Husbandry and Care of Primates (Chapter 29, ZOOKEEPING)

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Introduction

Humans belong to the order primates, and the many similarities they share with their closest living relatives make primates extremely popular species among zoo visitors. The primate order is diverse in its species and characteristics. The order includes the prosimians (e.g. lemurs, lorises, and tarsiers), New World monkeys (e.g. marmosets, tamarins, titis, sakis, capuchins, and squirrel, howler and spider monkeys), Old World monkeys (e.g. baboons, colobus, guenons, langurs, macaques, and mangabeys), apes (e.g. gibbons, siamangs, bonobos, chimpanzees, gorillas, and orangutans), and humans. Primates range in size from 30 grams for the smallest of the mouse lemurs, Berthe's mouse lemur (*Microcebus berthae*), up to 200 kilograms for the largest of the great apes, the mountain gorilla (*Gorilla beringei beringei*), and they have an equivalent range across the species in locomotor patterns, foraging strategies, mating systems, social structure, and behavior (Strier 2011, 30-58). However, primates as an order share a suite of characteristics that unite them as a taxonomic group and distinguish them from other mammals.

The two major taxonomic groupings of primates are the strepsirhines (wet nose connected to upper lip) and haplorhines (dry nose not connected to upper lip). It is important to note that throughout the literature, the terms prosimian and anthropoid are often used interchangeably with the terms stepshirine and haplorhine, although they are not synonymous (Fleagle 1999). The difference lies in the classification of the tarsier, which is a prosimian but shares many derived molecular and morphological features with monkeys and apes, although its ecological niche is akin to that of other nocturnal prosimians.

Although there is much debate on the number of species and their taxonomic assessment, Table 29.1 contains a generally accepted classification of the extant species of primates (adapted from Groves 2001).

This chapter will cover the primary techniques and best practices in husbandry for keepers caring for primates in zoos. After reading this chapter, the reader should have a comprehensive understanding of

• the natural history of primates and the importance of incorporating key features into primary husbandry practices
• the basic anatomical features used in describing primates
• a general knowledge of the complexity of primate behavior and social systems, and the importance of understanding species-typical behaviors
• a general understanding of the key features of primate enclosures, important for maximizing the expression of primate behavioral repertoires
• the technical skills important for keepers working with primates and for developing a rapport with individual primates in order to provide optimal care
• basic observational skills needed for managing primate social and clinical health
• the importance of incorporating operant training techniques into husbandry practices
• principles and techniques for managing primate reproduction and infant care
• knowledge of the conservation status of primates and important *in situ* and *ex situ* efforts being taken by various organizations to further our understanding of their needs to ensure their survival.

Natural History

Primates evolved in tropical habitats; they retain many characteristics that are adaptations to this environment and to an arboreal lifestyle. Morphologically, primates have a generalized skeleton and dentition; however, the primary characteristics that define the order are the opposability of the digits, a large brain relative to body size, and a long developmental period with an increased learning and socialization period. Napier and Napier (1967) provide a complete list of characteristics that define primates; however, the following are the most notable features that are key to understanding their needs:

• shoulder joints that allow high degrees of movement in all directions (brachiation)
• five digits on the fore and hind limbs with an opposable first digit (hallux) and grasping hands and feet
• the replacement of claws with nails, a flat nail on the hallux, and sensitive tactile pads
• a trend towards a reduced snout and flattened face, attributed to a reliance on vision at the expense of

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Table 29.1. Classification of living primates

Order Primates

Suborder Strepsirhini: prosimians (excluding tarsiers)
Family Cheirogaleidae: dwarf lemurs and mouse lemurs
Family Daubentoniidae: aye-ayes
Family Lemuridae: lemurs
Family Lepilemuridae: sportive lemurs
Family Indriidae: woolly lemurs
Family Lorisidae: lorises and pottos
Family Galagidae: galagos

