-arabic feeders and such unusual food items as yogurt, eggs, and novel insects elicit the attention of all lorisines.

Tarsiers seem to be lacking in responsiveness or inquisitiveness, but they do seem to appreciate complex cage interiors. Providing the widest possible variety of prey items also elicits fuller expression of their hunting regimen. Housing of tarsiers alone is inadvisable because it leads to inactivity. Same-sex pairs can show hostility, but groups of as many as six or seven can be formed without apparent conflict.

PERSONNEL

Most prosimians are not aggressive toward humans, but caregivers might find it startling when an aye-aye jumps toward them or even clings to them. They are quite fearless and extremely inquisitive and will examine hands, head, feet, etc., in detail.

Nonaggressive prosimians, however, will strenuously resist restraint. Sifakas can deliver powerful kicks, the aye-aye has a powerful bite, lorisids are adept biters, and the slow loris even has a poisonous mix of saliva and glandular secretions.

During capture or restraint, many prosimians will resist vigorously with some peril to both handler and animals. Violent leaping and struggling in nets can produce self-injuries in indrids, and tarsiers seem especially stressed by handling. A minimum of restraint should be used, and personnel should be mindful of the fragility of the smaller species. Capturing animals while they are asleep in nest tubes or boxes is preferable to vigorous chasing.

VETERINARY CARE

Whereas most prosimians exhibit few health problems, some special comments are in order. Infants that are rejected by their mothers and hand-reared are notoriously sickly. Whenever possible, rejected infants should be fostered on another mother; lemurid mothers can easily rear two young at once. As a health precaution, lemurids should be weighed at least twice a year and whenever they are handled or there is concern for their health. Minimal interference in groups in large enclosures is possible. Lemurids readily recover from moderate trauma, and even simple fractures have been noted to have healed without treatment (although we do not advocate ignoring such injuries). When injuries (e.g., lacerations, fractures) require treatment, every effort should be made to provide treatment that will allow the animal to be returned immediately to its group. That will minimize the possibility of group rejection, which might occur after a separation of only 1 or 2 days. Substantial effort should be made not to separate sick or injured lemurs from their social group, lest separation cause depression or social rejection.

Weight checks will reveal normal seasonal weight changes associated with winter torpor, but the weight of mouse and dwarf lemurs should otherwise be stable among adults. Fecal examinations (flotation and smear) should be carried out twice a year or whenever stool is abnormal. Newly arrived animals should receive fecal examinations weekly for at least 3 weeks. Stress produced by overcrowding sometimes leads to illness, especially liver and kidney problems.

Sifakas are very susceptible to changes in diet, which can lead to diarrhea. Trichomoniasis can be a secondary problem with such diarrhea and requires treatment with metronidazole. Diarrhea and other septic conditions in indrids lead quickly to electrolyte disturbances, so quick and aggressive intervention is warranted. Intravenous fluids are the mainstay of such intervention; monitoring of intravenous fluids is essential because they tend to sequester in the large intestine. Third-generation cephalosporins are preferable to aminoglycosides in these animals. Because of the fermentative processes in their digestion, injectable antibiotics have to be used. Sick sifakas, if possible, should be paired with or kept in sight of other conspecifics to avoid anorexia and depression. Inasmuch as much of their bodily fluid is extracted from ingested plants, anorexia quickly leads to dehydration, electrolyte imbalances, and death. Sifaka are extremely sensitive to acepromazine, which causes almost immediate apnea and should never be used for sedation.

Aye-ayes are generally hardy, and adults weigh about 2.5-3 kg (5.5-6.6 lb). They might continually scratch at cuts or scrapes, especially about the face, and this greatly delays healing.

Kidney failure and liver failure are frequent causes of death in lorisids and are perhaps diet-related. Fecal examinations should be conducted twice a year. Lorisids fight each other with attacks to the head, genitals, and tail, and the bite wounds are very likely to develop *Pasteurella* abscesses. Stressed mothers might overgroom infants. Much more than lemurs, lorisids require isolation from stressful factors. Sources of stress include the presence of too many cages in one room with consequent high levels of calls and vocalizations. Technicians should avoid disturbing nursing mothers. Stress is also contributed to by cages that are too small. Signs of stress include urine burns and overgrooming, which leads to hair loss.

Tarsiers seem to be susceptible to severe ketosis, which might be age-related and appears unresponsive to medical treatment. Nutritional factors and the need to eat only live food affect the course of illnesses, because the animals stop feeding when weakened by illness. Pesticide residue can be a contributing factor to high infant mortality and loss of health. Tarsiers seem to be unusually sensitive to pesticide residue because of their diet, which is composed largely of insects, so every effort should be taken to keep their environments free of such substances.

SPECIAL CONSIDERATIONS

Lemurids are sensitive to *Toxoplasma* and *Yersinia*, and every effort should be made to keep these organisms out of their enclosures. Fecal material from cats and poultry are likely vectors, and *Yersinia* thrives in standing pools of water. *Yersinia* can be controlled by preventing the formation of standing water pools in runs.

Ruffed lemur females, and other lemurs less often, sometimes neglect their young, especially when they are first-time mothers. They can be encouraged to "bond" with and nurture their infants by placing both mother and infants in a small kennel after parturition where the mother cannot stray from the young, and mothers will usually allow infants to be pushed underneath them by technicians if they stray too far.

Cheirogaleid odors are often very powerful. Coquerel's mouse lemur has a particularly pungent and penetrating odor; it is normal for the species, and strong odors do not indicate unsanitary conditions. There is no evidence that air exchanges of more than 10 per hour improve this condition.

Indrid mothers can be aggressive to infants during weaning, and this is a critical period when a juvenile can rapidly dehydrate and die because of insufficient fluid intake. Intervention involves administration of subcutaneous or intravenous fluids (not oral fluids). As stated earlier, sick indrids should not be kept in small cages for extended periods. For proper health and reproduction, indrids seem to need outdoor access.

Unlike all other prosimians, aye-ayes actively bite into wooden structures in cages. When they are to be transported, it is advisable to line the inside of airline kennels with wire.

Both lorises and galagos need a fairly high relative humidity (50-60%) to avoid peeling and cracking of the skin.

If their cages have insufficient or inappropriate surfaces for marking, lorisids (especially males) suffer urine burns. Ventilation and drainage holes should be drilled into the bottom of PVC nest tubes. Lorises and galagos might urinate in these tubes while sleeping and can develop urine scald if the urine is not allowed to drain. For that reason, some caregivers prefer sleeping boxes made of wood, which is more absorbent.

When transported in large cages, tarsiers sometimes died from injuries sustained because of their great leaping capacities and general excitability. It has been found that a very small cage—20 × 12 × 14 cm (8 × 5 × 6 in)—with screen-sided panels protects them. Each box can contain two vertical dowels in central positions. The animals cling to these dowels but cannot jump. Tarsiers are very easily dehydrated, and lack of humidity can cause desiccation of the skin of digits or tail and lead to loss of all or part of these extremities. Humidifying procedures are therefore mandatory.

6

New World Monkeys: Callitrichids

Scientific Name[1]	**Common Name**
Marmosets	
Callithrix jacchus	common marmoset
Cebuella pygmaea	pygmy marmoset
Tamarins	
Leontopithecus sp.	lion tamarin
Leontopithecus rosalia	golden lion tamarin
Saguinus fuscicollis	saddle-back tamarin
Saguinus labiatus	red-bellied tamarin
Saguinus oedipus oedipus	cotton-top tamarin
Saguinus oedipus geoffroyi	Geoffroy's tamarin
Callimico goeldii	Goeldi's monkey

New World monkeys (*Ceboidea*) are generally divided into marmosets and tamarins (Callitrichidae) and the "true" monkeys (Cebidae). The callitrichids are distinct from the cebids in having claws on most digits other than the great toe

1 This is a list of scientific and common names of species discussed in this chapter, not a comprehensive taxonomic list.

(hallux) and having two, rather than three, permanent molars. Goeldi's monkey (*Callimico goeldii*) has claws but also three molars, and some authorities prefer to consider it with the cebids; but we consider it with the marmosets and tamarins because all display the common adaptation of climbing main trunks with the aid of claws.

All callitrichids are small arboreal primates ranging from Costa Rica to southern Brazil and Bolivia in nature. The smaller forms, like the pygmy marmoset (*Cebuella*), at about 120 g (4 oz), subsist mainly on insects and tree saps obtained from gouge holes; medium-size marmosets, at 300-400 g (11-14 oz), and the larger tamarins (*Saguinus* and *Leontopithecus*) and Goeldi's monkey, at 600-1,000 g (1.3-2.2 lb), are more omnivorous, but marmosets are also heavily dependent on exudate feeding (Rylands 1993). Marmosets are often distinguished from tamarins by their procumbent incisors; tamarins also have more robust and longer canine teeth.

Comprehensive descriptions of the natural history, behavior, and communication of callitrichids can be found in Rylands (1993) for marmosets and tamarins, Soini (1988) for pygmy marmosets, Stevenson and Rylands (1988) for marmosets, Snowdon and others (1988) for tamarins, Kleiman and others (1988) for lion tamarins, and Heltne and others (1981) for Goeldi's monkey. The reproductive biology and captive breeding of marmosets and tamarins are summarized in Hearn (1983).

HOUSING

The ideal captive environment is conducive to good physical health, provides for successful reproduction and the raising of offspring, and enables animals to acquire the behavioral skills that they would need in their natural environment (Snowdon and Savage 1989). The size and, perhaps more important, the furnishings of the captive environment affect the behavior of callitrichid monkeys (Box 1988; Caine and O'Boyle 1992; Chamove and Rohrhuber 1989; Molzen and French 1989). Most studies have dealt with the positive effects of well-constructed environments on behavior, but Schoenfeld (1989) described the impoverishing effects of a drastic reduction in environmental complexity on social behavior and infant care in a family group of common marmosets.

Large cages, containing branches and other substrates for climbing, have been used successfully in many long-term breeding colonies. They promote physical well-being and meet the behavioral needs of laboratory primates. Caging should permit callitrichids to assume normal body postures (e.g., sitting on a support with the tail hanging down without touching the cage floor) and to engage to some extent in normal locomotor behavior, such as climbing, running, and jumping.

Wild marmosets and tamarins only occasionally descend to the ground and in captivity prefer to be above caregiving personnel (Poole 1990). Therefore, it is advisable not to house these primates in two-tier cages. There are reports of less activity and poorer reproductive performance when animals are housed in the lower tier of a two-tier cage system (Heger and Neubert 1988; Scott 1989). When space is at a premium, narrow, high cages are preferred over wide, low cages placed one on top of the other. An alternative to providing tall cages is to suspend cages from the ceiling, so that there is space between the cage floor and the floor of the room. Covering the cage floor with wood chips or shredded paper substantially increases the use of the floor by common marmosets and cotton-top tamarins (McKenzie and others 1986).

Marmosets and tamarins might be reluctant to retrieve food from the cage floor. If tall cages are used (say, 2 m, or 6.6 ft, high), animals rarely descend to less than 0.5-1 m (1.6-3.3 ft) above the floor. Therefore, food and water should be offered on a feeding platform or in a bowl placed high in the cage and in a position that avoids contamination from feces and urine.

If small cages are used, it is beneficial to provide a large exercise cage for temporary use. One method of increasing the effective space is to use transparent air-conditioning ducting attached to the side of cages (Hearn 1983). Animals can be trained to move voluntarily through the ducting to enter other cages or transport cages, thus minimizing the stress of handling. Animals that are removed from groups because of illness or behavior problems can still be allowed close visual access through the ducting. Finally, a loop of ducting running from one side of the cage around the back or over the top to the opposite side creates a runway that is frequently used by juveniles and subadults in play.

The nature of the furnishings in the cage appears to be even more important than the absolute amount of space in facilitating species-typical behavior. It is desirable to have a variety of wooden or fiber structures in a cage. Branches and ropes allow animals to display manipulative behavior and a range of natural movements, including leaping from branch to branch. Such cage furnishings will need to be replaced every 2-3 months as they wear out (e.g., bark stripped from branches) and as necessary to maintain sanitation. Panels can be used to divide the cage into visually shielded compartments; this allows submissive animals to move out of sight of dominant cagemates. The nest box can be provided with a locking door to double as a transport box when required.

Chemical communication by means of scent marking is important in the sexual and social behavior of all callitrichids (Epple 1986). Branches are the normal substrate for scent marking with urine and the secretions from specialized scent glands. Animals that are provided only with smooth, nonabsorbent surfaces, such as stainless steel or plastic, scent-mark these surfaces. The sticky, lipid-containing marks coating the surfaces of smooth objects tend to soil the animals' fur.

The amount of scent-marking behavior varies among species and even among individuals of the same species. Therefore, a cage-washing schedule that constitutes a compromise between the need for sanitation and an intact odor environment will have to be worked out on an individual basis. Cages can be sanitized on a regular but less frequent schedule than might be used for other animals. It is still advisable to exclude at least one perch or the nest box when the cage is washed so that some of the social odor is retained.

Animals that have to be housed in small cages should be provided with environmental enrichment devices for the development of behavioral and ecological skills (Poole 1990; Scott 1989). Successful enrichment devices are ones that make use of the natural exploratory and foraging behavior of the animals. The use of artificial gum trees (McGrew and others 1986) can be used effectively for *Callithrix jacchus* in that it stimulates species-typical activity(see also Molzen and French 1989). Simple, disposable objects can stimulate long periods of activity. Juveniles mainly, but also adults, explore small cardboard boxes, play in and around them, and eventually tear them to shreds. A large plastic bottle (e.g., a gallon milk jug) that has a large opening cut into it and is suspended by the handle has a similar effect. Paper towels and even toilet paper stimulate activity: the animals tear them apart and compete for possession of the shreds.

The social and territorial behavior of marmosets and tamarins needs to be taken into account in designing appropriate housing. Under most environmental conditions, wild callitrichids are highly territorial. Under crowded colony conditions, they display high levels of threat behavior toward other visible groups. Moreover, high levels of abortion and infant loss have been reported in captive colonies of some species, such as cotton-top tamarins (Glatston and others 1984; Kirkwood and others 1983; Scullion 1987) and saddle-back tamarins (G. Epple, Monell Chemical Senses Center, unpublished data), and it has been suggested that these problems are related to chronic arousal caused by the proximity of neighboring groups in a colony situation. When several groups are housed in the same room, visual baffles placed between adjacent cages usually appear to be sufficient to reduce threat displays and aggressive behavior, even though animals in one cage can hear and smell other groups of animals; but Epple (unpublished data) found it necessary to install sound-absorbing baffles in a large colony of saddle-back tamarins to reduce the noise that was amplified by the painted concrete surfaces of the room. In contrast, Johnson and others (1991b) found that cotton-top tamarin groups housed in visual contact with other conspecific groups had better infant survival than groups housed in visual isolation; the cages were similar in the two conditions. These observations show the importance of careful evaluation of specific colony situations and of species, as well as individual requirements, by colony managers.

Another means of reducing the arousal caused by housing several groups of the same species in proximity is to place groups of different callitrichid species next to each other. Associations between different callitrichid species occur regularly in nature (Castro and Soini 1977; Heymann 1987; Pook and Pook 1982; Terborgh 1983). Polyspecific groups often travel together and share territories but do not compete with each other socially.

Because of their natural social organization (see "Social Behavior," below), it is recommended that callitrichids and Goeldi's monkeys be maintained in stable male-female pairs or small family groups. Nonrelated adults of the same sex should not be housed together unless they are very familiar with each other and no adult of the other sex is present. If breeding is not desired, same-sex siblings can live together. In cases where a conspecific companion is not available, the monkeys can be housed with a companion from a related species of callitrichid. Captive animals engage in many normal social activities with companions belonging to related species.

If single-cage housing is unavoidable, it might be possible to house pairs in adjacent cages and provide either full visual contact or a "contact window" that allows some social interactions between familiar individuals. If singly housed animals are given temporary access to a companion, the same animals should always be placed together. Colony managers have found that some animals cannot be successfully paired with a social companion, because of either extreme aggression or extreme submissiveness. Therefore, the type and degree of social stimulation provided to animals should be carefully monitored.

NUTRITION

Wild marmosets, tamarins, and Goeldi's monkeys consume a varied diet that includes tree exudates (sap or gum), fruits, buds and flowers, nectar, insects, and small vertebrates. Much of their time is spent in foraging. Marmosets and pygmy marmosets have specialized dentition for gouging holes in trees from which exudate can be extracted and in the wild obtain much of their food that way. Foraging for tree gums takes up most of the time of wild pygmy marmosets (Soini 1988), and the contribution of gum to the diet of the more frugivorous-insectivorous marmosets varies among species (Stevenson and Rylands 1988). Captive *Cebuella* and *Callithrix* species produce gouge holes in every material that they can manage to chew. Natural branches in the cage will not only provide the normal substrate for this important activity, but also direct the animals' attention away from materials that might damage their teeth. McGrew and others (1986) designed a sap feeder made of wooden doweling with holes drilled inside that was filled with gum arabic. Common marmosets quickly learned to excavate holes in this feeder to obtain gum. Tamarins lack the dentition to create exudate flows themselves, but they use exudate flows created by other animals.

Young monkeys, at about 4 weeks of age, begin to beg for solid food from animals that carry them. They obtain most of their food from other group members, which share food with them for several months. During this time, the youngsters seem to learn to recognize the group's food spectrum and to distinguish between wholesome and unwholesome foods. That experience might influence food selection and preferences later in life.

The natural diet of marmosets and tamarins contains high concentrations of proteins, and protein requirements for these species have been estimated at around 20% (Tardif and others 1988). Coprophagia has been reported to be associated with lower percentages of dietary protein (Flurer and Zucker 1988). Most laboratories housing callitrichids feed a commercial diet high in protein (25%) to substitute for the high protein content of insects. Vitamin D_3, found in insect chitin, is important in promoting absorption of calcium and other minerals. Callitrichids cannot metabolize vitamin D_2, so diets fed to them in captivity should have adequate concentrations of vitamin D_3 (Hunt and others 1967a, b). Many colonies use lighting that mimics the full spectrum of sunlight to promote vitamin D_3 synthesis and absorption.

Several laboratories have maintained colonies on unsupplemented single diets. Such diets might fulfill all the nutritional requirements of these primates, but they do not always appear to be palatable enough to be eaten by all individuals in sufficient amounts. Primates that naturally forage on a large variety of foods are adapted to variety and might need variety to stimulate intake. In many colonies, additional feedings of high-protein foods—such as cottage cheese, yogurt, chicken, ground beef, and mealworms—are provided early in the morning and in late afternoon. A variety of fruits and high-protein foods also will accommodate individual dietary preferences and allow each individual access to some highly preferred foods while maintaining overall nutritional balance. Individual food preferences should be carefully monitored. Although most animals will consume a balanced diet when given a choice among foods, some might reject all other foods in favor of fruit. For such animals, it is advisable to exclude fruit from the first feeding of the day and provide it in the late afternoon. All fruits and vegetables should be carefully washed before feeding them to the monkeys.