Suborder Haplorhini: tarsiers, monkeys, and apes
Family Tarsiidae: tarsiers
Family Callitrichidae: marmosets and tamarins
Family Cebidae: capuchins and squirrel monkeys
Family Aotidae: owl monkeys (douroucoulis)
Family Pitheciidae: titis, sakis, and uakaris
Family Atelidae: howler, spider, and woolly monkeys
Family Cercopithecidae: colobines (colobus and langurs) and cercopithecines (baboons, guenons, macaques, and mangabeys)
Family Hylobatidae: gibbons and siamangs (lesser apes)
Family Hominidae: great apes and humans

olfaction (most notably in haplorhines, and less so in strepsirhines)
• a complex visual system, including stereoscopic and color vision
• a large brain in comparison to body size, with a welldeveloped cerebellum and enlarged cerebral cortex
• two pectoral mammary glands
• typically one young per pregnancy
• a trend towards holding the torso upright, leading to bipedalism
• a long gestation, developmental, and learning period with concomitant socialization.
It is important to note that not all primates exhibit these traits, not every trait is unique to primates, and no one trait defines the order. Rather, primates are generalist mammals, and as an order they are characterized by a suite of features which are well adapted to living in trees (arboreality).

Primates inhabit the equatorial regions of three continents: (1) from the rain forests of southern Mexico to northern Argentina, (2) from the archipelago of Indonesia to the mountains of southwest China, and (3) from the sub-Saharan bushlands and savannas to the equatorial rain forests of the Congo Basin and south to the scrub forests of South Africa and the spiny forests of Madagascar (Lehman and Fleagle 2010, 1-6; Wilson and Reeder 2005, 111-84). Primates play an import role in seed dispersal, and as a result they occupy an important ecological niche in tropical forests and woodland savannas. Most nonhuman primates spend some portion of their day in trees either foraging, sleeping, or taking refuge from predators. The majority of primate species are diurnal and arboreal; however, some species have evolved a nocturnal niche (lorises, galagos, owl monkeys) while some are primarily terrestrial (baboons and macaques). Primates exhibit great diversity in foraging strategies, and a wide range in food item preferences across species. For instance, lorises, nocturnal lemurs, and tarsiers primarily consume insects (i.e., are insectivorous); marmosets, tamarins, and galagos exploit tree sap and gum (i.e., are gumnivorous); geladas are unique in being grass and seed eaters (i.e., are gramnivorous); langurs and colobus and howler monkeys feed primarily on leaves (i.e., are folivorous); mountain gorillas have a restricted diet of leaves, roots, and shoots from herbaceous plants (i.e., are herbivorous); spider monkeys, guenons, gibbons, and orangutans feed predominantly on fruit (e.g., are frugivorous); and capuchins, baboons, and chimpanzees include both plants and animals in their diets (i.e., are omnivorous; Fleagle 1999; Strier 2011).

Primates are highly social species, with most individuals living their entire lives in groups. As with other primate adaptations, the nature of those groups differs among species with regard to group size, ratio of adult males to females, mating system, and social structure (Strier 2011). The structure of primate social groupings fall into the following catgories:

• **solitary:** characterized by solitary adults and females with dependent offspring. Adult males have large home ranges that overlap that of several adult females. This type of social grouping is found in mouse lemurs, galagos, and orangutans.
• **monogamous:** a mated pair and their immature offspring. Species that exhibit this social structure are highly arboreal and territorial. Adults have a low tolerance for adults of the same sex and there is little sexual dimorphism. Monogamous primate species include gibbons, siamangs, indris, tarsiers, titis, and owl monkeys.
• **polyandrous:** one adult female, more than one adult male, and their immature offspring. This structure is rare among primates and is most notably observed in marmosets and tamarins, although they exhibit facultative polyandry.
• **polygynous:** characterized by a single adult breeding male, several adult females, and their dependent offspring. Females form the nucleus of the group; a high degree of sexual dimorphism is exhibited. This is the most common type of social structure found in primates. Species exhibiting polygynous social groups include capuchins, guenons, langurs, and gorillas.
• **multimale/multifemale:** several adult males, several adult females, and their immature offspring. Dominance hierarchies and marked competition over access to mates and limited food resources is evident in both males and females. This type of structure is found in some lemur, squirrel monkey, colobus, macaque, and baboon species.
• **fission-fusion:** group size and composition change throughout the year with varying environmental fluctuations (fruiting seasons) and reproductive cycles (females in estrus). Individuals enter and leave communities from time to time, as is the case in spider monkeys and chimpanzees.

Many primate social behaviors have evolved to facilitate group living. Affiliative behaviors, such as allogrooming— when one individual grooms another of the same species— serve a hygienic purpose but primarily function as social bonding mechanisms. And grooming frequencies among individuals can be used as indicators of an individual's dominance status within the group. Agonistic behaviors, which include patterns of aggressive-submissive interactions and displays, are also commonly exhibited in primate groups. Dominance hierarchies (a hierarchy of ranked status among individuals, maintained by agonistic behaviors) are established among group members and often result in greater access to resources, such as sleeping sites, preferred food items, and mates for those ranked highest. In captive conditions it is important to acknowledge dominance hierarchies within primate groups; the challenge is to respect the hierarchy while ensuring that each individual group member's basic needs are being met.

Primates in Captivity

Primates have a long history of being kept in captivity in some form or another. Illustrations and references to primates appear in literature dating back to the era of exploration and colonization of the African and Asian continents, when primates and other exotic wildlife were often given as gifts to royalty for private menageries. In the late 1800s and early 1900s, zoological parks began acquiring primates for exhibition purposes. However, a lack of understanding of primate dietary and social requirements resulted in a high rate of mortality. Over the ensuing decades, as information from field scientists on primate behavioral ecology emerged, the survival rate of primates in captivity gradually increased, and in 1956 zoos achieved their first captive-born gorilla (Crandall 1964, 167). In the 1960s the fields of psychology and anthropology flourished, and primates featured prominently in studies on language acquisition, beginning with the seminal ape sign language study with the chimpanzee Washoe and subsequently extending to studies with gorillas and bonobos (Gardener *et al.* 1989). Additionally, primates also became the focal species for use in biomedical research, resulting in eight US regional primate research centers being established by the National Institute of Health for studies on human health. Primate collections in zoos also flourished between i960 and 1970, with many different primate species being acquired from the wild for the establishment of zoo collections. Three important legislative regulations affected US captive primate collections: (1) the 1985 Amendment to the US Animal Welfare Act (1966), regulating the treatment of animals in research, exhibition, transport, and by dealers, and requiring a physical environment that "promotes the psychological well-being of primates"; (2) the US Fish and Wildlife Service Endangered Species Act of 1973, which put in place restrictions for the importation of endangered species "to prevent the extinction of endangered species and their habitats," and prohibiting "activities with these protected species unless authorized by a permit from the US Fish and Wildlife Service"; and (3) the Convention on International Trade of Endangered Species of Wild Flora and Fauna (CITES). As a result of increasing regulations on the acquisitions of primates from the wild, regional zoo associations initiated cooperative captive breeding programs to establish sustainable breeding populations of species for zoo collections (1980: AZA Species Survival Plan [SSP]; 1985: EAZA European Endangered Species Programme [EEP]).

The Zoo Environment

Primates are adapted to a natural habitat in which their survival depends upon a complex behavioral repertoire and high levels of vigilance, problem solving, and awareness of social group dynamics. Primate enclosures should be designed to meet the physical, psychological, and behavioral needs of the species. The unique arboreal adaptations of primates make them adept at climbing, leaping, and in some cases swimming; thus adequate containment measures for each species' physical propensities must be considered in any primate enclosure and exhibit design, to prevent an animal's injury or escape.