Animals 15 years old or older often have dental decay or loss of teeth and might be unable to eat hard pellets. They must be provided with food that they can chew. Aged animals might also have special nutritional requirements, such as an increased need for vitamins.

Marmosets and tamarins are small animals with a high metabolic rate. In the wild, animals sleep in hidden locations for 13 hours per night. Feeding rates are high in the hours before sunset and immediately after animals arise in the morning. It is important that captive animals have fresh food available early in the morning and in late afternoon.

SOCIAL BEHAVIOR

All callitrichids are social, but most live in small groups, which often consist of a single reproductively active pair and their offspring. In wild populations, some variability has been noted, but except for Goeldi's monkeys, which do well with more than one breeding female present, a single breeding pair and their offspring do best in captivity.

The skin of marmosets, tamarins, and Goeldi's monkeys contains specialized scent glands. Glands are typically found in the anogenital region, the suprapubic area, and above the sternum and possibly on the face at the borders of the mouth. The oily secretions from these glands, mixed with urine and genital discharge, are deposited on all items in the animals' environment, and in some species on the bodies of cagemates, through scent-marking behavior. Different species use different glands for scent-marking; moreover, the context in which scent-marking is exhibited varies somewhat among species. Geoffroy's tamarins, cotton-top tamarins, and Goeldi's monkeys also show a self-marking behavior. The scent marks are important components of the communication systems of these primates. The marks can contain information on species, subspecies, and individual identity, on hormonal condition, on social rank, and on the age of the scent. Scent communication plays a role in a variety of social and sexual interactions and in attachment between group members and the infants that they care for. Scent from a breeding female also contributes to the suppression of ovulation in nonbreeding females of several species. As is true of other mammals, monkeys might feel comfortable in their home environment with their own scents present (Epple and others 1993).

Scent-marking rates increase when conspecific intruders are present and during territorial encounters. The close proximity of neighboring groups in a colony situation can arouse some animals so strongly that they scent-mark excessively, soiling themselves and their cagemates. In such cases, the problem can sometimes be corrected by switching neighbors or placing the animals next to a group of another callitrichid species or an empty cage.

REPRODUCTION AND DEVELOPMENT

Callitrichids and Goeldi's monkeys typically show little or no sign of estrus and no obvious changes in outward physical appearance or in vaginal cytology during estrus. Estimation of gonadotropins and of ovarian steroids in blood, urine, or feces shows that female ovulatory cycles vary greatly, from 15 to 28 days. Mating behavior does not closely reflect a female's hormonal state. Mating might peak during the periovulatory phase but also occurs at other times, even during pregnancy, when a period of behavioral receptivity can occur. Mating is typically very quick. Mating solicitation is indicated by rapid tongue flicking and looking over the shoulder by the female, and both partners might tongue flick during copulation (Epple 1978).

Callitrichids have been assumed to be monogamous (one male mating with one female), but the results of several recent field studies have found both polyandry (one female mating with more than one male) and polygyny (one male mating with more than one female). However, a survey of captive cotton-top tamarin colonies found few departures from monogamy, and the departures did not lead to stable breeding conditions (Price and McGrew 1991). Under captive conditions, callitrichid groups contain a single breeding female. Reproduction is suppressed by means of behavioral or physiological mechanisms in all other females, although mating might occur (see below for details). In some species, trios consisting of two males and one female have been maintained, but one male has quickly become subordinate to the other. Peer groups of young marmosets can be formed (Abbott and others 1989; Barrett and others 1990) but such groups need to be carefully monitored because levels of aggression are generally high in the first hours and some animals might have to be removed. The groups quickly stabilized with one male and one female taking the dominant breeding position.

The gestation period varies: about 129 days in golden lion tamarins; 140-150 days in common marmosets, pygmy marmosets, saddle-back tamarins, and Goeldi's monkeys; and up to 184 days in cotton-top tamarins. In both wild and captive populations, twin births are the norm, although triplets are sometimes seen. All marmosets and tamarins tend to exhibit a postpartum estrus, but the extent to which this results in a new pregnancy varies among species. In cotton-top tamarins, the period from parturition to postpartum ovulation is affected by the number of infants being nursed. Females with one or no surviving infant ovulate sooner than females with twins. Females that typically nurse both twins at once have an earlier postpartum ovulation than females that nurse each twin separately (Ziegler and others 1990).

Infant callitrichids are carried full time for the first month of life. They normally cling to the neck and shoulder region of their carrier. Infants that cling to the hips or to the ventral side of the carrier are usually weak, and tails hanging down limply instead of curling against the carrier's body can also be a sign of weakness. Weak infants should be monitored carefully. In Goeldi's monkeys, ventral carrying of an infant during the first week of life seems to be normal.

The breeding system of callitrichids is cooperative, involving both parents and other group members in the care of infants. Pregnant females should, therefore, never be housed alone. If the breeding male dies or has to be removed, the female should be placed with another male. An experienced male that is placed with a pregnant female will help the female to raise her offspring. There is great variability within and between species in the patterns of parental care, but both mothers and fathers are actively involved in infant care from the earliest ages. Siblings also become involved in infant care; males are generally more involved than females. Various investigators have observed competition between group members for access to infants. In a moderate-size family group, the mother is rarely observed carrying infants except during nursing. Infants begin to make brief forays away from their carriers within 4-6 weeks. They start eating solid food at about 4-6 weeks, often begging food from adults, and they can be completely independent of care from group members by 10 weeks.

With the birth of new infants, 5- to 7-month-old siblings become active as playmates; with the birth of another set of infants, these animals, now juveniles, become actively involved as infant caregivers. Especially for tamarins, this experience is very important for the development of appropriate parental behavior (Snowdon 1996). Animals that never participate in the care of younger siblings might kill or neglect their own offspring once they start to breed. Animals that are assigned to become breeders, therefore, should be left with their own parents at least until the next two sets of younger siblings have been weaned. Animals that are removed from their parents at an earlier age because the development of parental skills is unnecessary can be successfully socialized in small peer groups consisting of juvenile males and females.

Under captive conditions, some animals can be kept in their natal groups for indefinite periods. Animals that are 5 years old can still take a subordinate role within their family. However, animals (generally of the same sex) can start harassing one another quite suddenly, and this requires removal of one or both animals. Such behavior is quite unpredictable. Parents generally do not intervene in the fights and harassments among offspring. Once animals are mated, there are rarely any signs of tension or conflict between mates, and they can remain together for the rest of their lives. Some callitrichids survive in captivity for more than 20 years.

In the cooperative breeding system of callitrichids, reproduction is suppressed in all female group members but one. Reproductive suppression is achieved either by suppression of sexual behavior or by suppression of ovulation, probably through a combination of pheromonal cues from the breeding female and nonspecific behavioral cues (Abbott and others 1989; Barrett and others 1990; Epple and Katz 1984; French and Stribley 1987; Savage and others 1988; Ziegler and others 1987). In common marmosets, about 50% of the families studied by Abbott and Hearn (1978) had a daughter that ovulated, although none became pregnant. In contrast, in peer groups only one female ever ovulates (Abbott and others 1990). In cotton-top tamarins, but not in common marmosets, after removal of a noncycling female from her group, stimulation by a novel male is necessary to induce ovulation (Widowski and others 1990). Female cotton-tops housed alone or with brothers fail to ovulate. The mere sight, smell, and sound of a novel male suffice to induce ovulation. Once ovulation has begun, it can continue in the absence of a male (Widowski and others 1992). In golden lion tamarins, subordinate females' estrogen cycles are synchronized with those of the reproductive female, but with much lower estrogen concentrations; however, they do not become pregnant (French and Stribley 1987).

Johnson and others (1991a) reported extreme reproductive suppression—including reduced parity, reduced number of live births, and increased spontaneous abortions—during a period when a common marmoset colony was disturbed by nearby building construction. G. Epple (unpublished data) experienced identical problems with a breeding colony of saddle-back tamarins. Those observations suggest that breeding callitrichids should be isolated from loud noises and other disruptions.

COGNITION

Marmosets and tamarins have well-developed visual, olfactory, and auditory perceptual skills. Saddle-back tamarins can recognize former social partners even after separations of several years (Epple and Niblick 1997). Formal tests of cognition have often failed to provide evidence of cognitive abilities, possibly because removal of animals from social groups for testing is highly disruptive. However, Savage and others (1987) successfully tested color discrimination in cotton-top tamarins by moving the test apparatus to the home cage. Eglash and Snowdon (1983) with pygmy marmosets and Hauser and others (1995) with cotton-top tamarins have found evidence of precursors of the mirror self-recognition of apes. Hauser (in press) and Hauser and Carey (1998) have studied expectations about objects and events, including numerosity and understanding of causality in cotton-top tamarins. When tested appropriately, the cognitive abilities of callitrichids are highly developed.

Callitrichids living in a naturalistic environment seem to maintain a “cognitive map” of their environment and detect even minor changes. Under such conditions, neutral novel objects can stimulate little interest, and attempts to provide for environmental enrichment have been disappointing. Saddle-back tamarins living in a greenhouse habituated quickly to novel objects, usually in less than 15 min. Reintroducing the same objects 3 months later failed to produce any sign of interest (Menzel and Menzel 1979). Novel objects themselves might not be effective, but enrichment devices that allow animals to remain actively involved with searching for food items (Molzen and French 1989) do effectively encourage sustained activity and might be good enrichment devices (Box 1988; McGrew and others 1986; Molzen and French 1989).

PERSONNEL

Marmosets and tamarins recognize individual humans on the basis of odor (Cebul and others 1978), voice, and appearance. Callitrichids can develop strong likes and dislikes of individual humans. The monkeys appear to have long memories and respond with fearful behavior to hearing the voice or footsteps of someone who has captured them several months earlier. Curiously, personnel in several colonies have found that shoes might be an important element of an individual caregiver’s appearance. On the basis of this anecdotal evidence, it might be wise for caregivers to wear the same shoes, lest the animals become agitated. Colony managers have observed that hand-raised animals socialized to people can become overaggressive, especially when the animals reach puberty.

Personnel whose primary experience is with other species need to know about the cooperative breeding, twinning, and extensive caretaking by fathers and other group members. They should learn some of the important vocalizations and behavioral patterns of callitrichids so that they can diagnose potential problems from behavioral observations. Familiarity of the monkeys with their caregivers is extremely valuable, particularly in breeding colonies, because parents with newborn infants are easily alarmed by unfamiliar humans and if so alarmed might neglect or attack their babies.

Capturing should be avoided as much as possible. Clear discriminative stimuli, such as different-color coats or uniforms, worn when handling is necessary can help monkeys to predict and discriminate the handling event and thus prevent generalization to caregivers performing routine colony tasks. The presence of a familiar technician who does not participate in the capture itself might be helpful in calming animals that have been captured.

If handling is necessary, the animal in question should first be removed from the colony room. The distress vocalizations of monkeys that are caught and handled tend to arouse the entire colony room and in some species can cause prolonged symptoms of stress, such as diarrhea. Frequent handling might be avoided in some species, such as the common marmoset, by training the animals to accept medications with rewards of preferred food (Hearn 1983). However, tamarins appear to be more excitable and less amenable to training than marmosets. Responses can differ between individual animals, so various catching methods, such as locking the animals in the nest box and removing them from there or using a small net, are useful. A net might be useful for these animals because the animals tend to associate being handled with the net rather than with the person who catches them. The use of nets, however, should be undertaken with caution because animals can be injured by the hoops and handles of nets or by becoming entangled in the nets themselves.

VETERINARY CARE

Veterinarians should be experienced in handling small animals that have high metabolic rates. Because of their high metabolism, animals that become sick can deteriorate quickly. An animal can appear in good health in the morning, show signs of sluggishness or ataxia in the afternoon, and die by the following morning. Animal-care personnel should be trained to monitor behavior for signs of illness. Signs include chronic piloerection, sluggishness, ataxia, diarrhea, lack of appetite, dull and sunken eyes, weight loss, and changes in routine behavior. They are usually noticeable only by human observers who are familiar with the individual monkey.

Marmosets and tamarins can be trained to step on the platforms of remote reading scales, and regular weighings are possible. Technicians can monitor the physical well-being of the animals through these weights, and interventions can be undertaken for animals that show substantial loss of weight. Therefore, well-trained and concerned animal technicians are invaluable to the veterinarian. They can alert the veterinarian to health problems or behavioral problems (for example, stress due to severe dominance relationships between animals). A familiar technician can calm the animals during treatment and can administer many medications topically or orally in food without the need for handling the animals. The feeding of high-protein snacks each morning and each afternoon not only increases the protein content of the diet, but allows animal-care staff to monitor the animals more often.

Marmosets and tamarins are susceptible to a number of human diseases, including measles, mumps, and cold sores caused by *Herpesvirus simplex*. These disease agents can cause potentially fatal infections. *Herpesvirus saimiri* is carried by squirrel monkeys; although it is not associated with any disease in these monkeys, it causes leukemia or malignant lymphoma in callitrichids, so marmosets and tamarins should not be housed in a room that contains squirrel monkeys (Adams and others 1995). Callitrichids and cebids should not be housed together, because of risk of disease transmission (Bennett and others 1995).

A "wasting syndrome" has been described in many species of captive callitrichids that includes such symptoms as weight loss, anemia, colitis, and extensive diarrhea; but there appear to be great differences in susceptibility between colonies of the same species and no clear agreement about the etiology. Suggested etiologies have involved nutrition, infectious agents, and environmental social stress; in cotton-top tamarins, spontaneous adenocarcinoma of the colon has been described. Some colony managers have found that the condition of some animals experiencing apparent social stress can be improved by moving the affected animals to a new social environment (Knapka and others 1995; Morin 1983).

7

New World Monkeys: Cebids

Scientific Name[1]	**Common Name**
AOTINAE	
Aotus sp.	night monkey, owl monkey, dourocouli
Aotus griseimembra	night monkey, owl monkey
Callicebus sp.	titi monkey
PITHECIINAE	
Pithecia sp.	saki
Chiropote sp.	bearded saki
Cacajao sp.	uacari
CEBINAE	
Cebus sp.	capuchin monkey, organ-grinder monkey
Cebus albifrons	brown and white capuchin
Cebus apella	brown or tufted capuchin
Cebus capucinus	white-faced capuchin
Cebus olivaceus	wedge-capped or weeper capuchin
Saimiri sp.	squirrel monkey
Saimiri boliviensis	Roman arch squirrel monkey

[1] This is a list of scientific and common names of species discussed in this chapter, not a comprehensive taxonomic list.

Saimiri oerstedii	gothic arch squirrel monkey
Saimiri sciureus	gothic arch squirrel monkey
Saimiri ustus	gothic arch squirrel monkey
ATELINAE	
Ateles sp.	spider monkey
Brachyteles sp.	woolly spider monkey
Lagothrix sp.	woolly monkey
ALOUATTINAE	
Alouatta sp.	howler monkey

The family Cebidae includes 11 genera: *Alouatta* (howler monkeys), *Aotus* (night or owl monkeys), *Ateles* (spider monkeys), *Brachyteles* (woolly spider monkeys), *Cacajao* (uacaris), *Callicebus* (titi monkeys), *Cebus* (capuchin monkeys), *Chiropotes* (bearded sakis), *Lagothrix* (woolly monkeys), *Pithecia* (sakis), and *Saimiri* (squirrel monkeys). The most comprehensive references available on the natural history of these genera are the two volumes in the series *Ecology and Behavior of Neotropical Primates* (Coimbra-Filho and Mittermeier 1981; Kinzey 1997; Mittermeier and others 1988). The taxonomy of these genera is still being revised; according to one authoritative source (Mittermeier and others 1988), revisions are likely to increase the number of recognized species and subspecies.

The squirrel monkeys are the most common cebids in laboratory environments. Opinions vary about the number of species, and Hershkovitz (1984) has argued for the recognition of four species. On the basis of the pattern created by pigmentation and the white hair around the eyes, squirrel monkeys have been described as gothic arch (*Saimiri sciureus*, *S. oerstedii*, and *S. ustus*) or roman arch (*S. boliviensis*) (Hershkovitz 1984). Variation in head and body color from yellow-orange to black to gray-green is noted among species and subspecies. Species have pronounced differences in susceptibility to experimentally induced diseases and social behavior. Differences in the number of acrocentric autosomes are noted in karyotypes among species and subspecies of squirrel monkeys. The "squirrel monkey" is clearly several kinds of monkey.

Aotus (the night or owl monkey, also sometimes called the dourocouli) is found in many laboratories and should be recognized as a group of nine species (Hershkovitz 1983). Differences in dipliod chromosome numbers among karyotypes exist, and one who ignores these differences cannot readily form breeding pairs.

Species of *Cebus* are often in exhibits and increasingly often in laboratories. Various common names have been applied to these "organ-grinder monkeys." Most are called capuchins with an inconsistent use of modifiers, such as wedge-capped or weeper (*C. olivaceus*), white-faced (*C. capucinus*), and brown and white or white-fronted (*C. albifrons*). *Cebus apella* (the tufted or brown capuchin) is perhaps the most commonly seen.

The other genera of Cebidae are less commonly seen in captivity, although woolly monkeys (*Lagothrix*) enjoyed an unfortunate early popularity in the pet trade, and spider monkeys (*Ateles*) are often seen in exhibits.

Genera in the *Cebidae* share only a few features of ecology, social organization, and life history. All are primarily arboreal, and all except *Aotus* are diurnal. The basic locomotor pattern for all genera is quadrupedal walking, but capuchins, howler monkeys, spider monkeys, woolly spider monkeys, and woolly monkeys have prehensile tails, which are used in various degrees to support the body. All those can hang suspended by the tail alone, and the last four are considered "semibrachiators," meaning that they often suspend themselves from supports using only their hands and tail. Most cebids are agile climbers and capable of substantial leaps. With the exception of the uacaris, whose tails are only one-third as long as their bodies, the tail is usually longer than the body in cebids. Spider, woolly, howler, and woolly spider monkeys have a naked "fingertip" at the end of the tail, and they use the tail not only in brachiation but also to manipulate objects not within hand reach.