The main factors that are of primary importance in primate enclosures are the size, in terms of usable space; the containment barrier (glass-fronted, mesh, or moated); the basic design in relation to capture and husbandry methods; and the provision of a complex environment to meet the animal's physical, cognitive, and social needs (Kleiman *et al.* 1996, 2010). Primates will use three-dimensional space; therefore, enclosures should make use of all available space, with its complexity and quality taking precedence over its total size (Wolfensohn and Honess 2005, Hosey *et al.* 2009).

Enclosures should be large enough and contain ample furnishings to provide for the group housing of conspecifics as well as providing the option for temporarily maintaining individuals singly or in subgroups due to medical and/or social situations (McCann *et al.* 2007). Individuals should be able to exhibit normal postural and locomotor patterns and express species-typical behaviors (e.g., exploration, brachiation, foraging, resting, playing, and allogrooming). They should have a secure and suitably complex environment, with food and water easily accessible and adequate opportunities to negotiate diverse social interactions with group members. Attention should be made to the species' size, use of vertical space, and other important species-specific characteristics. Other species-specific characteristics may include perching preferences (arboreal versus terrestrial), sleeping sites (nestboxes versus shelving), foraging devices (group feeders *versus* timed dispensers), and refuge areas (areas within enclosures for safe distances from the public, keepers, and/or other group members). All primates have a vertical flight response when alarmed by an unfamiliar or threatening stimulus. Thus, the vertical dimension of the enclosure is of great importance. The enclosure should be equipped so that individuals are able to retreat above human eye level (Reinhardt and Reinhardt 2000). Furthermore, many primates—particularly

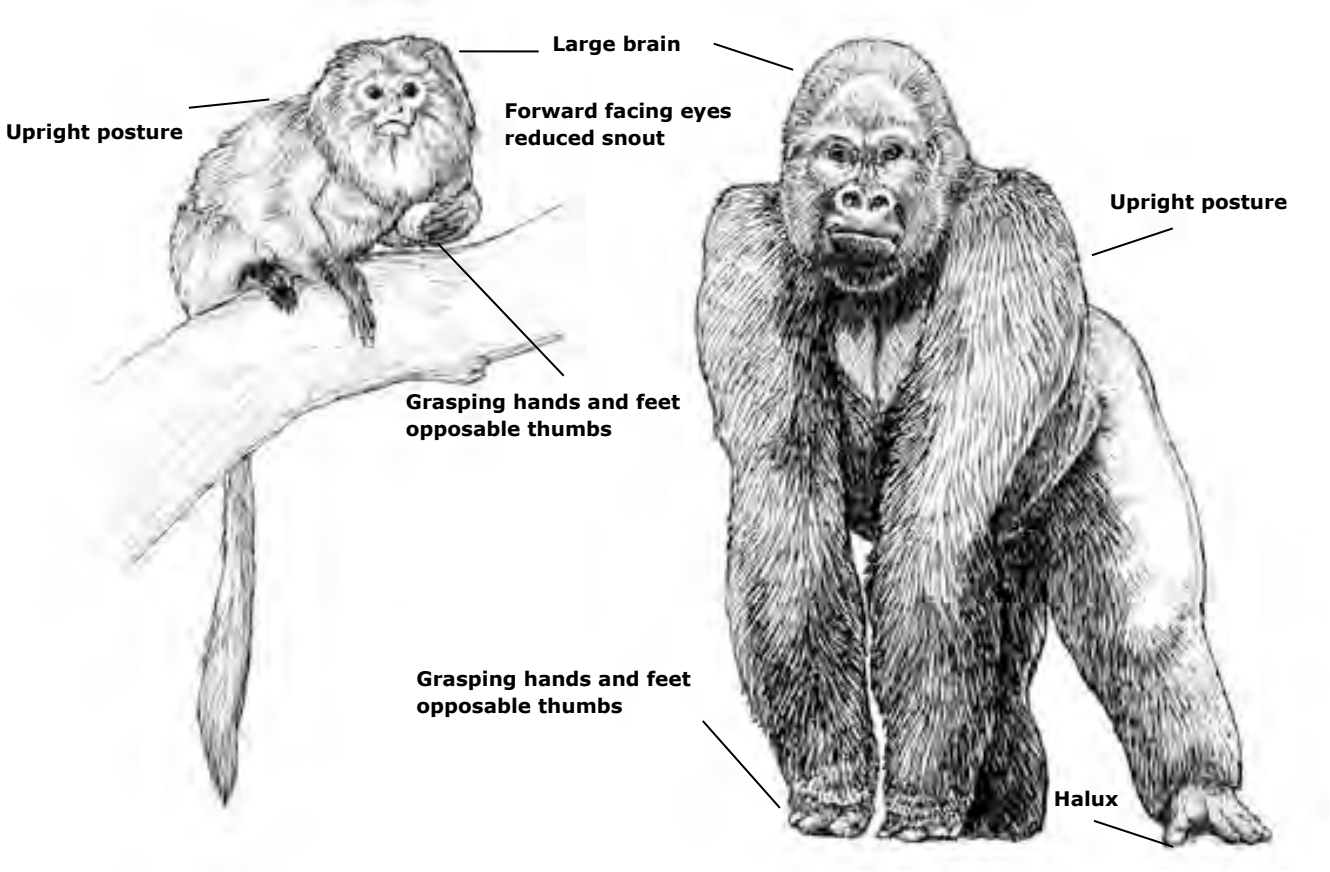

Figure 29.1. Basic anatomical features of primates. Illustrations by Kate Woodle, www.katewoodleillustration.com.

marmosets, tamarins and lorises—prefer the highest available areas and rarely use the lower half of their enclosures. Thus, key resources such as food, nestboxes, and heating sources should be placed high in the enclosure so that individuals can access food and shelter at preferred enclosure heights (Buchanan Smith *et al.* 2002).

Humidity, Ventilation, Temperature and Lighting

The majority of primate species are found in tropical habitats that experience high humidity, and this aspect of their environment should be approximated as closely as possible in captive conditions. Humidity levels can affect the condition of the skin and coat and should be kept at above 50%, although many primate species can tolerate lower levels. Primate enclosures in the United Kingdom and the United States require humidity levels that range between 30% and 70% (Wolfensohn and Honess 2005, 26). Special considerations should be made for young, geriatric, or clinically compromised individuals. Shade structures, shelters, air coolers, and fans can provide relief from high humidity, and misters can be effective for increasing humidity levels where needed.

Indoor primate enclosures should be sufficiently ventilated at all times when animals are present such that odors, drafts, ammonia levels, and moisture condensation are minimized (USDA/APHIS 3.76). Air changes inside housing should be conducted at a rate of 10 to 15 per hour, with at least 10% fresh air in recycled air when outside ambient temperatures are below 13 °C (55 °F) and up to 50% when outside ambient temperatures will not cause a significant decrease in indoor temperatures (AWR 2005; Wolfensohn and Honess 2005, 25).

The majority of primate species should be maintained within temperature ranges of 18 to 28 °C (65 to 82 °F; Wolfensohn and Honess 2005, 24). In some notable exceptions (e.g., *Colobus guereza*, *Macaca fuscata*, *Theropithecus gelada*, *Gorilla beringei beringei*) their geographic range includes temperate forests and/or high altitudes, and therefore they can tolerate lower ambient temperatures. Most species will acclimate to lower temperatures, but should be exposed to them gradually. This could include allowing individuals access to outdoor enclosures only during the warmest times of the day and then gradually increasing the amount of time they are allowed outdoors, or keeping indoor areas at slightly lower temperatures to allow animals to acclimate to colder ambient temperatures outdoors. Primate extremities (tails and digits) are particularly susceptible to cold temperatures. In ambient temperatures that fall below the average range for primates, individuals should have access to heat sources and shelters for protection against wind and rain. There must be enough heat sources so that all the animals have access to them and are not prevented from using them by more dominant individuals. Extreme care should be taken in the placement of heating devices (heat lamps and radiant heaters) to ensure that an individual cannot be burned by touching them. In temperature ranges

above 32 °C (90 °F), cooling mechanisms such as fans and misters should be incorporated; shaded areas should always be available to prevent prolonged exposure to the direct sun, and enough sheltered areas so that dominant animals cannot monopolize them.