The genera differ markedly in appearance, from the striking bald head and distinctive coat color of the red or white uacaris to the spiky hair of the spider monkey and black uacaris. The adults range in size from *Saimiri*, at about 750 g (1.6 lb), to the *Lagothrix*, at nearly 10 kg (22 lb). Cebids generally show far less sexual dimorphism than Old World monkeys, and males are often only slightly larger than females. In contrast with other primate groups, in which sexual dimorphism increases with body size, the largest cebids are relatively monomorphic in size. However, the two sexes in sakis and some species of howler monkeys are of different color, even though of similar size; a naive observer might think that the two sexes were of different species because the color difference appears even in infancy.

Life-history characteristics also vary among genera (Napier and Napier 1967, 1985). Infants nurse for from as little as 3 or 4 months (*Saimiri*, *Callicebus*, *Pithecia*, and possibly *Chiropotes*) to 2 years or longer (*Ateles* and *Lagothrix*). Average interbirth intervals range from 1 year to 2.5 years (or longer). Maximal life span (in captivity) varies from about 25 years for squirrel monkeys and titis to nearly 50 years for capuchins (and probably spider and woolly monkeys as well).

All genera except *Callicebus*, *Pithecia*, and *Aotus* (which are monogamous) live in mixed-sex groups; modal group size and organization vary widely among species. Diets also vary widely; some species are nearly completely folivorous (eating a diet of leaves), some are frugivores, and some are omnivores. Many species are found in association with other primate genera whose ecological niches overlap; this is especially common for *Saimiri* with *Cebus apella*.

Differences among genera in ecology and behavior are enormous, as should be expected by the length of evolutionary time that they have been radiating into specialized niches in their natural environment. Moreover, their ecology and behavior are quite divergent from those of Old World monkeys, in line with the differences in habitat types and predator and competitor complements. The net result of their history of adaptive radiation in a particular setting is that virtually all aspects of captive management of these species should be tailored to the individual species to accommodate the variations among them in size, diet, social organization, reproductive cycles, locomotor patterns, and activity levels. In the remainder of this chapter, general points are presented where possible, and specific recommendations relevant to husbandry and well-being for particular genera that differ from these general points are noted.

HOUSING

The vertical dimension appears to be more important for these nonhuman primates' use of space than the horizontal dimension. Housing should provide adequate vertical space and postural supports to enable all animals to move and perch with their tail hanging in a normal position of rest without touching the floor. Perches with multiple heights within the enclosure are desirable. Space should permit jumping laterally and vertically. Climbing structures, swings, and other flexible supports are used by animals of all ages in some species but especially by youngsters. The ground or floor is used by some species if low perches or objects on the floor make vertical movement easy and if the floor is a "soft" material (such as a covering of straw or wood chips). Bedding material supports species-normal exploratory activity in capuchins and other manipulative species; supports foraging activities if small food items, such as sunflower seeds, are scattered; and reduces the likelihood of injury or hypothermia in infants that fall to the floor. Cage furnishings should also permit the use of the tail and suspensory postures in genera with prehensile tails, e.g., spider monkeys.

Large cebids do well at normal to high temperatures of 21-29°C (70-84°F); however, smaller cebids such as squirrel monkeys seem to do better at temperatures in the higher end of this range (e.g., 26-29°C, or 78-84°F). If outdoor housing is used, warming areas are needed for most species if the ambient temperature falls below 10-15°C (50-59°F). It should not be assumed that animals will spontaneously seek out the sheltered areas when the temperature falls. Titi monkeys, for example, will remain in a preferred outside sitting spot, and spider monkeys will sunbathe even when temperatures are dangerously low. Animals might need to be confined in heated quarters under such conditions.

Cebids eat small amounts of food over long periods of each day. They often nibble a bit of food and then drop it, perhaps to retrieve it again later. Food presented in a pan is usually removed by the animals as soon as it is delivered. In enclosures with raised mesh floors, food often drops below the mesh floor, and special efforts are required to ensure that food is available ad libitum.

The owl monkey (*aotus*) should be provided with a nest box. A reversed light cycle is recommended with caregivers active during the "night" phase, when the area can be illuminated by red light.

Because cebids lack ischial callosities for sitting, they must "perch" using their feet rather than sit. Squirrel monkeys are likely to develop pressure sores on the dorsal surface at the base of the tail unless they are provided suitable perches and climbing structures, so it is important that appropriate materials be selected for the construction of perches (Abee 1985). Furthermore, pressure sores can occur in weakened animals that are unable to assume a proper perching posture. Squirrel monkeys are prone to hypothermia, especially if they are stressed, and materials that are poor thermal conductors or thermoneutral (such as wood and PVC pipe) are preferred over metal, particularly in environments in which the ambient temperature can fall below 24°C (75°F) (Abee 1989). At lower temperatures, the animals assume a "huddle" posture in which the back is arched and the tail is wrapped around the body. The same posture can be seen when the animals are sleeping, resting, or ill. At higher temperatures, squirrel monkeys "sprawl" by straddling a perch or branch and allowing the limbs and tail to hang below. Squirrel monkey housing should be designed so that animals do not need to walk on wet abrasive floors, because animals are prone to develop contact dermatitis if forced to spend long periods in direct contact with urine-soaked concrete surfaces.

NUTRITION

Most cebids maintain good health when fed commercial monkey chow that is specifically formulated for New World monkeys (i.e., is rated as high in protein—at least 25%—and contains vitamin D_3) supplemented daily with fresh fruits and a vitamin-mineral supplement. Diets containing less protein and fat and more fiber might be preferable for some genera, such as *Aotus*, which have large ceca adapted for digestion of fruits and leaves. Furthermore, species prone to renal disease might benefit from reduced-protein diets. Vitamin supplements can be supplied by mixing them with fruit pieces or with a soft food base (such as yogurt, applesauce, infant cereal, or cooked grains). Some species (squirrel monkeys and capuchin monkeys) appear to need more folic acid than what is provided in commercial chow, particularly to support pregnancy and growth (Knapka and others 1995; Rasmussen and others 1982); consideration should be given to folic acid supplementation as necessary.

Howler monkeys are the most folivorous of the New World monkeys and are nutritionally difficult to maintain in captivity (Benton 1976; Shoemaker 1979, 1982). Strong tea instead of water has been suggested to provide the tannins that they normally obtain from leaves. Large amounts of leafy greens supplemented with *Lactobacillus acidophilus* are also recommended.

Aotus does well when given commercial diets with 5% or less fat and a high fiber content. Some taxa (such as *A. griseimembra*) might require supplemental parenteral administration of alpha-tocopherol (vitamin E) to prevent vitamin E-responsive anemia lest clinical signs, including severe anemia and myopathy, develop. This can occur in animals whose baseline serum vitamin E levels appear normal (Meydani and others 1983; Sehgal and others 1980).

SOCIAL BEHAVIOR

Members of monogamous genera (*Aotus*, *Callicebus*, and *Pithecia*) have been successfully housed in captivity as mated pairs with offspring. Introducing adult strangers of the same sex is not always possible. Adult male night monkeys are aggressive toward one another; females can be housed together, but newly formed pairs should be observed to confirm compatibility. It is not known whether this applies to the other monogamous genera.

In monogamous species, it is sometimes possible to maintain offspring in the natal group until they reach sexual maturity. In cebids of polygamous genera, group size in captivity is limited mainly by space. Capuchins and squirrel monkeys have been maintained in groups containing 35 members or more with multiple adult males present. The introduction of new members to a group is usually problematic, especially if adults of the same sex are already resident. Considerable variation is to be expected. Given adequate space, woolly and spider monkeys can be kept in groups with multiple adult males. Adult male squirrel monkeys generally tolerate each other well in the absence of adult females, but fighting can occur if mixed-sex groups are formed at the start of the breeding season.

Many cebids readily accept an animal returned to the group after a week or more, and capuchins can be safely returned even after several months. Any major social reorganization that occurs in the absence of an individual animal complicates its return. Return of animals to large social groups appears to be easier if it occurs with only a portion of the home group present and if the small group is allowed to return to the main group a few minutes later. Spider monkeys are particularly excited by reintroductions, and such events warrant careful monitoring.

Attacks on infants occur occasionally in capuchins and in woolly, howler, and spider monkeys. The precursors of attacks are generally not evident, and animals behave tolerantly with infants under normal circumstances. It is thought that social instability can trigger attacks on infants.

As with the callitrichids, many cebids form polyspecific associations in the wild and are quite tolerant of extraspecifics. Squirrel monkey and capuchin associations are particularly common in the wild, but squirrel monkeys carry *Herpes tamarinus* and should be kept isolated from night monkeys and susceptible callitrichid species (Adams and others 1995). Mixed-species assemblages have otherwise been maintained in exhibits without adverse consequences.

Cebids use feces, urine, genital discharge, saliva, and secretions from specialized scent glands in the skin for the purpose of scent marking. Sniffing and licking urine, scent marks, or the bodies of conspecifics are common in all species. Techniques vary, but urine washing and distribution of urine over parts of the body occur in various forms in most genera. Titi, woolly, and spider monkeys distribute saliva over parts of the body, including a sternal gland on the chest. Capuchins and uacaris rub plants and other items in their environment into their fur. Chemical signals might identify an individual animal's sex and play important roles in reproductive behavior, aggressive interactions, and other kinds of behaviors. Sanitation procedures should take into consideration the possible importance of odors for the cage inhabitants. The presence of odors in a monkey run should not be taken to mean that sanitation is inadequate (Williams and Bernstein 1995; see also "Sanitation" in Chapter 3).

REPRODUCTION AND DEVELOPMENT

Age at reproductive maturity ranges from 2 years in *Saimiri*, *Callicebus*, and *Pithecia* to 5-6 years in *Lagothrix*, *Ateles*, and *Cebus*. Members of some genera breed seasonally (e.g., *Saimiri* and *Cacajao*); members of others (such as *Cebus*) do not. In some genera, females exhibit marked proceptive behavior (i.e., they seek out and actively solicit a male) and mate preferences. Duration of gestation in cebids ranges from about 4.5 months (in *Aotus*) to 7.5 months (in *Ateles*) (Napier and Napier 1985).

Single births predominate. Infants can cling unaided from birth but do not locomote independently for several weeks to several months; they ride dorsally soon after birth (the precise age at which dorsal riding begins varies with the genus, from birth to about 2 months). However, in some genera (capuchins, woolly monkeys, and spider monkeys), mothers often cradle infants ventrally for extended periods and assist a newborn infant in clinging to the ventrum if the mother moves while it is in a ventral position.

In the monogamous genera (night monkeys and titis; there is no information on this point for sakis), infants are routinely carried by fathers when they are not nursing. In capuchins and squirrel monkeys, infants can be carried by adults and juveniles other than the mother (Fragaszy and others 1991; Williams and others 1994). The period of infant dependence varies among genera; in the larger forms (e.g., *Ateles*), infants can remain on the mother and nurse for up to 2 years. Nursing periods among cebids are generally longer than is typical of Old World monkeys.

In species in which both parents are involved in infant care (titi, night, and owl monkeys), rejection of an infant by either parent might require human intervention. A male titi can provide adequate care for an infant rejected by its mother, but the infant will require hand feeding. Male titis can be box-trained and exhibit little protest when an infant is gently removed, fed, and returned. When a father rejects an infant, the mother alone often becomes agitated with the constant burden of the infant. If such signs occur, the infant might have to be removed to prevent injury.

Male squirrel monkeys display an unusual pattern of seasonal "fatting." Males can gain 20-30% in body weight and become noticeably bulkier in the shoulders and upper torso as the breeding season approaches. Not all males show this change—it is most commonly observed in the Roman Arch species—and it is not required for fertility. Males gradually lose the weight during the course of the breeding season.

COGNITION

Cognition in squirrel monkeys, capuchins, and some of the other New World and Old World genera has been reviewed by Rumbaugh (1967) and Fragaszy (1985). Cebids seem generally similar to rhesus monkeys in several cognitive capacities, although they appear to be somewhat less able in conceptual and relational learning tasks. There is, however, wide latitude in their activity levels and responsiveness to the physical and social environment. Capuchins, for example, show greater manipulative ability than rhesus monkeys and are the prototype of the active monkey for which provision of opportunities for productive activity is essential to well-being. When not locomoting, they are most often busy with their hands (Fragaszy and Adams-Curtis 1991). When no other opportunities are present, their attention is directed to surfaces in the cage or nearby objects, such as locks. This activity can be safely redirected by providing them with such objects and materials as wood, soft plastic, straw, and small containers (Fragaszy and Westergaard 1985; Visalberghi 1988). They will spend much time shredding and destroying disposable objects. They also retain interest in objects that require dexterous probing or scraping (Fragaszy and Visalberghi 1989; Westergaard and Fragaszy 1987; Westergaard and Suomi 1993).

Other cebids are less manipulative than capuchins; *Aotus* and *Callicebus* perhaps are least so. Monitoring other members of the social group appears to be more important to these animals than physically interacting with the inanimate environment.

PERSONNEL

New World monkeys (cebids and callitrichids) in general are less likely to be aggressive toward humans than the more common species of Old World monkeys. They often exhibit curiosity toward humans and do not respond aggressively when prolonged direct eye contact is made. They will often approach familiar people and readily accept food or objects offered by hand. That can be useful when supplementing the diet or medication of particular animals (Abee 1985). It might be necessary to get a timid animal away from other group members for such supplementation.

Despite their generally unaggressive behavior toward humans, New World monkeys will resist restraint and can deliver serious bites in self-defense. An animal attempting to climb on and explore a human might bite vigorously if pushed away or frightened. Former pet animals are especially likely to cause problems. They can form strong attachments to some people and "defend" favored people against other people.

Personnel should avoid sudden movement and loud noises in animal areas; this might be especially important when they are dealing with night monkeys, titis, and especially newly arrived woolly monkeys. Night monkeys seem particularly sensitive to loud noises and changes in routine. Titis might "freeze" and exhibit labored breathing in unfamiliar environments and exhibit similar signs of distress when confronted with changes in their environment. Woolly monkeys sometimes become lethargic and refuse to eat on first arrival at a facility. Extensive gentle attention from a well-trained person is often effective in helping these animals to adjust to a new environment.

Most cebids quickly learn to recognize familiar people and will respond to them in accord with the nature of their experiences. Technicians who deal with the daily care of these animals should interact with their charges primarily in ways that are pleasant for the animals. If they can avoid it, they should not participate in capture or restraint procedures. When it is necessary that such personnel participate in activities that the animals find aversive, the use of a distinctive uniform only for such occasions might facilitate the re-establishment of good relations during routine husbandry. Personnel should routinely devote some time to positive interactions with animals, such as provision of vegetables and fruit rewards during daily observation.

Most cebids will readily move from one cage to another for cleaning and maintenance tasks, and every effort should be made to avoid wetting the animals or requiring them to move across wet floors. They can also be trained to enter transport boxes for individual handling, and this obviates capture with gloves or nets.

VETERINARY CARE

The veterinary medical care of cebids is similar to that of callitrichids, and readers are referred to the "Veterinary Care" section of Chapter 6 also. In addition to attention to the nutritional requirements of cebids, veterinary personnel should be vigilant for signs of dehydration. Relatively small primates, such as squirrel monkeys, can dehydrate quickly. Squirrel monkeys can dehydrate and develop hypoglycemia in less than 24 hours if their access to water is disrupted (Abee 1985). They will not feed without water, and many New World monkeys will show adverse effects if deprived of food for a day. Most eat more or less continuously during the daylight hours.

Stress responses, mentioned previously, can also influence feeding and drinking. Juvenile squirrel monkeys stress easily and can become dehydrated as a consequence. Spider and woolly monkeys seem particularly susceptible to stress associated with restraint and handling. Woolly monkeys also seem to show a high frequency of high blood pressure, and veterinary procedures should take this into account.

Cebids are susceptible to most of the common viral upper respiratory illnesses that people develop (Adams and others 1995). Personnel who have symptoms of such illnesses should avoid working closely with animals. Measles is also readily transmitted to New World monkeys. Night monkeys are particularly susceptible to viral diseases of humans, such as *Herpesvirus simplex* and measles (Weller 1994). Personnel should not be allowed to work with night monkeys if they have cold sores. Personnel that have family members with measles should not work with cebids. Personnel who have been vaccinated against measles should not have contact with cebids for at least 2 weeks after vaccination..

Several diseases that occur commonly in night monkeys are uncommon in other neotropical primates. Dilative and hypertrophic cardiomyopathy, possibly the result of chronic hypertension, is peculiar to night monkeys and can lead to sudden death or chronic heart failure (Weller 1994). Chronic glomerulonephritis is commonly observed in aged animals (Abee 1985; Chapman and others 1973; Hunt and others 1976; Stills and Bullock 1981). Hemolytic and necrotizing myopathy responsive to vitamin E supplementation has been observed in *Aotus griseimembra* (Weller 1994). Medical management of the diseases of night monkeys is complex and requires close veterinary supervision.

Cebids are susceptible to a number of intestinal parasites, but the usual veterinary medical treatment for such problems is generally effective. A well-planned program of examinations and treatment will prevent most disease problems.

Cebids appear to be more resistant to tuberculosis than are Old World monkeys; few problems with this disease have ever been reported. But *Herpes tamarinus*, which can cause serious disease in callitrichids, is also a serious problem for night monkeys and is often carried by squirrel monkeys without producing clinical signs (Adams and others 1995). As a general policy, squirrel monkeys should be housed in isolation from night monkeys and from susceptible callitrichid species. (Consult Appendix B for a list of diseases known to be transmitted among primate taxa.)

One other problem that the veterinary staff should be alert for is the possible development of gestational diabetes in woolly monkeys. Captive management of New World monkeys remains relatively poorly understood, and vigilance on the part of the veterinary and husbandry staff is the best precaution possible.

Cebids are not known to pose any special bacterial- or viral-disease hazards to the humans that interact with them. Therefore, personnel bitten or scratched by a New World monkey can be treated in a similar way as bites and scratches from a dog or cat (NRC 1997a).

8

Old World Monkeys: Cercopithecids

Scientific Name[1]	**Common Name**
CERCOPITHICIDAE (cercopithecids)	
CERCOPITHECINAE (cercopithecines)	
Macaca sp.	macaque
Macaca arctoides	stumptail macaque
Macaca assamensis	assam monkey, mountain monkey
Macaca cyclopsis	Formosan macaque
Macaca fascicularis	crabeaters, crab-eating macaque, cynomolgus (or cyno), irus monkey, Java monkey, kra (or kera), long-tail macaque, Philippine monkey
Macaca fuscata	Japanese macaque, snow monkey
Macaca mulatta	rhesus monkey
Macaca nemestrina	pigtail macaque
Macaca nigra	Celebes black ape, Sulawesi macaque, crested macaque, Cynopithecus niger
Macaca radiata	bonnet monkey

[1] This is a list of scientific and common names of species discussed in this chapter, not a comprehensive taxonomic list.