Light intensity, duration, and spectral requirements for captive primates should approximate those in the wild (Wolfensohn and Honess 2005, 26-27). Most zoos are in regions of the world that differ from the near-equatorial light cycles of the tropics, and thus natural daylight hours are reduced. For diurnal primates, access to light for 12 hours out of each 24-hour period is recommended. For nocturnal species, a reverse light system should be implemented. Timers can be used to mimic natural light cycles. For indoor enclosures, windows or skylights transparent to full-spectrum ultraviolet (UV) light are recommended *in lieu* of artificial light. It is strongly recommended that primates have access to natural lighting to prevent the developmental problems associated with vitamin D deficiency, such as metabolic bone disease. Although exposure time to direct sunlight need only be for short periods (10 to 15 minutes per day), the benefits for normal developmental growth are paramount.

Substrate and Vegetation

Natural substrates are recommended for primate exhibit enclosures, as they provide a myriad of behavioral opportunities, and more closely approximate substrates the species would encounter in their natural habitat (McCann *et al.* 2007). They also provide a soft surface to protect infants that may fall to the ground as they develop their locomotor skills and learn to navigate through arboreal pathways. For indoor holding enclosures, cemented or sealed floors are the norm for practical sanitation reasons; however, supplemental materials are recommended to provide enhanced foraging opportunities and nesting materials (e.g., hay, wood wool, woodchips, and leaf litter). Traditional tiled and concrete floor enclosures provide a sterile environment for ensuring the clinical health of primates; however, they lack the features needed to meet an individual's psychological health. With appropriate cleaning and husbandry routines, enclosures that are stimulating and complex can meet both important aspects of primate well-being (Wolfensohn and Honess 2005, Hosey *et al.* 2009).

While providing natural vegetation in primate enclosures is recommended, care should be taken in species selection to ensure that the plant species and parts (leaves, fruit, seeds, or flowers) used are not toxic. Most primates will actively forage on live plant material; however, it is a fundamental husbandry practice to provide additional plants as browse in diets for leaf-eating species. Though browse plants provide an important component of a folivorous primates' diet, secondary plant compounds such as tannins and alkaloids may be present within these plants, and depending on the plant and primate species, they may cause digestive problems. Thus, browse species selection should be carefully decided among the veterinary and animal staff. Plants provided in enclosures as browse should be offered in an appropriate and safe manner. Bark and stems from fibrous plant species can cause physical obstructions in the gastrointestinal tract (Janssen 1994; Calle *et al.* 1995). Methods for avoiding ingestion of the stem or bark have included their removal prior to distribution, or the placing of the stems in a protective PVC tube where they cannot be stripped by the animal. Also of concern are ropes of indigestible *acacia* fiber, which have resulted in impaction and subsequent death in langurs offered a diet including acacia leaves (Ensley *et al.* 1982).

Husbandry

Primates should be provided with fresh, uncontaminated water continuously throughout the day, and it must be accessible to all individuals in the enclosure. It can be presented in a variety of ways, depending on the species and features of the enclosure, but the watering devices should be easy to disinfect to minimize the spread of disease. Watering devices can include rubber pans, bottles, or automatic drinkers ("lixits"), and should be checked daily to ensure that they are operational. Automatic waterers should be positioned to run continuously for individuals that have not been exposed to this method previously, until they have learned their operation. In addition to a clean potable water supply, pools or waterfalls in enclosures can be supplementary sources for water when they can be cleaned or filtered daily.