Macaca silensus	lion-maned macaque, lion-tail macaque, wanderoo
Macaca sinica	toque monkey
Macaca sylvanus	Barbary ape
Macaca thibetana	Tibet monkey
Papio sp.	baboon
Papio cynocephalus anubis	olive baboon
Papio cynocephalus cynocephalus	yellow baboon
Papio cynocephalus papio	West African baboon, Guinea baboon
Papio cynocephalus ursinus	chacma baboon
Papio hamadryas	hamadryas baboon, sacred baboon
Mandrillus sp.	drill, mandrill
Theropithecus sp.	gelada
Cercocebus sp.	mangabey
Cercocebus torquatus atys	sooty mangabey
Cercopithecus sp.	guenon
Cercopithecus aethiops	African green monkey, grivet, vervet
Miopithecus sp.	talapoin
Erythrocebus sp.	patas monkey, military monkey, hussar monkey, mustached monkey
Allenopithecus sp.	Allen's swamp monkey
COLOBINAE (colobines)	
Colobus sp.	
Colobus abyssinicus	black and white colobus monkey
Colobus badius	red colobus
Presbytis sp.	langur
Presbytis entellus	hanuman langur, sacred langur
Rhinopithecus sp.	snub-nosed langur
Rhinopithecus roxellana	Chinese golden monkey
Nasalis sp.	proboscis monkey
Nasalis larvatus	proboscis monkey
Simias sp.	Mentawi island langur
Pygathrix sp.	douc langur

The Old World monkeys (cercopithecids) are divided into two subfamilies, the cercopithecines (which have cheek pouches) and the colobines (leaf-eating monkeys) (Napier and Napier 1967, 1985).

The cercopithecines are represented in Asia and North Africa by one genus (*Macaca*); the rest are found only in sub-Saharan Africa, except *Papio hamadr-*

yas (the sacred baboon), which is also found on the Arabian peninsula. *Macaca* (macaques) and *Papio* (baboons) are generally considered closely related, and *Papio* is also closely related to *Theropithecus* (geladas) and *Mandrillus* (drills and mandrills). *Cercocebus* (mangabeys) is considered intermediate between these genera (*Macaca* and *Papio*) and other cercopithecines, and some would divide the mangabeys into two genera according to the degree of similarity to *Macaca* and *Papio* or to *Cercopithecus* (guenons). The guenons include many of the colorful forest species and the vervet or green monkey (*Cercopithecus aethiops*). *Miopithecus* (talapoins) and *Erythrocebus* (patas monkeys) are closely related. *Allenopithecus* (Allen's swamp monkey) is poorly known.

The colobines are found in both Africa and Asia; greater diversity occurs in Asia. African forms are sometimes placed in the single genus *Colobus*, but some authorities prefer to recognize several distinct genera. All agree that Asia has multiple genera of colobines, including *Rhinopithecus* (snub-nosed langurs—one species is known as the Chinese golden monkey) and *Nasalis* (proboscis monkey). *Pygathrix* (douc langurs) and *Simias* (Mentawi island langurs) are also generally recognized; the remaining langurs are either all grouped as *Presbytis* or divided into several related genera.

Old World monkeys all develop ischial callosities (specialized calluses used in sitting) prenatally and have the same dental formula as apes and humans: two incisors, a canine, two premolars or bicuspids, and three molars in each quadrant. Sexual size dimorphism is pronounced in many of the larger species. Other morphological characteristics—such as tail length, the presence of female sexual swellings, and distinct natal coat colors in infants—are extremely variable.

Old World monkeys include many forms that spend substantial portions of the day on the ground. Geladas and some baboons can live in areas where there are few trees, and they retire to rocky cliffs at night. Patas monkeys are also highly adapted to life on the ground. Most other forms, however, are never far from trees. Even macaques, which some describe as semiterrestrial, spend most of the day in elevated locations and seek the refuge of trees at night.

The colobines have enlarged salivary glands and a sacculated stomach and can digest mature leaves. They nevertheless prefer a diet of fruit, flowers, seeds, and buds and consume both young and mature leaves (Napier and Napier 1985; Struhsaker 1975). Cercopithecines are much more omnivorous, and some macaques will eat virtually anything that humans find edible, in addition to many items that humans pass by. This flexibility means that some macaques and baboons live close to humans in the wild state and will raid crops, steal from markets, and seek handouts from humans.

The most commonly seen monkey in captivity is *Macaca mulatta* (rhesus monkey), sometimes called the Indian monkey, although its distribution extends from Pakistan through India, Bangladesh, Burma, and Thailand into northern China (Napier and Napier 1985). Until recently, this was *the* laboratory monkey.

Substantial breeding colonies exist in the United States to supply the needs of federally mandated testing programs (Erwin and others 1995).

More recently, *Macaca fascicularis* has gained popularity in many laboratory programs. Limited numbers are available from the wild, but concerted efforts are under way in source countries to breed them. Rhesus monkeys can no longer be imported from India to the United States under Indian law, and relatively few are available from other countries (Johnsen 1995). The smaller long-tail macaques have a variety of common names, including long-tail macaque, cynomolgus (or cyno), crabeater, Java monkey, Philippine monkey, kra or kera, and irus monkey. They are found in southeast Asia and in the islands of the Philippines and Indonesia and exist as feral populations on a number of other islands where they have been introduced (e.g., Mauritius).

Other macaques often seen in captivity include *M. nemestrina* (pigtail macaques), *M. arctoides* (stumptail macaques, referred to as *M. speciosa* in older publications), *M. fuscata* (Japanese macaques or snow monkeys), *M. sylvanus* (Barbary apes), and, less commonly, *M. assamensis* (assam or mountain monkeys), *M. radiata* (bonnet monkeys), *M. sinica* (toque monkeys), *M. cyclopsis* (Formosan macaques), and the Sulawesi forms, which may be divided into up to seven species and include Celebes black apes, moor, tonkean, and Hecht's macaques. The older literature lists the Celebes black ape as *Cynopithecus niger*, but all the Celebes, or Sulawesi, forms are now accepted as macaques. The remaining macaques include *Macaca silensus* (the wanderoos or lion-tail or lion-maned macaques) seen in a few exhibition and breeding colonies, and *M. thibetana* (the tibet monkeys), seen only in a few exhibits outside China. The inappropriate use of the term *ape* in many common names reflects the presence of a very small tail sometimes overlooked by early explorers who called any monkey without a tail an ape.

Baboons of one type or another are also often seen in captivity. These are large, sexually dimorphic monkeys. The males often display canine teeth that rival those of lions and tigers in length, and a large male can weigh as much as 40 kg (88 lb). Baboons are found from West Africa across East Africa and south to the Cape of Good Hope. Most recognize *Papio hamadryas* (the sacred baboon) as a distinct species but argue about how to distinguish taxonomic groups represented by West African or Guinea, yellow, olive, and chacma baboons among the savanna forms. *P. cynocephalus* is used as the inclusive name; others are listed either as subspecies or species separate from the yellow baboon.

The gelada (*Theropithecus gelada*) and the colorful mandrill (*Mandrillus sphinx*) and less common drill (*M. leucophaeus*) are sometimes also referred to as baboons because they are also large African monkeys. They are sometimes popular in exhibits but much less common than the true baboons. Mandrill males have been weighed at over 50 kg (110 lb) and are very powerful animals.

A similar situation to the savanna baboon exists for another common form of African monkey in captivity, *Cercopithecus aethiops*. The West African forms are the largest and have the greatest sexual dimorphism. They do not have the red, white, and blue hindquarter display of East African forms and are sometimes called green monkeys instead of vervets. Differences in facial hair patterns distinguish grivets as well, but common names are not used consistently, and most lump all into a single species. The West African forms are likely ancestral to the wild populations found in several islands in the West Indies, but individuals from the West Indian population are smaller than those in the West African populations.

Patas, talapoins, and mangabeys are also found in captivity with some frequency, and patas are also called hussar, military, or mustached monkeys by some exhibitors. Other guenons are often seen in exhibits but seldom in laboratories.

Colobines are less often seen in captivity, and this can be attributed primarily to problems in developing adequate diets. The spectacular black and white colobus monkey (*Colobus abyssinicus*) and the sacred or hanuman langur (*Presybytis entellus*) are most often seen in exhibits. Representatives of other colobine genera from Asia are less-often displayed, but many Americans have seen the Chinese golden monkey (*Rhinopithecus roxellana*) and have seen postcard pictures of the proboscis monkeys (*Nasalis larvatus*) maintained in captivity.

A variety of social organizations characterize the Old World monkeys, but all are intensely social, spending all their lives in social groups except for brief periods of transfer between groups (Dittus 1980). In most cases, it is the male that transfers; but even in species in which males might spend some time out of a breeding group, they can form all-male bands and continue to live in a social milieu; in some species, a male can spend time as a solitary animal when in transit between sexual groups.

HOUSING

Old World monkeys have been successfully maintained in a variety of housing conditions in captivity. Types of housing include individual cages in climate-controlled buildings, indoor mesh pens, indoor-outdoor runs, corn cribs, corrals, and semi-free-ranging conditions, such as islands. If properly acclimated and afforded protection from wind, sun, and rain, some species can live outdoors in temperatures from around freezing to over 39°C (102°F) and in relative humidities characteristic of desert or tropical environments. When maintained in climate-controlled environments, these monkeys do well under conditions comfortable for humans (NRC 1996).

The design of housing for Old World monkeys differs little from that described in Chapters 2 and 3. Most housing was indeed developed in maintaining Old World monkeys. These are generally robust primates that will shake and attack cage structures, and sturdy construction is in order. Although many spend considerable periods on the ground, virtually all flee upward when disturbed, and they will use the upper portions of a cage preferentially if given perches or suitable structures to allow for use of the full volume of a cage (Watson 1991). Species differ in the extent of manipulative curiosity, but all should be considered as potentially destructive. This should be taken into account in the design of cages, swings, puzzles, toys, and other enrichment devices. Cage height should consider the length of the animal's tail so that it will not touch the floor when the animal is sitting on a perch (NRC 1996). Cage furnishings should be routinely inspected for broken and hazardous items that need to be repaired or replaced. Some of the first demonstrations of visual curiosity in nonhuman primates were carried out in Old World monkeys (Butler 1954). Most enrichment devices described in Chapter 2 were designed with Old World monkeys in mind and serve well for enriching singly-housed rhesus monkeys (see also Line and others 1990a).

NUTRITION

The dietary requirements for cercopithecine monkeys have been defined sufficiently to allow for successful breeding, growth and development, and maintenance (NRC 1978, 1996). If nutritional problems occur, they usually result from mismanagement of the diet, such as in its manufacture or storage. Appropriate handling of feed is described in the *Guide for the Care and Use of Laboratory Animals* (NRC 1996).

Cercopithecines can be successfully maintained solely on a fresh commercial feed, even though this is not recommended. Offering a variety of foods contributes to their psychological well-being (see discussion in Chapter 3). They will eat a wide variety of fruits, vegetables, and grains. Peanuts, popcorn, unsalted pretzels, dry cereal, shelled dry corn, millet seeds, and sunflower seeds can be used as treats; but potential contamination of natural food items should be considered, and reasonable caution is in order. Whereas adequate diets of wholesome foods obtained from the market can be achieved, it is far more convenient to ensure nutritional balance by using one of the many specially formulated commercial diets. Commercially available, nutritionally balanced food treats come in a variety of sizes, shapes, colors, flavors, and textures.

The colobines are more difficult to provide for nutritionally. Their diet should be heavily supplemented with green leafy vegetables. Some institutions have found that alfalfa is of benefit in caring for some colobines. A good commercially available diet is best to start with, but it will require considerable supplementation to maintain colobine monkeys.

SOCIAL BEHAVIOR

Most species of macaques and baboons live in large troops consisting of numerous adults of both sexes. These social groups are often divided into smaller units called matrilines, which consist of mothers and their female offspring. Adult males are immigrants, unrelated to the females, that leave their natal troop at around the time of puberty (Dittus 1980). In contrast, females spend their entire lives in their natal troop. The sex ratio of adults is typically female-biased. This has been attributed in part to the mortality associated with adolescent male emigration and in part to the longer developmental periods of males. Most social groups usually move through their habitat as a single large troop, but some flexibility in forming subgroups can be seen.

Whereas that general pattern applies to most macaques and baboons, some exceptions should be noted. Hamadryas baboon troops are divided into one-male units (an adult male with several adult females and their offspring). Males actively "herd" their females, but males of several of these units will act together to repel predators or intruders. Furthermore, a large loose troop structure can be discerned during the evening, when several bands are found in proximity on cliff faces.

Geladas also form one-male units, but males do not herd females. Unlike hamadryas baboons, in which one-male units disperse during the day, gelada units disperse at night and can form large feeding herds on days when feeding conditions are favorable. The social organization of the mandrill and drill are less well known, but basic one-male units have been suggested for these forest-floor dwellers.

Guenons, with the exception of vervets, and patas monkeys generally live in small one-male units. During the breeding season, males might temporarily enter some breeding groups, but, in patas monkeys at least, other males are generally found in all-male bands. Talapoins typically live in large social groups consisting of many adults of both sexes. In captivity, females might dominate males when not in breeding condition, and new males might be attacked by females.

The presence of strong matrilines is characteristic of groups of macaques and baboons in expanding populations, but strong matrilineal subgroups might not be universal. They are not readily detected in declining populations or in those in equilibrium, and evidence of strong matrilineal organization is not found even in expanding troops of sooty mangabeys (*Cercocebus torquatus atys*). The social organization of the various mangabey species is not yet well described.

Colobine monkeys generally live in one-male units with other males living in all-male bands. *Colobus badius* (red colobuses) and *Rhinopithecus* (snub-nosed langurs) form multimale troops of somewhat larger size. Some variation is also noted among *Presbytis entellus* (hanuman or sacred langurs), in which multimale troops might exist temporarily or more permanently in some habitats.

Many African monkeys form polyspecific associations in the wild, and mixed-species groups of guenons have been maintained in captivity without adverse consequences. The high prevalence of simian AIDS viruses in African monkeys, however, argues against mixing them with Asian species. Macaques in particular appear to be highly susceptible to such infections. Different species of macaques will also readily hybridize when mixed-species pairs are formed; however, even though compatible pairs tolerate each other, macaques generally do not do well in mixed-species groups, and formation of such groups for social enrichment is not recommended.

REPRODUCTION AND DEVELOPMENT

Old World monkeys exhibit true menstrual cycles with the sloughing of the uterine wall lining at the end of the luteal phase of the cycle if fertilization has not taken place (Catchpole and Van Wagenen 1975). Some species (e.g., rhesus, bonnet, and Japanese macaques) are seasonally polyestrous with a hiatus in ovulatory cycles during late spring and summer months. Others (e.g., crab-eating macaques) show seasonality only in some circumstances. Other Old World monkeys might show a tendency to give birth more frequently in some months (e.g., sooty mangabeys), whereas others seem to give birth with equal frequency in all months. Indoor housing can be expected to alter these observations from wild populations. Menstrual cycles are generally 4-5 weeks long, and copulations tend to be concentrated at midcycle, although some species (e.g., *Macaca arctoides*) seem less hormonally controlled and others respond more to social conditions than to absolute hormone concentrations (e.g., rhesus monkeys).

Sexual swellings (edematous engorgement of the skin, usually in the perineal area) are distributed in an erratic pattern among Old World monkey taxa. In species in which they do occur, females will cycle between full swellings at or near the time of ovulation to no swelling during the late luteal to early follicular phase. Some taxa also maintain partial or even large swellings during pregnancy. Sexual swellings and other visual, chemical, auditory, and behavioral cues might synchronize the reproductive activity of the two sexes. The size of sexual swelling varies among species and among individuals within a species. In some taxa, it is common only among adolescent females and disappears in fully mature females.

In some species, clear evidence of male-male competition is seen (e.g., baboons), but female choice also plays an important role (e.g., in rhesus monkeys). In some, consortships are formed that endure beyond the time required for copulation; but in most multimale groups, females will mate with more than one male, and the degree of correlation between dominance, observed matings, and paternity is highly variable.

Male-male competition is highly variable in expression, but in most groups male aggression is ritualized and produces few serious injuries. Under natural conditions, male transfer between groups during the breeding season might account for more wounding than males fighting over females (Ruehlmann and others 1988). Infanticide has been reported in several locations for hanuman langurs when a new male takes over a group (Blaffer Hrdy 1977). Although suggested in a wide variety of other species, its prevalence is debatable. In most cases, even when it does occur, it is most likely when a new breeding male replaces the former resident male.

Gestation generally requires 5-6 months, and a single infant is usually produced. Infants sometimes are dramatically different in coat color from adults and often have unpigmented hands and faces. That condition does not vary according to any systematic taxonomic scheme, and the period before full adult coloration varies. The functional significance of natal coats remains speculative.

Weaning is not an abrupt event but a process lasting over several months. Although many infants continue to nurse until the next sibling is born, most can feed themselves at 6 months but remain socially dependent on their mothers and return to their mothers when disturbed and to sleep. Young infants are carried ventrally, and only in some species (e.g., baboons and geladas) do they predictably transfer to dorsal carriage after the first 2 or 3 months (Altmann 1980; DeVore 1963).

After the first year, juvenile animals can become more and more involved in peer groups, especially males. Several years might pass before puberty occurs. Puberty is also not an event but a process, and the gradual change to full adult status can take several years, a period sometimes recognized as the period of adolescence and subadult states (Bernstein and others 1991). First menstruation can precede fertility by a year or more and often occurs when a female is only half her full adult weight and before she sheds all her milk dentition (deciduous teeth). Males can achieve fertility long before they normally participate as adult males in breeding. It is during this time that males often transfer out of their natal group.

Cercopithecine monkeys are relatively easy to breed in captivity, and infants can be produced under almost any condition that allows a fertile male access to an ovulating female. Early rearing conditions, as discussed in Chapter 3, will have a substantial impact on the social development of infants and later reproductive competence. In general, infants reared in social contexts that approximate those of natural troops have the best prognosis as future breeders.

COGNITION

Studies of cognition using Old World monkeys have generally focused on macaque subjects. Rhesus monkeys have been the subject of numerous perceptual studies, and information on visual capacities is summarized in DeValois and Jacobs (1971). (See also Bayne and Davis 1983 and Leary and others 1985.)

Whereas Old World monkeys are not generally recognized as tool-users, they are highly skilled in manipulating objects. They are adept at numerous puzzle problems (e.g., bent wire) and readily learn to use joysticks to perform video tasks (Washburn and Rumbaugh 1992). Once skilled in a task, they will work at it with persistence, not needing to be rewarded with food to sustain their performance (Harlow and others 1950; Washburn and Rumbaugh 1992), but they prefer to work on tasks of their own selection. Many activities originally reinforced with food seem to become reinforcing in themselves, and monkeys will often work a familiar task, ignoring the food rewards offered.

Although capable of complex learning, monkeys have not displayed the kind of language skills seen in the great apes (Savage-Rumbaugh and others 1998). Gallup (1982) suggests that there is a large cognitive discontinuity between the great apes and monkeys as demonstrated by their consistent failure in such tasks as recognizing themselves in mirrors. The significance of mirror self-recognition in studies of cognitive capacity is controversial, and self-awareness might not be dependent on self-recognition in a mirror; moreover, not even all great apes demonstrate such a capacity. Great apes do, however, appear to show a greater diversity of learning skills than any monkey taxon, although most great apes' accomplishments might be matched in some particular monkey taxon.

The common practice of housing rhesus monkeys singly calls for special attention because it is well established that social deprivation can be counter to the goals of this report (Bayne and Novak 1998). Although many of these animals might become pair housed as encouraged in this document, others will remain singly housed for reasons of research, incompatibility, or health. Addressing the welfare of these singly housed animals requires a concerted approach by investigators, veterinarians, and IACUCs. Every effort should be made to house these animals socially (in groups or pairs), but when this is not possible, the need for single housing should be documented by investigators and approved by the IACUC. A common approach is for the institution's environmental-enrichment (or psychological well-being) plan to require all primates to be socially housed and to require justified exemptions for all others. There are reasons for single housing, that should not be accepted as the default situation. Institutions should provide social housing unless single housing is approved by the IACUC.

PERSONNEL

It is essential that personnel working with Old World monkeys be made aware of the various disease risks involved (Adams and others 1995) and the fact that many Old World monkeys are capable of inflicting serious bite wounds and have surprising strength for their body size. Macaques and some other cercopithecines also interpret the human stare as a challenge and might attack a person who is visually inspecting them, but most monkeys are not constantly hostile to people and will respond to considerate and consistent treatment. Personnel must take reasonable precautions to protect themselves from disease risks and attack (CDC 1990, 1993; CDC-NIH 1993; NRC 1996, 1997a). Even members of species that are more tolerant of humans can suddenly attack humans if an infant screams or if there is some other sudden disturbance. Rhesus monkeys are consistently more hostile than other macaques toward people, but personnel working with even the tamest of monkeys should be alert to the potential for attack.

Old World monkeys have been implicated in the transmission of several diseases to humans. (Adams and others 1995; CDC 1993; NRC 1997a). Most people prefer not to handle alert adults macaques and baboons, but human handling clearly is necessary to ensure the health and well-being of nursery-reared infant macaques and baboons. In the case of adults, techniques involving training, tunnels, pole and collar devices, leashes, transfer cages, and pharmacological restraint agents can greatly reduce the need for physical contact between monkey and human (Chambers and others 1992; Clarke and others 1988; Knowles and others 1995; Laule and others 1996; Phillippi-Falkenstein and Clarke 1992; Reinhardt 1992a, 1995, 1997a).

Behavioral training is absolutely essential for caregivers and other relevant personnel (Laule and others 1996). Both baboons and macaques are hardy animals and stoic in response to illness and injury. The same is generally true of other cercopithecines and colobines. Moreover, the thick hair of many guenons might completely hide even extensive wounding. Good detecting skills might be required to discern wounds, emaciation, and other serious conditions. In general, only a knowledgeable and alert observer can recognize changes in individual behavior in a macaque or baboon that are indicative of altered health. Caregivers familiar with their charges can develop different strategies that facilitate the caregiver-monkey interaction with “difficult” animals. Most monkeys respond appropriately to consistent considerate treatment but can be quite dangerous when teased, tricked, or bullied.

VETERINARY CARE

No requirements for the veterinary care of Old World monkeys differ from the general requirements for nonhuman primates (Butler and others 1995; NRC 1996). Old World monkeys can be trained to cooperate in some routine procedures when those procedures occur regularly (e.g., the use of vaginal swabs and blood-sampling). In some cases, individual animals can even be trained to accept restraint for short-term treatment regimens, which eliminates the need to subject them to repeated pharmacological restraint. (See “Restraint and Training,” Chapter 3.)

Monkeys can be medicated for illness or for other reasons in several ways—through gavage or injections or by masking the agent in a food treat. Medications can be sprinkled or spread on bread and covered with peanut butter, jelly, or both; and they can be hidden in fruit. Monkeys will often suck on a tube for medicated fruit juice as well. Although oral dosing is least disruptive to the animal and thus most desirable, some monkeys will not eat the treat and so require other strategies. It is also important to determine that the monkey consumes the treat, rather than storing it in a cheek pouch and later rejecting it. Offering a second piece of food immediately often forestalls detailed inspections of the first treat by the animal. Knowledgeable personnel can determine which method works best and which foods mask medications best for a particular monkey.

If any Old World monkey goes off-feed during an illness, it should be offered a variety of foods to stimulate appetite. For macaques, relatively bland but acceptable foods include cooked white rice, fruit-flavored yogurt, and bran cereal. Baboons are particularly fond of yams, fruit-flavored yogurt, and commercially prepared infant formulas.

Ill monkeys are sometimes removed from their social group. As the time away from the group increases, the potential for successful reintroduction to the original group decreases. For very short stays (less than a couple of days), reintroductions are generally not traumatic, provided that aggression was not the initial reason for removal. Careful reintroduction and monitoring of the group for outbreaks of aggression will help safeguard animal well-being. If the animal is out for a long period, reintroduction to the original group might be contraindicated. In some cases, an animal removed for treatment can be housed in a cage within the group pen. That permits access for treatment but at the same time maintains social contacts. Difficulties during reintroduction vary according to species. They are most common in macaques, such as rhesus and crab-eating monkeys, and less in other species, such as baboons.

A number of diseases are transmissible from monkeys to humans and vice versa (Adams and others 1995; CDC 1993; CDC-NIH 1993; NRC 1997a). The most publicized risks involve cercopithecine herpesvirus 1 (*Herpesvirus simiae* or B virus), which is known to be carried by a high percentage of macaques and may be carried by other Old World monkeys—which produces little outward sign of infection in macaques but is almost always fatal in humans. During the active phase, the virus can be transmitted to humans through bites or scratches. It can also be transmitted to human mucus membranes (e.g., in the eyes) from discharges from various bodily orifices of macaques or other inanimate objects or materials on which disease-producing agents can be conveyed (fomites). The number of recorded human infections is small, considering the number of people working with Old World monkeys, but prudence is certainly in order in the handling of Old World monkeys. Ebola-Reston virus, another disease of Old World monkeys is not known to have caused any morbidity in laboratory animal workers (although serum titer conversions have been documented), but the consequences of exposure are severe and prudent precautions must be observed (Adams and others 1995; CDC 1990; CDC-NIH 1993; NRC 1997a). Unlike the macaque, the baboon has no specific disease entity that is considered zoonotic. In both macaques and baboons, bacteria—such as shigellae, salmonellae, staphylococci, and *E. coli*—are sometimes found and are transmissible to humans.

Of particular significance for Old World monkeys is tuberculosis, which can be transmitted from humans and by other infected monkeys. Although tuberculosis in primates is not reportable to the Centers for Disease Control and Prevention (CDC), except during quarantine (CDC 1993), the most frequently used species (rhesus monkeys and crab-eating macaques) have had the most reports of infections. Tuberculosis is also a possible but less-probable infection in baboons. Primates and all personnel working closely with them should be routinely screened for tuberculosis.

Seizures, similar to human epileptic seizures, are sometimes seen in macaques, baboons, and chimpanzees. Medications used for epileptic humans sometimes are effective in alleviating the problem in macaques and baboons. Although many seizures can be traced to traumatic origins, some are thought to be genetically influenced, and this should be considered in breeding programs. Animals subject to seizures should be maintained in cages that decrease the risk of injury during seizures (e.g., by avoiding the possibility of long falls to a hard floor). Readers should refer to Bennett and others (1995) and *Occupational Health and Safety in Research Animal Facilities* (NRC 1997b) for a comprehensive discussion of the diseases of nonhuman primates.

All primates imported into the United States must undergo a minimal 31-day quarantine period at a CDC-licensed and CDC-inspected facility (CDC 1991, 1993). This rule includes wild-caught animals and those from captive breeding colonies. As a result of a suspected filovirus threat associated with newly imported animals in 1989 (CDC 1990), the CDC quarantine requirements became much more rigorous. Special permits and transportation restrictions were developed for three species (rhesus monkeys, crabeaters, and African greens or vervets). The special transportation and quarantine requirements have now been extended to cover all primates. The protective clothing, limited access of personnel, restriction of human interaction, disinfection requirements for equipment or objects being taken out of the quarantine areas, and relatively short holding times make many environmental enrichment and well-being programs used in normal colony situations difficult to accomplish during CDC quarantine. Nonetheless, many of the enrichment options discussed in Chapter 3 can be provided: some animals can be socially housed, caging can be arranged so that animals can see and hear each other, food treats and supplements that do not require special delivery devices can be offered, perches can be provided, and uniform procedures can be established early so that animals can anticipate regular husbandry events as soon as possible. During quarantine, well-trained and motivated caregivers can provide an enormous difference in reducing the stress of the animals. Despite the limitations imposed by quarantine, a variety of enrichment techniques are possible and will prove especially beneficial under the restrictive conditions of quarantine.

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Apes: Hominoids

Scientific Name[1]	**Common Name**
Lesser apes	
HYLOBATIDAE (hylobatids)	
Hylobates sp.	gibbon
Symphalangus sp.	siamang
Great apes	
HOMINIDAE (hominids)	
Pan sp.	chimpanzee
Pan paniscus	bonobo, pygmy chimpanzee
Pan troglodytes	common chimpanzee
Gorilla sp.	gorilla
Gorilla gorilla gorilla	lowland gorilla
Gorilla gorilla graueri	western highland gorilla, eastern lowland gorilla
Gorilla gorilla beringei	mountain gorilla
Pongo pygmaeus	orangutan
Pongo pygmaeus pygmaeus	Bornean orangutan
Pongo pygmaeus abelii	Sumatran orangutan

[1] This is a list of scientific and common names of species discussed in this chapter, not a comprehensive taxonomic list.

The apes are classified in the superfamily Hominoidea. The lesser apes (gibbons and siamangs) are placed in the family Hylobatidae. Great apes and humans are placed in Hominidae, but some would place the orangutan (*Pongo*), in a family by itself, Pongidae. Some recognize chimpanzees and gorillas, the two knuckle-walking African apes, as members of the same genus, *Pan*, but others prefer to keep the gorilla (*Gorilla*) separate to highlight the greater relationship of chimpanzees (*Pan troglodytes*) to bonobos or pygmy chimpanzees (*Pan paniscus*).

The hylobatids, or lesser apes, are all specialized for brachiation (arm swinging). The siamang is roughly the same height as the gibbon with slightly less elongated arms, but it weighs nearly twice as much. Gibbons are all of similar structure with greatly elongated arms, hands, and fingers and are divided into species on the basis of pelage, vocalizations, and variations in throat-sac adaptations. All hylobatids are native to the rain forests of southeast Asia and Indonesia. They live in monogamous groups and are territorial frugivores. Capable of long flying leaps, swinging from hand to hand suspended beneath branches, they are extraordinarily graceful to watch. They also “sing” duets, and the calls are loud but melodious. These calls are analogous to bird calls in that they often advertise a defended territory. Their arms are so long that if they are forced to walk on the ground and brachiation is not an option, they must walk bipedally. The gibbon’s thumb is unusual in that the metacarpal is free; this allows the gibbon to use this “extra” joint to fold the thumb across the heel of the hand in locomotion.

Great apes are popular in zoological exhibits, and the chimpanzee is often the animal of choice in some research settings (NRC 1997b). The mountain gorilla, famous from numerous television shows about wild animals, has only rarely been seen in captivity; exhibitors almost always display the lowland variety. A third subspecies, the western highland gorilla (or eastern lowland gorilla), is also recognized in the wild. Orangutans all belong to a single species (*Pongo pygmaeus*), but Bornean and Sumatran subspecies are recognized, and the orangutan species survival plan (SSP) insists that they be kept segregated. Hybrids are readily produced in captivity, but geographic separation prevents gene flow between the two subspecies in the wild. Although earlier systematists recognized four subspecies of chimpanzee, little effort has been made to segregate or even identify chimpanzee subspecies in captivity. (See also work by Morin and others 1992, 1994 on subspecies identification in Africa.) The bonobo is, however, a morphologically and behaviorally distinct species (Napier and Napier 1985; Susman 1984).

HOUSING

Adult gibbons and siamangs are not tolerant of other adults of the same sex for any long period, although large numbers of immatures can be safely housed together in the presence of an adult or adult pair (Bernstein and Schusterman 1964). Perhaps as a function of the large cage area necessary for their brachiating locomotion, relatively few gibbons or siamangs are found in laboratory settings, although exhibitions often feature these animals in settings that permit display of their graceful locomotion. Cages provided with horizontal supports that permit suspensory locomotion are well suited for these animals, and they will normally remain in high locations, descending to the floor only occasionally. They are not physically powerfully animals, and cages can be made of lighter material than required for Old World monkeys of comparable size.

The great apes, in contrast, are extremely powerful animals with enormous hand strength. All three genera of great apes are commonly found in exhibits, but only the chimpanzee is found in laboratory settings in substantial numbers (Byrd 1977; Fritz and others in press; NRC 1997b). Exhibits generally maintain great apes in small groups in outdoor compounds provided with heated indoor shelters. The orangutan is generally regarded as semisolitary in the wild, and, although it will do well in small social groups in captivity, it might be wise to have only a single adult male in such a group. Adult male chimpanzees can be housed together (Alford and others 1995), and male gorillas that grow up together can be tolerant of one another. A few laboratories maintain chimpanzees in individual cages under biocontainment conditions. Even under these conditions, however, chimpanzees will benefit from visual and auditory contact with others (NRC 1997b; see also discussion below.)

Although chimpanzees and gorillas locomote primarily as quadrupeds, supporting their weight on the soles of their feet and knuckles of their hands, both are active climbers and often suspend themselves by their hands. Accordingly, cages should be tall enough to permit any ape to hang by the fingers without touching the floor. Among the great apes, orangutans are least suited to terrestrial locomotion, and they are generally quadrumanous, cautious, slow climbers in which diagonal limbs (e.g., right arm and left leg) move in synchrony as in quadrupedal walking (Hunt 1991). Although generally slow, orangutans can move very rapidly when alerted or during acts of aggression. They probably will profit the most from platforms, ropes, and hanging structures, although all apes will make good use of such furnishings (Fritz and others in press).

All great apes construct sleeping nests in the wild and will use straw, cloth, and any other suitable materials to make nests in captivity. Young apes appear to need to practice this skill lest they fail to make nests as adults (Bernstein 1962, 1967). Young apes, and especially orangutans, enjoy crawling inside cloth bags, barrels, and similar containers. Such items stimulate much play, but as with all such objects, care should be taken to avoid items that could be dangerous to the animals through ingestion or entanglement.

When adequately adapted, apes can tolerate temperature extremes, as can Old World monkeys, but shelter from direct sun, wind, rain, and temperature extremes should be available, as recommended in the *Guide* (NRC 1996) and required by Animal Welfare Regulations (9 CFR Subchapter A). Because their black bodies absorb heat from direct sun rays, there is potential for chimpanzees and gorillas to suffer from heat stroke at relatively mild temperatures, although chimpanzees are routinely maintained outdoors in the southern United States with temperatures in the shade routinely above 38°C (100°F). Chimpanzees tolerate cold quite well for short periods but bonobos and lesser apes require shelter even at air temperatures of 10°C (50°F) and above. All animals should have access to indoor "night quarters."

Chimpanzees often engage in charging and drumming displays, which intimidate cagemates and visitors and can weaken cage structure. Inanimate objects and other group members are sometimes hit during these displays. Under these conditions, a door for retreat into a separate area is particularly helpful. Barrels are provided to enable this species-typical behavior in some facilities and constitute an effective and less-expensive option than repairing damage to caging or handling injuries to other animals. Proper design might be more important than space itself in the design of ape quarters (Fritz and others in press; NRC 1996, 1997b). Chimpanzees in social groups will make use of separate areas. The opportunity to join and leave a social group at will during times of tension is beneficial for animals that might be picked on during noisy displays. Chimpanzees have well-developed mechanisms to restore social harmony (de Waal 1989), but the opportunity for brief voluntary separation is helpful.

Ideally, housing permits the full range of locomotor expression, and socially housed chimpanzees enjoy space to play. Areas that are divided by a large obstacle provide a circular arena for such games as chase. Vertical space is also very important to apes, and one or two areas a few meters (9-15 ft) high, permitting a broad view of the surroundings, are favored locations (Traylor-Holzer and Fritz 1985). If possible, outdoor areas should have other than concrete floors, preferably natural grasses or bedding. A deep straw, pine- or cedar-bark, or woodchip cover 25-30 cm (10-12 in) deep has worked well in outdoor enclosures (Brent 1992; Rumbaugh and others 1989) and decomposes into a medium not conducive to insects. The ground cover stays clean as long as all fecal and urine-soaked material is removed daily.

Most agree that the best enrichment for a chimpanzee is another chimpanzee. Even in social groupings, however, attention should be given to the inanimate part of their environment. Attempts by zoological and research institutions have demonstrated the value of providing a wide assortment of furnishings for chimpanzees' use and amusement, including providing them with large uprooted trees (Maki and Bloomsmith 1989); "termite" feeders (Maki and others 1988); television or live-action video of other chimpanzees (Rumbaugh and others 1989; see also Platt and Novak 1997 for use in macaques); puzzle feeders (Maki and others 1989); traffic cones (Fritz and Howell 1993a); nesting materials, such as woodchips (Brent 1992), straw, cloth, or shredded paper (Fritz and others in press); and novel methods of providing food treats (see also Fritz and Howell

1993a; Rumbaugh and others 1989), including ice cubes with or without flavoring (Fritz and Howell 1993b).

When social grouping is not possible, attention must be given to the needs of the singly housed animal. These needs change with age, health, and experience. Immature chimpanzees respond positively to the opportunities to play or be groomed by a familiar human (Fritz and Fritz 1985; Reisen 1971; Shefferly and others 1993), and can prefer social interaction to food (Mason and others 1962, 1963). Older animals, too, benefit greatly by interactions with known caregivers (Baker 1997; Fritz and Howell 1993a; Laule and others 1992, 1996). Dogs also provide infant chimps with a playmate (Black 1992; Thompson and others 1991). Even when single housing is required, such as for biocontainment, much can be done to enrich the environment (Brent and others 1989; Fritz and others 1997; Lambeth and Bloomsmith 1992; Nadler and others 1992). These and many other enrichment options discussed throughout this report demonstrate relatively simple strategies to enrich the lives of these animals. Not the least of these approaches is positive human interaction (Fritz and Howell 1993a; Mason 1965). See also NRC (1997b) and the chapter in the Universities Federation for Animal Welfare handbook (Fritz and others in press) for additional discussion of chimpanzee biology, behavior, housing, and enrichments.

NUTRITION

Apes in the wild have a diverse diet that is based on fruits and selected leaves and stems but can also include roots, bark, nuts, insects, bird eggs, and small mammals (Goodall 1963, 1986; Napier and Napier 1985). The natural diet of gorillas includes a greater percentage of fibrous plants than commonly eaten by other apes. In captivity, if necessary, apes can be maintained on a commercial diet specifically prepared for primates; however, they seem to relish a more varied diet that includes fruits, vegetables, and treats. If apes are fed only natural foods, a wide variety of items to ensure adequate protein intake, as well as vitamin and mineral supplements, should be provided. The nutritional management of nursery-reared infant chimpanzees have been reviewed by Fritz and others (1985).

Foods may be presented in clean feeders, cut into small pieces and widely scattered, or left whole and unpeeled to extend feeding time (Bloomsmith 1989). Also, spreading selected treats, such as nuts and grains, in bedding or grass will give apes an opportunity to forage. If apes are housed in social groups, it is necessary to provide enough food so that the most timid animal in the group can get its full allotment, or positive reinforcement training can be used to overcome severe competition at mealtime (Bloomsmith and others 1994). For enrichment, such food items as honey, mustard, peanut butter, raisins, and nuts can be placed in puzzle or foraging devices (Maki and others 1988, 1989). Some moderation should be practiced in the use of high-calorie treats.

Coprophagy, regurgitation, and reingestion are common in captive apes (Fritz and others 1992b; Howell and others 1997; Morgan and others 1993) and to some degree in wild chimpanzees (Goodall 1968, 1986). It appears that these practices are more frequent when animals are insufficiently occupied, yet providing forage in deep bedding has been implicated as a contributing cause of coprophagy in some animals (Fritz and others 1992). These practices are difficult to eliminate, but the best recommendation possible at present is to provide the animals with a rich social and physical environment and keep indoor areas as free as possible of feces.

SOCIAL BEHAVIOR

Despite the sometimes solitary nature of wild orangutans, all great apes profit from social companionship. Proper social stimulation is crucial for normal development of infant and juvenile animals (Fritz and Howell 1993a; Mason 1965, 1991; Mason and others 1962, 1963), and the adverse consequences of early social restriction are only somewhat ameliorated by later rehabilitation efforts (Davenport and Rogers 1970; Davenport and others 1973; Fritz 1986, 1989; Rogers and Davenport 1970). The advice on early rearing given in Chapter 3 also applies in the case of the apes. Mother-reared female apes generally become competent breeders and mothers and will provide adequate care for their infants in the presence of their usual companions, including their adult male partners. Sometimes the appearance that a mother is not attentive, or is abusive, to her infant stimulates caregivers to intervene. Often, however, these attentions are unneeded or even harmful, and personnel trying to protect infants from the attention of other group members (or from lack of attention from the mother) might do more harm than good by interfering in such situations. One common instance of this is when newborn chimpanzees are not observed to nurse for the first 48 hours or more. If the infant is well hydrated and reasonably active it probably means that it is nursing at night or at other unobserved times, and intervention is not warranted.

Males reared in social groups containing cycling females, infants, and adolescents usually develop normal copulatory skills and paternal behaviors. Socially restricted or nursery-reared males, however, often are inadequate breeders and parents (Fritz 1986). Adult male gorillas display remarkable gentleness in wrestling and play-fighting with older infants and young juveniles.

An issue of concern in today's biomedical chimpanzee colonies is how to sustain male copulatory skills without producing offspring. Owing to the burgeoning biomedical chimpanzee population (NRC 1997b), most chimpanzee-colony managers are attempting different strategies to accomplish this goal, including the use of Norplant® in females, vasectomizing some males that can serve as role models for prepubertal males, and separation of the sexes. It is probably too early to recommend one strategy over the others, for each has merits and problems. For example, the duration of efficacy of Norplant® in chimpanzees is not known but could be considerably shorter than in women (Mike Keeling, personnel communication), vasectomizing chimpanzees is more difficult in chimpanzees than in other primates in which it has been accomplished, and separation of the sexes can lead to insemination (or bitten penises) through wire cages and sexual frustration and aggression in males housed near cycling females (Alford and others 1995). In one recent case in which young adolescents of both sexes were housed together, a 5 1/2-year-old male inseminated four older females with which he was housed; this is the youngest documented male to sire offspring (International Species Information System, ISIS personal communication to the committee), and it shows the risk posed by opposite-sex housing of even young adolescents.

REPRODUCTION AND DEVELOPMENT

The apes all show regular menstrual cycles at intervals of about 5 weeks. Chimpanzee females develop huge (3-5 L) perineal swelling, with ovulation immediately after reduction in swelling, but only minor changes in the labia might be detected in gorillas and orangutans and none in lesser apes. Gestation periods are 7-8 months, and a single infant is generally born, although twins and even triplets have been observed in chimpanzees (Greissmann 1990).

During the first half-year of life, the infant ape has essentially continuous body contact with its mother; it begins to engage in exploration, food-getting, and social interaction beyond its mother during the second half of the first year. Normally, mothers do not allow others to hold their infants for the first few weeks of life. If possible, infant apes should remain with their mothers and have contact with other members of their own species. If infant apes require removal from their mothers, it is essential that they receive around-the-clock care from familiar caregivers who are sensitive to their needs for contact and motion (Fritz and Fritz 1985). Infants are highly sensitive to sudden movements, such as being picked up or laid down quickly. Transfer of an infant from person to person should be slow, and infants should not be subjected to forced handling by strangers. They need to be fed on demand (Fritz and others 1985).

Past practices of placing a mother-separated infant in a cage and taking it out only for feeding and cleaning are to be discouraged because they contribute to social and cognitive developmental problems. When care was provided by a large and changing cadre of people, specific attachment to a psychological mother was precluded. Under those conditions, great apes do not develop normal emotional responses and are likely to become unpredictable and dangerous both to human beings and to other apes.

Breeding takes place regularly in small groups, and there is some evidence that a single gorilla female in captivity, as well as in the wild, reproduces more poorly than if she is kept with at least one other female. Although chimpanzee males might compete for a receptive female, most competition consists of noisy display.

Gibbons and siamangs will breed when maintained as pairs. Males are reported to show care of older offspring (they might sleep with a juvenile and spend much time with it) after new infants are born. These animals do well in family groups.

Infant apes can be nursed for 3 years or longer, and interbirth intervals of 4 years or more are not unusual (Fritz and others 1991). Development to full adult size can take 9-10 years in gorillas and even longer in orangutans. One curious observation in orangutans is that the presence of a fully adult male inhibits the development of cheek flanges and other secondary sex characteristics, but not fertility, in maturing males (Kingsley 1980; Rodman 1988).

As with New World and Old World monkeys, sexual maturity can precede full physical size, and pregnancies have been reported in exceptional females as young as 6 or 7 years old. A period of adolescent sterility might follow puberty and first menstrual cycling. Females also reach sexual maturity and full body size several years before their male age peers.

Genital rubbing between bonobos of every age-sex combination has been observed in natural groups. This should be regarded as part of their social repertoire, rather than sexual behavior, and it neither enhances nor decreases reproductive activity (Thompson-Handler and others 1984).

COGNITION

Although gibbons and siamangs have not been noted for advanced cognitive capacities, great apes exhibit remarkable complex learning and tool-using skills. They readily develop concepts in formal training, and orangutans and chimpanzees can recognize themselves in mirrors and in televised images (Gallup 1977, 1982; Lambeth and Bloomsmith 1992; Menzel and others 1985). Enrichment devices to stimulate activity will occupy much of the time of captive great apes (Bloomstrand and others 1986; Paquette and Prescott 1988; Rumbaugh and others 1989). They interact with objects creatively and will spend substantial amounts of time with simple tools and sticks. They like fabrics—such as squares of carpet, various types of cloth, or blankets—for examination, destruction, and use as nesting materials (Bernstein 1962, 1967). Chimpanzees also become adroit in performing a wide variety of complex video tasks, using a joystick to control events on a monitor.

If they are reared from birth in an environment where humans speak to them communicatively and extensively, there is evidence that at least bonobos and chimpanzees can understand many requests. That can be helpful, for example, when an attendant asks a chimpanzee to trade a cage lock or piece of equipment for food (Laule and others 1992).

If chimpanzees are allowed to see and hear real-world events on video monitors while they view the same events directly, they are likely to "discover" that monitors can portray parts of the world that they otherwise cannot see (Bloomsmith 1989). For example, chimpanzees can garner important information from video monitors about the locations of foods and incentives and about the course of activities in areas beyond their view (Menzel and others 1985). Chimpanzees can come to prefer watching specific video-taped recordings, especially those of other chimpanzees they know, but there is little reason to believe that they profit from watching ordinary television programming other than nature films on conspecifics. They might attend to programs showing vigorous human interactions, such as dancing and sports (e.g., wrestling, boxing, and football) (D.M. Rumbaugh, unpublished data). Providing television sets for animals in laboratories and on exhibit has a certain appeal to humans, but benefits to the animals are dubious.

Despite their impressive cognitive abilities and interest in a wide variety of puzzles and cognitive challenges, there is as yet no way to assess a "need" for intellectual exercise in great apes. Ordinary social living in a well-designed enclosure might provide chimpanzees and other great apes all the intellectual stimulation that they require. Although attempts at enrichment should certainly be directed at singly caged animals in restricted environments (Nadler and others 1992), those in social groups also benefit greatly from an enriched environment.

PERSONNEL

Caregivers should be sensitive to apes as individuals. Apes often do not trust unfamiliar people, so new caregivers should be introduced systematically and gradually. In this way, both humans and apes learn what to expect from one another, and experienced personnel recognize the needs of their charges (Baker 1997). Feeding time is a very important time of day, and feeding practices should be such as to encourage caregiver-animal communication. Feeding and cleaning practices can serve to establish good relationships between caregivers and apes that, in turn, enrich the apes' lives and also inform the caregivers regarding the animals' behavior and physical condition.

Not only should personnel be trained and experienced in the behavior of apes, but it is imperative that they be trained in safety. Great apes are very powerful, active, and sometimes devious. Primates in general will harm people only in defense or in reaction to a threat, but a chimpanzee's aggressive actions are unpredictable and often seem premeditated. Such serious injuries as loss of fingers, bite and scratch wounds, and lacerations have been suffered by people working with apes. Chimpanzees should be treated with respect throughout their development. They have long memories and will recognize a favored or disfavored human after several years of separation.

Personnel should be continually reminded of established safety procedures. Cages should be designed to prevent the apes from reaching outside the cage.

Gibbons are capable of very rapid movement and can grab and bite with lightning speed. Even the bonobo, the smallest of the great apes, has enormous digit strength and can pull objects from or hold onto a human of much greater body size. Great caution should be used when handling unsedated apes, especially after they attain a weight of 12-15 kg (26-33 lb). Even the most reliable animals have the potential for causing serious harm to humans with whom they are in direct contact.

In addition to a general occupational-health program for people working with primates, consideration should be given to immunizing ape caregivers against hepatitis B, poliomyelitis, and influenza viruses, as well as to those currently recommended by CDC for health-care workers. Personnel with colds should not have contact with apes or they should at least wear industrial-level respirators covering the nose and mouth. Apes are susceptible to colds, and an infection with *Streptococcus pneumoniae* can be fatal.

Several of the great apes learn to spit and throw. Chimpanzees can spit more than a pint of water and throw feces with great accuracy. Such behavior is directed at disfavored people and strangers and sometimes is used merely to provoke a responsive person. A trusted human can usually "talk" an animal out of such behavior by a calm, gentle approach, but this is not always successful. The response of a human when being spat on might inadvertently serve to "reward" the ape and increase the likelihood of its spitting in the future.

VETERINARY CARE

Daily health observations by experienced persons are critical to the physical well-being of apes. Persons knowledgeable about an ape's particular personality and behavior might become aware of illness before traditional clinical signs are apparent. Veterinarians should strive to work as a team with all personnel who have contact with the apes (e.g., behaviorists, caregivers, technicians, and investigators) to develop a program to monitor the condition of the animals. Training time might be protracted, but the reward of less stress for the animals and humans can be very worth while. During treatment, drugs, especially liquid formulated ones, can be masked in flavored gelatin drinks or fruit juices, and an animal might readily accept even unusual items when they are offered by a favored person. A squeeze cage might be used as a last resort when there is no other safe way to deliver injectable medications. It is far preferable to train chimpanzees to present an arm or thigh against a wire-mesh cage wall (Laule and others 1992, 1996). They often accept injections for a small treat afterwards.

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Research Needs

The foremost mission of the Department of Health and Human Services (DHHS) is to address the health and welfare of the human species. That mission cannot be accomplished without relevant research using nonhuman primates as models. The mission of the U.S. Department of Agriculture (USDA) is to ensure animal welfare by governing their care and treatment.. Nonhuman primates are commonly maintained in biomedical institutions to support high-priority research into issues of human well-being, and those institutions are obliged to address the welfare of the animals. However, the ability to generalize findings from our close primate relatives depends on maintaining animals in a state that is representative of normal functioning. Thus, research into the well-being of nonhuman primates is essential to ensure that the missions of DHHS, the Department of Veterans Affairs, the Department of Defense, and USDA are carried out effectively. Those and other agencies depend on the collection of data on nonhuman primates.

Assessment of the well-being of nonhuman primates depends on the development of an adequate theory of well-being and on an adequate understanding of the animals' psychological, social, ecological, and physical characteristics. Although much is known about laboratory primates, we still have much to learn about what is necessary to maintain them in a condition of well-being.

A working definition of *psychological well-being* has been presented. However, research is needed both to evaluate potential measures of psychological well-being and to develop techniques that promote it. Such techniques should be appropriate, practical, cost-effective, and, above all, compatible with colony management and the conduct of research. Although professional judgment and lay judgment will continue to have their roles in programs to monitor and enhance the well-being of laboratory primates, intuition and personal judgment should be viewed as adjuncts or as the first step of hypothesis formation, not as a substitute for scientific investigation. Enrichment methods that have not been subjected to empirical testing should be viewed simply as unvalidated ideas, regardless of how well intended they might be. Without appropriate measurement and verification, we might do more harm than good in our efforts to improve animal conditions.

With an eye to achieving a better and, insofar as possible, a scientific perspective of psychological well-being, we propose the following topics for research. We recognize that the list is not all-inclusive.

THEORY OF PSYCHOLOGICAL WELL-BEING

The phrase *psychological well-being* arose in a regulatory, rather than scientific, context. Psychological well-being is a hypothetical construct, and the validity of a hypothetical construct can be determined only in relation to a theory that defines its properties and in relation to empirical data that address the fit between predicted and observed phenomena. We do not have a theory to guide thinking and research on well-being; the development of a coherent theory of psychological well-being is an obvious research need. Such a theory ought to incorporate cognitive, behavioral, and physiological characteristics of the organism in an integrated view of well-being. It also ought to encompass the possibility of species, age, sex, and individual differences in responsiveness to the same immediate environmental situation. Some of the work that has been done so far in this domain is based on notions of how humans behave and how they react to environmental situations. That might be a suitable place to begin the development of hypotheses, but it clearly is not sufficient. We must develop a theory so that we can agree on empirical measures of well-being, rather than relying on conflicting subjective judgments about internal states in other species.

INDEXES OF WELL-BEING

The acceptance of particular behavioral or physiological measures as operational indexes or correlates of psychological well-being can follow only from a theory that defines well-being in compatible terms. The use of multiple measures of psychological well-being until such a theory has been developed has been advocated. However, the relationships among several commonly used measures are not well understood. For example, chronic stress has both behavioral and physiological components, but their interrelationships have not been characterized fully. Furthermore, if stress is considered a manifestation of ill-being under some conditions, is the absence of chronic stress equivalent to well-being? The answer to the latter question should not be presumed to be yes.

In addition to identifying important research, this chapter addresses a fundamental problem in our approach to these concerns. Who would deny that all animals are equipped with capabilities for avoiding particular situations—the kinds of activities often referred to as flight-or-fight responses? The animals of concern are in fact wild animals and have little familiarity with captive-specific stimuli. In addition, these responses have a well-known physiological basis that enables the animal to cope with perceived conflict or danger. When precipitating stimuli are more or less continuously present, we conclude that the animals in question are chronically mobilized for responding, and so can be described as being "stressed." Psychological well-being would seemingly be enhanced, therefore, by also reducing the level of stimulation.

Conversely, captive animals display activities that have nothing to do with flight-or-fight, have a different physiological basis, and typically occur in relaxed contexts, e.g., grooming, play, foraging, or exploring. A paucity of these species-typical acts leads to the conclusion that animals are "bored," living in a chronic state of under stimulation. Not infrequently, animals under these circumstances invent their own ways of self-stimulation, often in the form of behaviors that we regard as undesirable (throwing feces, coprophagy, spitting, regurgitation, pacing, flipping, etc.). The enhancement of psychological well-being in these instances is realized through an increase in the level of stimulation, particularly with stimuli that bear an appropriate level of novelty.

A complete elimination of environmental stressors might be undesirable (NRC 1992; Selye 1974). Animals and humans seem to seek out some level of stimulation or stress that they find optimal. That level might be different across individuals and certainly across species. Alternatively, adaptive mechanisms might habituate a primate to the point where it is no longer physiologically stressed (e.g., animals adjusting to intermittent but continual pestering by cagemates). Research is needed to evaluate those ideas more fully.

In discussing atypical behavior, or stereotypies that either are detrimental to well-being or serve no adaptive function, it is critical to differentiate repetitive movements, stereotyped patterns, and potentially self-abusive behavior that indicate a lack of well-being from patterns that constitute potentially harmless idiosyncrasies (Berkson 1967; Mason and Berkson 1975). Often, it is not the occurrence but the frequency or the situation in which they occur that signifies a lack of well-being. Patterns of unusual behavior seen in play contexts are rarely viewed with concern, whereas the same patterns seen in other contexts might indicate ineffective adaptation. Many forms of behavior considered abnormal in adults are not viewed with alarm when seen in infants, e.g., digit-sucking and repetitive-movement patterns might be regarded as harmless in very young animals, but their appearance in adults, where they substitute for more effective typical coping responses, is cause for concern. Clearly, we need to conduct more research aimed at identifying indexes of well-being and determining which manifestations of atypical behavior indicate a lack of psychological well-being.

NATURAL HISTORY

Although considerable information is available on the natural history of some primate species, we do not yet know how to incorporate aspects of natural history into a practical, sensitive, and valid program of colony management that serves the dual interests of primate well-being and the research enterprise. We should avoid the conclusions derived from nature films that every animal's natural environment is either idyllic and peaceful or dominated only by bouts of hunting, wounding, and starvation. Rather, we should investigate animals' environments to identify characteristics relevant to well-being in captive animals. For example, how do the stressors encountered in captivity compare with those encountered in a given animal's natural environment in source, frequency, intensity, or duration?

A number of natural-history variables seem to bear on the psychological well-being of captive primates, including arboreal and terrestrial activities, social-organizational patterns and occasions for groups to form and disperse, dependence on long-term social affiliations or bonds, dietary needs and food-getting behaviors, preferred temperature norms and ranges, mating and infant-care patterns, natural communication modes, and modes of locomotion and movement. Further research is needed to determine the relative importance of those factors for different species of primates maintained in captivity. It should not be our goal to duplicate natural environments with all the hardships sometimes suffered by wild animals, but rather to identify favored activities, preferred patterns, and the general rhythms in life that organize behavior.

INDIVIDUAL DEVELOPMENT

Research has already demonstrated that several species of monkeys and apes do not develop normally when reared under conditions of social deprivation (Fritz and Howell 1993a; Mason 1965, 1991; Mason and others 1962, 1963), and the adverse consequences of early social restriction are only somewhat ameliorated by later rehabilitation efforts (Davenport and Rogers 1970; Davenport and others 1973; Fritz 1986, 1989; Rogers and Davenport 1970). Efforts have been made to identify the exact types of social stimulation required for normal development in some species, and there is some debate concerning minimal amounts of stimulation that are required to produce normal social and reproductive skills. That is of practical importance not only for rearing orphaned animals or animals abandoned by their mothers, but also because the pressure to produce infants in a breeding colony can result in early weaning and separation to reduce lactational amenorrhea, when it is present, and advance the next conception. It is clear that learning through social interactions is essential for many primates to be able to predict the social consequences of behavior directed toward live partners, to acquire appropriate communication skills, to care for infants properly, and to recognize predators. It is not clear, however, what types of experience will foster social competence or other aspects of species-normal behavior. Can cross-species fostering substitute for normal social environments, or does a cross-fostered animal lose some of its species-typical behavior (Seyfarth and Cheney 1997)? To what extent is housing with adult males, females other than the mother, and immature animals of both sexes necessary or sufficient for normal development? Can infants be successfully reared with aged adults or peers, thereby freeing young adults for rebreeding?

Although the importance of social stimulation during infancy is well established, considerably less is known about the influence of social contact during the juvenile and adolescent stages of development. The issue is important, inasmuch as primates are often moved from their familiar social groups and housed elsewhere. More information is also needed on the adaptation of wild-born animals to captivity and on how to prepare captive animals for release to free-ranging conditions or to the wild. We also need to know whether primates reared in free-ranging situations require strategies for promoting psychological well-being that are different from those required for animals born and reared in captivity.

SUBJECT CHARACTERISTICS

Several characteristics of individual animals can influence their psychological well-being in captive settings. Age and sex play major roles. It is important to determine what factors are necessary for the development of social competence in males and females. This information, for various species, might have important implications for the long-term success of captive breeding groups. One could argue that animals that fail to develop social competence for life in a social group and successful reproduction and parenting are damaged animals. The extent to which such animals are psychologically damaged and the importance of these failures require further exploration. Likewise, we need to understand the effects of age on psychological well-being and to determine effective strategies for maintaining both very young and very old animals in a state of well-being.

CAGING

Cage design can be important in fostering well-being in captive primates. To that end, research is needed to evaluate the effects of particular caging materials (plastic, wood, and metal) and cage designs (dimensions and cage configuration) in eliciting species-typical patterns of behavior in the different species of primates maintained in captivity (e.g., Crockett and Bowden 1994; Shimoji and others 1993). The cage sizes for particular species are currently determined by the typical weight of species members. Such an approach fails to provide for performance standards based on typical postures or locomotor expression, such as stride length. The extent to which performance standards can be translated into appropriate cages and housing depends on thorough study of species, age, and sex differences. It is important to specify cage configurations, in addition to absolute size. Other kinds of information will also be needed. Perch height should be examined in the context of both body conformation and tail length. Information on species-typical resting patterns can be relevant, inasmuch as some animals sit and others sprawl with arms and legs extended. Various stride characteristics should be identified. For example, if an animal travels horizontally with a quadrupedal gait, how long is each normal stride? For arm-swinging species, what is the arm span in travel (as opposed to maximal reach), and what height is necessary for the feet to clear the ground? How far apart should supports be for vertical clingers and leapers? Those basic measures should be characterized during development for both sexes of each species.

According to the experience of many primate-colony managers, the vertical dimensions of housing affect the well-being of some species. Under natural conditions, many primates spend much of their lives aboveground and escape upward to avoid terrestrial threats. Therefore, these animals might perceive the presence of humans above them as particularly threatening. In addition, such environmental variables as lighting, temperature, and airflow are likely to be affected by height, and these in turn could influence an animal's physiological state. Clarification of the contribution of such factors to well-being is needed. New cage designs should be developed to foster the humane capture of primates that are maintained singly or in groups. Cages should facilitate the regrouping of animals, their transfer between cages, and their access to different cages. Different kinds of materials should be examined that might provide for optimal use of limited intracage space by particular species and accommodate species-typical behaviors, such as marking, leaping, and chewing. Optimal use of available cage space might well depend more on the placement of perches, platforms, moving and stationary supports, and refuges than on cage size itself.

SOCIAL GROUPS

Primates are noted for their social behavior and proclivities. Although individual caging of primates might be required by protocols of approved studies or by reason of the social incompetence or health of a given animal, group caging is often more appropriate in light of the social needs of a species. Field data from various species have revealed long-term bonding relationships between parent and offspring, siblings, and others. Several factors should be studied to understand more fully the impact of social housing on psychological well-being. These include group formation, group composition, group size, and group stability. It is essential that suitable procedures be developed for placing animals in groups. Although much is known about pair formation (Reinhardt 1989a, b) and group formation in some species (Bernstein 1969, 1971, 1991; Bernstein and Mason 1963; Bernstein and others 1974a, b; Williams and Bernstein 1983), relatively little is known about other species. Likewise, relatively little information is available on the importance of group composition (age and sex classes) in promoting psychological well-being. On a social level, do particular combinations of animals (species, sex, and age) provide more positive, rather than negative, social interactions and facilitate the development of relationships? With respect to reproduction, does the presence of mothers contribute to the reproductive success of daughters with their first infants (Fairbanks 1988)? Knowing the answer to the last question might be important in reducing infant losses by primiparous mothers.

Group size is typically dictated by a practical consideration—the size of the cage or enclosure. An additive principle is used today to determine cage size for groups: the amount of floor area needed is established by multiplying the cage size required for an individually housed monkey by the number of animals in the social group. Few data are available to indicate the soundness of this strategy for the various species of captive primates. Further research is needed to determine how cage floor space and volume should be modified as the number of animals increases.

Extensive evidence suggests that for most species, stable social groups are preferable to groups that are continually reorganized. Should captive maintenance ensure, whenever and wherever possible, long-term social pairings of primates? One implication is that timed mating programs might need to consider the normal social partners of individual animals that are ordinarily removed and paired briefly for reproductive purposes. Another implication is that social bonds might be necessary for normal physiological responses in some primate species. It has sometimes been stated that long-term social bonds might contribute more to the well-being of primates in biomedical experiments than any other factor. That assumption requires verification; the extent to which social companionship yields more-normal physiological responses should be established scientifically. Finally, if long-term social arrangements exist, what are the implications for translocation of animals between social groups, between laboratories, and so on?

ENVIRONMENTAL ENRICHMENT

The environment can provide a captive primate with many objects designed to stimulate the expression of cognitive abilities. The degree to which such activity improves psychological well-being is unknown. Measures are needed to show whether increased activity of various sorts is beneficial. A need also exists for research and development on environmental design for captive primates to determine what features enhance primates' interest in their surroundings; their care, nurturance, and general well-being; their capture and transfer with minimal disruption and trauma; their physical comfort; the expression of species-specific behavior; and their social interactions with cagemates. Other than increasing activity itself, the beneficial effects of such devices as television, video tasks, mechanical puzzles, and manipulanda should be demonstrated. Research and development on these topics should be systematic, based on a comprehensive theory or concept of primate maintenance, and conducted and reported so as to contribute to the literature of animal science and animal behavior.

The committee believes that nonhuman primates benefit by having some control over their environment (see Markowitz and Aday 1998 for a discussion on providing captive animals control over their environment) and that, lacking such control, they generally benefit by being able to predict environmental events over which they have no control. Considerable research will be required to demonstrate that control and prediction enhance the psychological well-being of nonhuman primates. The benefits of predictability could vary in accordance with whether the procedure is positive, negative, or innocuous to the animals. Extensive work will then be required to learn which features in the environment are most critical to this sense of well-being.

COGNITION

Primates in general have substantial cognitive capacities for complex learning and memory. We know that primates' cognitive abilities and the specifics of their attention and motivational processes vary, probably in relation to ecological factors that are important to their adaptation to their natural environment. In addition, each species is naturally curious about or interested in particular kinds of things and will readily learn and remember particular kinds of things. These special interests and abilities are often related to the natural lives of animals in their species-typical habitats.

The following questions, however, remain to be answered: Are the cultivation and use of cognitive capacity basic to the well-being of captive primates? How can primates' intellect (i.e., cognition) be challenged in cost-effective ways to help to sustain their well-being, particularly where social companions are few or absent? How can knowledge of primates' natural history contribute to the design of materials and tasks that will be of interest and will stimulate appropriate behavior and enhance well-being? What species-related criteria are relevant to the empirical assessment of well-being as influenced by the cognitive operations of learning and memory?

HUSBANDRY PRACTICES

Husbandry practices are likely to have a substantial effect on psychological well-being, but little research has been done to underscore this point. For example, to what extent should routine procedures be predictable, and to what extent should the primate be an active participant in the process? How can one measure the adverse effects of deviation from routine?

Special attention should be focused on such procedures as quarantine and shipment, which generally entail translocation, social separation, dismantling of social groups, and marked alterations in ambient temperature, diet, water, caging, and animal technicians. The effects of quarantine and shipment should be subject to analysis and assessment from the perspective of animal well-being. Such study might afford a unique opportunity to do research on stress and its attenuation.

Special attention and research efforts should be directed to understanding the few animals in a colony that show signs of distress or disturbance (e.g., a type of sentinel) despite the presence of measures that support the well-being of all other animals in a colony. Care for these individual animals is particularly troublesome, in that they represent isolated problems in a population that appears to be exhibiting overall well-being. The temptation is to invest disproportionate resources in the chronic care of one animal or to remove the problem by euthanizing the animal (see Kreger and others 1998). Systematic investigation of individual differences in psychological well-being that leads to an understanding of why particular animals "slip through" despite the best possible plans will improve our understanding of the interaction of factors that contribute to the well-being of all animals.

ANIMAL TECHNICIAN'S AND CAREGIVER'S ROLE IN WELL-BEING

The animal technician's and caregiver's roles are pivotal to the social support of primates, particularly animals that are singly caged. Caregivers can serve as important points of social contact from which primates can garner positive interaction, instructions (where to go and what to do during cage-cleaning, transfer, etc.), and emotional security. They might also serve important roles in managing events when protracted fights, quarrels, and incessant hassling among primates break out. How might these relationships between animals and humans best be established, and how can existing relationships be improved? How can caregivers and technicians best be trained in key aspects of animal behavior? What aspects of training are most effective and deserve support? These ideas should be investigated further so that the caregiver's optimal role can be defined with reference to primate well-being. The effect of rotating caregivers in a colony and of changing caregivers on weekend, holiday, and other schedules merits investigation.

Some of the programs involving animals' well-being require time and effort (e.g., animal training) and commitments from the institution's senior management. Ways to increase the efficiency of human operations to help promote well-being need to be documented. Important to research and zoological institutions alike is how federal and private inspectors can best be trained to make accurate appraisals of well-being.

RESEARCH INNOVATIONS

Research procedures should not be sustained merely because they have been used in the past. Research procedures that entail a demonstrated negative effect on well-being should be subject to review and should be modified or supplanted with other methods that are less disruptive to well-being. That consideration is of particular importance where, by tradition, very young animals might be housed or chaired singly for long periods. Such procedures might sorely compromise normal development because they occur during the formative, hence sensitive, years of early development.

How can biological samples be collected so as to minimize restraint, isolation, loss of social support, the stress of isolation, pain, and other factors that can disrupt well-being?

In sum, whereas a great deal is known about the natural history and behavior of nonhuman primates held in captivity, much more information is required. Even with substantially greater information, the development of prescriptive recipes for primate well-being would not be desirable. A variety of solutions might achieve the same general goal—animals that are maintained under conditions that promote their physical and psychological well-being. The aim of research in this regard should be to find means by which to assess psychological and physical well-being and to provide the knowledge necessary to develop programs to achieve the general goal—animals maintained for research, exhibition or education can all be maintained under conditions that are consistent with the goal and will provide for their well-being. It is the responsibility of all who keep nonhuman primates to ensure that personnel are appropriately trained to develop procedures consistent with the goals of the institution and with the psychological and physical well-being of the animals in their charge.

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Appendixes

A

Samples of Nonhuman-Primate Environmental-Enhancement Plans

This appendix is intended to give institutions examples of the structure and content of plans for nonhuman-primate well-being but not actual plans. The structure and content of actual plans should address the species housed and the goals and aims of the institution. These descriptions have included many of the items in the checklist (Chapter 2), including processing of raw vegetables and fruit, manipulation, control, species-typical activities, enriched environments and positive daily interactions with care staff to reduce stereotypical and self-injurious behavior, food-rewarded learning, and complex sensory stimulation.

Plan 1 - An expanded example - not a blueprint!

The University of the Southeast
Nonhuman-Primate Environmental-Enhancement Plan
Revised March 6, 1998

INTRODUCTION

In accordance with the Animal Welfare Act of 1970 and in conformity with the policy of this institution, this document presents the nonhuman-primate environmental-enhancement (EE) plan used at the University of the Southeast (USE) to promote the physical and psychological well-being of nonhuman primates

(NHPs). The enhancement procedures have been developed to address the social needs of each species and to provide enrichment of the physical environment in order to encourage and enable expression of species-typical behaviors. The plan considers each species and each of the primary housing environments in use at USE.

I. Goal and Aims

A. Goal

The goal of this plan is to ensure the health and well-being of each NHP at USE as elaborated in the following sections. This plan provides *general* guidance for USE in achieving the goal and is supplemented by standard operating procedures (SOPs) to address such events as the introduction of individuals to pair or group housing, removal of an individual from a social group, and nursery rearing of infants.

1. Animals on research protocols sometimes require exemptions from the requirements of this plan (see Section V, "Special Considerations"). When exemptions are required, they are justified by the principal investigator to the Institutional Animal Care and Use Committee (IACUC) which has sole authority to grant exemptions. In all cases, housing of animals used in research will be designed to minimize disruption of the animals' social and cognitive behaviors.

2. Rhesus monkeys in the breeding colony are housed in harem groups in corn-crib and corral housing that allows for expression of species-typical behaviors. The housing is enriched with various manipulanda and feeding opportunities, as described in the breeding-colony SOP. (Actual SOPs are not included in this document.)

Marmosets are housed in pairs with nest boxes. They are easily stressed, so they are housed away from colony traffic areas and observed by familiar care staff. Scents are retained in the cage by rotation of the cleaning schedule, as detailed in the sanitation SOP.

3. Thirty days before animals are to be transported to another institution, they are housed in facilities separate from the stable, closed breeding colonies. Exemptions to the requirements of this plan are like those for research animals and are elaborated in an IACUC-approved sale-of-animals SOP.

4. Animals used for educational purposes are not excluded from this plan unless specifically exempted by the IACUC.

5. Animals used for exhibition purposes are not excluded from this plan unless specifically exempted by their keeper with approval of the veterinarian.

B. Aims

The aims of this plan are to provide an environment suitable for the expression of a broad range of species-typical positive behaviors, including locomotion, social interactions, foraging, and manipulation. It also seeks to minimize expression of negative behaviors, such as aggression, self-wounding, stereotypical behaviors, and coprophagy.

The plan recognizes and seeks to avoid stressful events, such as unpredictable activities associated with husbandry that can be interpreted by the animals as unpleasant. Colony routines for each species are spelled out in the species' SOP and include standards for minimizing interaction with unfamiliar persons; for clothing to be worn by care staff, research staff, and veterinarians; and for presentation of food treats.

The plan seeks to provide the animals with an enriched environment in which each can exert some degree of control over its environment as appropriate for its species.

Key to the effectiveness of this plan is the training of personnel in the natural history, behavior, and husbandry of the species and in the biomedical routines employed. Training and specific responsibilities and authorities of personnel are detailed in the training SOP.

II. Pertinent Information

A. Natural History

[This section can be excerpted from the relevant sections of this report and from the references cited.] A separate section should be provided for each species housed at the institution. It might include the following:

1. Rhesus Monkeys

a. Habitat diversity with emphasis on aspects of the natural habitat that can be provided in captivity.

b. Feeding habits with emphasis on foraging and variety of foods eaten.

c. Social organization with emphasis on the type and size of social organization and movements of animals into and out of social groups.

d. Cognitive and manipulative skills with emphasis on examples from the literature that can be adapted to the captive environment, such as swings, perches, forage, and objects to scent mark, chew, or destroy.

2. Squirrel Monkeys

a. Squirrel monkeys are arboreal primates that live in the middle-level canopy of rain forests, so cages should provide multiple levels of perches and at least one swing.

b. These animals spend up to 75% of their time foraging through the forest litter, so food is placed on the cage floor after cleaning to force foraging. Puzzle feeders do not work.

c. These animals are normally housed in social groups with the above environmental enhancements.

d. Ideally, these animals would be housed in social groups of up to

20 animals in indoor-outdoor housing with perches, swings, and hide boxes.

B. Records

Documentation of each animal's history is important for providing for and assessing its well-being. USE's records are maintained in the office of the veterinarian and include the following information:

1. Source of Animals

Whether the animal was born at USE, purchased from a U.S. Department of Agriculture class A or B vendor, acquired from another institution, or taken from the wild.

2. Rearing History

Where the animal was born (wild or captivity) and whether it was reared in social groups (single or mixed-sex) or with peer groups.

3. Housing History

Chronology of types of housing and partners for each animal and holding rooms.

4. Health and Behavior history

Clinical and behavioral records. Behavioral profiles of each animal (e.g., regurgitates often, overgrooms when housed in pair group, or self-mutilates when single-housed) are maintained from the earliest age possible and updated on daily observation sheets during routine observations of the animals as a baseline for diagnosing the etiology of abnormal behavior and planning for remedial intervention.

III. Social Interactions

This plan provides for the social housing of each animal. Exceptions to the policy that each animal shall be socially housed are detailed in Section V, "Special Considerations."

A. All animals in single cages are evaluated for their potential for pair or group housing. The position of USE is that all animals shall be socially housed, unless exempted under Section V. Strategies for the introduction of animals to pair or group housing and for the removal of animals from pair or group housing (e.g., because of sickness, aggression, or research protocols) are specified in the group housing SOP.

B. When animals are required to be separated and reunited repeatedly, consideration is given to the stress caused by removing an animal from a social group and the risks posed by repeatedly re-establishing group formation. These considerations and protocols are provided in the group housing SOP.

C. Animals housed singly benefit from visual, auditory, and olfactory contact with nearby conspecifics. Unless exempted under Section V and approved by the IACUC, all single-housed animals will be housed to maximize the beneficial aspects of this sensory stimulation.

D. Some of the institution's NHPs benefit from frequent, positive human contact. The degree of this interaction varies by species and history and interaction is conducted with due consideration to the risk to humans. Guidelines for positive human interaction (e.g., giving treats and making positive facial gestures) with the NHP are detailed in the human interaction SOP. Additional USE policies regarding human interaction with macaques are provided in the institution's occupational health and safety program.

E. USE maintains a small chimpanzee breeding colony in which nursery rearing becomes necessary when infants are rejected by their mother and surrogate rearing is not possible. The nursery rearing SOP provides the details for these procedures and discusses the value of the use of other species (such as dogs) for comfort and social interaction of infants.

F. All animals (socially and singly housed) will be provided the opportunity to perch.

IV. Environmental Enrichment

A. <u>Single-Housed Rhesus Monkeys</u>.

Cage complexities will be provided for individually housed primates. Exemptions for scientific reasons will be granted in accordance with Section V, "Special Considerations", and with 9 CFR "Animal Welfare"; "Part 3—Standards"; §3.81. An animal will receive different enrichment devices every 2 weeks because of randomness in the cage change schedule. Animal care staff will be responsible for the implementation of the nonsocial program. The cage complexities may include:

- Toys: Kong®, Plaque Attackers®, Tug-A-Toys®, Nyla-Rings®, solid vinyl rings and tugs, grooved vinyl dumbbells, flexible PVC tubing, and Boomer® balls.
- Food enrichment: Artificial fleece boards, artificial turf boards, puzzle feeders, PVC knots filled with banana pellets, shakers, fruity rawhides, and treats given by authorized personnel.

Each animal will have at least one toy inside and one toy or food device outside the primary enclosure. Food enrichment will be provided at least two times each week unless the animal is exempted from this type of enrichment.

Special consideration for environmental enrichment will be given to specific individuals or groups as needed:

1. Infants and juveniles, whose social development will be carefully monitored.

2. Animals that cannot be socially housed (especially those held in environments that limit visual, auditory, tactile, or olfactory interaction with conspecifics or members of other compatible species), for which enrichment strategies will be specially tailored.

3. Nonhuman primates in psychological distress, as determined by behavior or appearance.

4. Nonhuman primates participating in approved animal study protocols that require restricted activity for longer than 12 hours.

B. <u>Pair- and Group-Housed Squirrel Monkeys</u>

Environmental enhancement for pair- and group-housed squirrel monkeys is necessary but sometimes difficult. Squirrel monkeys are vastly different from macaques in their desire to manipulate toys and to maintain an interest in novel aspects of their environment. The procedures adopted by USE consider the natural behaviors of squirrel monkeys and the special husbandry procedures that they require.

1. Perches, Swings, and Cage Complexities

a. Perches. Squirrel monkeys are arboreal primates and typically spend most of their time in middle-level canopy of the South American rain forest. The genus can make maximal use of three-dimensional space. USE provides each cage with multiple levels of perches, which were determined from reference to the literature and by testing to be optimal for the species. (Scientific articles on the husbandry and housing of squirrel monkeys by USE veterinarians and behavioral scientists have contributed to the well-being of this species.)

b. Swings. Given the squirrel monkey's arboreal abilities, each social cage is provided with at least one swing consisting of plastic chain, looped PVC pipe, or other similar material.

c. Hide or nest boxes. Direct eye contact is an aggressive encounter for squirrel monkeys (as it is for macaques and many other species). USE provides "hide boxes" in each social cage to allow a submissive animal refuge from an aggressive animal. The use of hide boxes has been shown to reduce the frequency of fight-related injuries in *Saimiri* (see appended abstract published by USE scientists).

2. Food

a. Forage for food. Squirrel monkeys are foragers that spend up to 75% of their time moving through the forest eating. To encourage foraging in indoor-outdoor social cages, food is scattered in the litter on the cage or pen floor after daily cleaning. This forces the animals to move through the cage to select their food. Squirrel monkeys do not use puzzle feeders and grooming devices, which do not simulate food presentation for this species.

b. Variety of food items. In all caging situations, a number of different food items are used to vary the diet of the animals. In addition to a commercial monkey chow, squirrel monkeys are fed vegetables and fruits (based on seasonal availability and including bell peppers, string beans, yellow squash, yams, and grapes) on a rotating schedule that is documented on the daily room-check sheets. Peanuts and mealworms are used as special treats to aid the animal-care personnel in observing the animals. This task is indicated on the daily room-check sheets. Fruits and vegetables are fed whole, which increases the processing time required to open or shuck the item.

3. Contact with Caregivers

a. Daily observation. Using peanuts and mealworms, the animal-care personnel interact positively with the squirrel monkeys at least twice a day. These daily observations allow the animals to become accustomed to the caregivers and allow the caregivers to identify developing physical or behavioral problems.

b. Food items. Food items are handed out by the caregivers twice daily. This positive interaction allows the animals to habituate to the caregivers and allows the caregivers to interact with the animals in a positive, non-threatening manner.

V. Special Considerations

A. Protocol-Restricted Activities

All NHPs at the institution are included in this plan unless excluded for cause by the IACUC or for health or well-being reasons by the attending veterinarian. Some research at USE requires such exclusions, including sleep and vision research in which animals are restrained in chairs for up to 4 hours a day 3 days a week when the electrical activity of the brain is monitored. The procedures for placement of electrodes are detailed in each investigator's protocol and outlined in the electrophysiology SOP. Chair restraint is discussed in the restraint SOP. When the protocol permits, these animals are pair-housed. Such animals are reintroduced to their cagemates after each period of restraint. Replacement of chair restraint with tethering is encouraged by USE and practiced by some investigators. This permits the animal to remain in its home cage but generally does not permit pair housing.

B. Exemptions from Social Housing

All animals housed in nonsocial situations require an exemption from this plan. The social housing exemptions SOP discusses each exemption.

Animals undergoing clinical treatment may be temporarily exempted from social housing at the discretion of the attending veterinarian. Such exemptions will be reviewed every 30 days, and an exemption will terminate when the animal finishes treatment. Long-term exemption from social housing may be authorized by the attending veterinarian for the following reasons:

1. Permanent Clinical Debilitation Due to Extreme Injury or Old Age.

It is sometimes necessary to separate chronically sick or debilitated animals from social housing. These animals are maintained in individual cages with multiple perches and varied foods, and have frequent contact with familiar caregivers. An "Exemption from Social Housing" form, signed by the attending veterinarian, is required.

2. Contagious Disease.

When an entire group or room of monkeys are known or believed to have been exposed to an infectious agent, the entire group will be kept intact and under quarantine during the diagnosis, treatment, and control of the problem unless otherwise required by the attending veterinarian. The procedure is specified in the quarantine SOP.

3. Aggression.

A monkey that is found to be hyperaggressive or vicious within their social group will be relocated to another social group if possible. If the animal is a danger to other animals, it will be placed in an individual cage on the orders of the attending veterinarian. An "Exemption from Social Housing" form, signed by the attending veterinarian, is required.

4. Social Incompatibility.

This category applies to animals that cannot defend themselves from the normal dominance-related aggression that occurs in the species. Removal of such an animal from the social group risks being unable to reintroduce it to the same group or introduce it to another social group and is a course of last resort. Environmental enrichments—including provisions for the animal to hide in boxes, culverts, and behind walls—are often useful in alleviating this condition An "Exemption from Social Housing" form, signed by the attending veterinarian, is required.

5. Requirements of a Research Protocol.

Exemptions from social housing are sometimes necessary to carry out a research protocol. This exemption is made for such protocols approved by the IACUC. The animals are separated from their social group for the time necessary to conduct the study. Approved protocols are monitored on an annual basis.

6. Other Conditions.

Other circumstances requiring single housing that have not been defined occasionally arise. A decision to remove an animal from its social or pair group is based on the professional judgment of the attending veterinarian in consultation with the investigator (if appropriate) and the IACUC. An "Exemption from Social Housing" form, signed by the attending veterinarian, is required.

VI. Monitoring.

A. Records

Recordkeeping is the cornerstone of USE's Environmental Enhancement Plan.

1. Health checks

Daily health checks are performed by caregivers trained to recognize normal and abnormal behaviors of the species housed and to detect signs of illness. Daily logs are used to record abnormal behaviors, changes in the amount of activity, and signs of illness. [A list of normal and abnormal behaviors can be developed for each species from the discussions in Chapters 5-9.]

2. Responses to routine practices

Alterations in behavior resulting from routine husbandry practices are noted. These often suggest early signs of illness or stress. Plotting of these behaviors over time assists the veterinarian in initiating changes in caging, personnel, or treatments at an early stage.

3. Training

Many NHPs respond favorably to food reward. Such training is a valuable adjunct in administering medication, performing clinical examinations, or simply observing the animal. Changes in the animals' response to food reward are noted on the daily log.

B. Remediation

1. Both successful and unsuccessful remediation strategies are documented. An example of successful remediation is the enrichment of a single-caged rhesus monkey environment that resulted in alleviation of hair loss caused by overgrooming. An example of an unsuccessful attempt at remediation is the failure to reintroduce an old male squirrel monkey to a social group after an extended separation. These and other remediation efforts are documented in each animal's clinical records and summarized in the remediation file.

2. SOPs for remediation are developed for all major strategies, and new SOPs are added as needed. Existing SOPs describe remediation strategies for introductions and reintroductions of rhesus and squirrel monkeys, marmosets, and chimpanzees; enrichment for rhesus and squirrel monkeys, marmosets, and chimpanzees in single and social housing; pair housing of male squirrel monkeys; aggression; infant nonsocial rearing; coprophagy; and endpoint criteria for deciding when euthanasia is the most humane option.

C. Assessment of the Plan

The plan is judged to be successful if

1. Individual animals are judged to be in a state of well-being *or* the cause of distress or atypical behavior in any animal can be shown to be derived from antecedent conditions or from an approved research protocol.

2. When antecedent conditions apply, practices are identified and implemented for the benefit of *future* animals and facility records exist for the presence, etiology, and remediation or accommodation of observed cases of lack of well-being.

Plan 2 – A short version.

Species of nonhuman primates that have been observed to live in social groups in a free-ranging state are being socially housed in their primary enclosure

- In a manner similar to their natural social structure.
- In accord with generally accepted practices described in the literature for captive members of this species.

Each animal is maintained in a pair or group if it has been determined to be compatible with other animals by regular behavioral observations and approved by the attending veterinarian.

Animals that are individually housed are maintained in this manner because of overaggression, health status, or justified experimental constraints and with the approval of the institutional animal care and use committee and facility veterinarian.

Cage complexities (perches, toys, foraging devices, etc.) made available to socially and individually housed primates include the following:

- toys: Kong®, Plaque Attackers®, Tug-A-Toys®, Nyla-Rings®, solid vinyl rings and tugs, grooved vinyl dumbbells, flexible PVC tubing, and Boomer® balls.
- Food enrichment: Artificial fleece boards, artificial turf boards, puzzle feeders, PVC knots filled with banana pellets, shakers, fruity rawhides, and treats given by authorized personnel.
- Cage furniture: Perches and shelves.

Environmental enrichment is being given special consideration to (select the type(s) that apply):

- Individually housed primate infants or juveniles.
- Individually housed primates that are unable to see or hear primates of their own or compatible species.
- Nonhuman primates in psychological distress, as determined by behavior or appearance.
- Nonhuman primates participating in approved animal study proposals which require restricted activity.
- Great apes weighing more than 110 lbs (50 kg).

Nonhuman primates experiencing restraint for more than 12 hours are provided daily with the opportunity for unrestrained activity for at least 1 continuous hour during the period of restraint unless continuous restraint is required by an approved animal study protocol.

B

Examples of Infectious Diseases That Preclude the Safe Housing of Mixed Genera of Nonhuman Primates[1]

Disease Agent	Reservoir Host	Susceptible Host
CMV	*Macaca* sp.	*Saguinus* sp.
Entamoeba histolytica	*Macaca* sp.	*Ateles* sp.
		Lagothrix sp.
		Callitrichidae
Herpesvirus ateles	*Ateles* sp.	*Saguinus oedipus*
Herpesvirus saimiri	*Saimiri sciureus*	*Callithrix* sp.
		Aotus sp.
		Ateles sp.
		Cebus sp.
		Cercopithecus aethiops
Herpesvirus T	*Saimiri sciureus*	*Aotus* sp.
	Ateles sp.	*Saguinus* sp.
	Cebus albifrons	
Mycobacterium tuberculosis	*Macaca* sp.	*Saimiri sciureus*
		Aotus sp.
		Ateles sp.
		Cebus sp.
Rubeola	*Macaca* sp.	*Saimiri sciureus*
		Cebus sp.
		Callithrix sp.

[1] Does not include many common enteric or respiratory bacterial infections or parasitic infections.

SHF	*Erythrocebus patas* *Papio cynocephalus* *Cercopithecus aethiops*	*Macaca fascicularis* *Macaca arctoides* *Macaca nemestrina* *Macaca assamensis* *Macaca mulatta*
SV40	*Macaca mulatta*	*Macaca fascicularis* *Erythrocebus patas* *Cercopithecus aethiops* *Pan* sp.
YABA	*Macaca mulatta*	*Macaca fascicularis* *Macaca arctoides* *Macaca nemestrina* *Erythrocebus patas* *Cercopithecus aethiops* *Cercocebus torquatus atys*

C

Biographical Sketches of Authoring Committee

Irwin S. Bernstein, MA, PhD, Chairman
Dr. Bernstein was Sociobiologist and Research Professor at the Yerkes Regional Primate Research Center and Professor of Psychology and Zoology, University of Georgia at Athens. His research focused on primate social behavior and endocrine correlates of sex, stress, and aggression.

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Dr. Abee was Chairman of the Department of Comparative Medicine at the University of South Alabama College of Medicine at Mobile, Professor in the Department of Comparative Medicine, and Adjunct Professor in the Department of Comparative Medicine, School of Medicine and Dentistry at the University of Alabama at Birmingham. His research focused on the reproductive biology of nonhuman primates and animal models of human disease.

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Dr. Bayne was Veterinary Behaviorist in the Veterinary Resources Program, National Center for Research Resources, National Institutes of Health, Rockville, MD. She conducted original and independent research on the living environment of laboratory nonhuman primates and its effect on their behavior.

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Dr. Butler was Chairman of the Department of Laboratory Animal Medicine at the Southwest Foundation for Biomedical Research, San Antonio, TX. His re-

search was conducted in the areas of colony management principles and primate medicine.

Judy L. Cameron, PhD
Dr. Cameron was Assistant Professor in the Department of Physiology at the University of Pittsburgh. Her research involved nonhuman primate models of female hormone regulation and physiology.

Christopher L. Coe, PhD
Dr. Coe was Chairman of the Department of Psychology, Harlow Primate Lab, a Staff Scientist at the Wisconsin Regional Primate Research Center, and Professor in the Department of Psychology at the University of Wisconsin at Madison. His research focused on stress and immunological responses in nonhuman primates.

W. Richard Dukelow, MS, PhD
Dr. Dukelow was Professor of Physiology and Animal Husbandry and Director of the Endocrine Research Unit at Michigan State University and Associate Dean of the Research College of Veterinary Medicine, East Lansing. His research included the biochemistry and physiology of reproduction, especially spermatozoa, capacitation, intrauterine devices, and embryonic mortality.

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Dr. Fragaszy was Associate Professor in the Department of Psychology at the University of Georgia at Athens. Her research was conducted in the areas of manipulation, gross motor behaviors, and activity states of nonhuman primates during development.

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Dr. Mason was Professor and Research Scientist in the Department of Psychology at the University of California at Davis. He studied primate behavior and developmental psychobiology.

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Dr. Miczek was Professor of Psychology at Tufts University at Boston, MA. His research involved drugs, and primate behavior and aggression.

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Dr. Novak was Associate Professor in the Department of Psychology at the

University of Massachusetts at Amherst. Her research focused on primate behavior, behavioral and psychobiological development of Microtine rodents, and the environmental enrichment of captive animals.

Martin L Reite, MS, MD
Dr. Reite was Professor of Psychiatry at the University of Colorado Health and Science Center at Denver. His research was on the developmental pathology of nonhuman primates.

Duane M. Rumbaugh, MA, PhD
Dr. Rumbaugh was Regent's Professor in the Department of Psychology at Georgia State University and Director of the Language Resources Center at Decatur. His research focused on the biobehavioral studies of language and cognition of nonhuman primates.

Paul W. Schilling, DVM
Dr. Schilling was Director of Primate Breeding Operations at Charles River in Key Lois, FL. His research involved the coordination, design, and evaluation of production cages to meet animal welfare requirements for environmental enrichment of socially housed animals.

Elwyn L. Simons, MA, PhD, DPhil
Dr. Simons was Scientific Director at the Duke University Primate Center and the James B. Duke Professor of Anatomy and Anthropology at Durham, NC. His research focused on primatology, primate and human paleontology, primate husbandry, and the behavioral evolution of prosimians.

Charles T. Snowdon, MA, PhD
Dr. Snowdon was Professor of Psychology and Zoology at the University of Wisconsin at Madison. His research examined communication and social behavior in field studies of endangered primates.

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