General animal care knowledge and experience is a basic foundation for keepers working with any species, including primates. It is paramount that keepers have a general understanding of primate natural history as well as the unique characteristics of the species under their care (e.g., husbandry requirements for a family group of tamarins will differ from those for nocturnal lorises or a troop of baboons). Additionally, keepers should educate themselves about the special care requirements of primate species that are readily available from studbooks, husbandry manuals, and primate husbandry care guidelines (Wolfensohn and Honess 2005; McCann *et al.* 2007). Primate husbandry care differs from those for other taxa in that special attention must be given to individual needs and the role complex social dynamics play in the management of the species. Thus, primate keepers should be highly observant of individual differences in physical and social needs, and should possess a keen understanding of group dynamics to be able to act appropriately and implement acceptable management techniques to provide the best care for individuals while respecting social complexities.

Primates are highly social; the cohesiveness of groups continually changes with intrinsic events, such as sexual maturation, and extrinsic events, such as the removal of a dominant animal. Thus it is most important for keepers to attain an astute awareness of the compatibility of individuals within groups, such as when a change in social dominance results in heightened aggression among group members. They

should also be flexible and adapt husbandry routines to accommodate the changes in social dynamics that occur when change in dominance relationships result in a change in a certain individual's access to food. Finally, they should have the patience to work with individual animals that may have differences in responsiveness to management routines. Often this may result in an individual animal being reluctant to routinely shift between enclosures due to a change in the social relationships among the other group members. As the primary caregiver of a primate group, a keeper must display appropriate demeanor when working with primates; developing a strong rapport with individual primates will form a foundation for their successful management. It is counterproductive and in some cases harmful for a keeper to become overtly agitated or show frustration in response to a breakdown in a management routine as a result of changes occurring in the primate social group. It is more productive to understand what motivates the incompatibility and find ways to mitigate any negative effects on the individuals' daily care.

It is important to emphasize that managing aggression is one of the most challenging aspects of primate captive care. While it is a natural part of primate social life, aggression within captive groups requires consistent monitoring of group dynamics, an understanding of the root of the aggression and whether it is acute or chronic, and ongoing communication among keepers, animal managers, veterinary staff, and in some cases the species' population manager, to arrive at a plan to manage the social incompatibility. Ultimately, management decisions must balance individual welfare needs, the longterm stability of the group, and the population goals for the species program; and the keeper features prominently in this process as the individuals' primary caregiver.

One of the primary responsibilities of a keeper is to be aware of the health status of the individuals in their care and to be able to detect the external signs of an individual's condition. Assessing the health condition of primates can be determined by the following indicators:

• changes in the quantity and quality of an individual's stool
• rapid weight gain or loss, or chronic deviations from the optimum weight
• coat condition and overall appearance (well groomed *versus* unkempt, with attention to any signs of hair loss)
• changes in food/water intake rates and appetite, excessive salivation, or difficulty in the ability to process food items
• activity level, lethargy, separation from group members, nonresponsiveness, tendency to seek heated areas
• changes in locomotion (gait) or posture, inability to negotiate all accessible areas of the enclosure
• changes in spatial distance from group members and/or lack of participation in daily activities
• self-directed behaviors such as excessive autogrooming or self-mutilation
• stereotypies or repetitive behaviors.

Keepers should know the normal range of physical attributes and social behavior of a species, and of the individuals in their care, so that they can notice deviations that may indicate other underlying processes.

Handling and Restraint

The handling of primates can be greatly facilitated by operant conditioning training. The use of positive reinforcement techniques are preferred as they can decrease stress for individuals. Primates can be reliably trained using positive reinforcement to cooperate with capture and immobilization procedures such as shifting into nests, transfer and/or induction boxes, crates, or squeeze cage systems; stationing on scales; presenting body parts for hand injections or blood sampling; and positioning for veterinary procedures such as ultrasound examinations.

While operant conditioning methods benefit an individual's well-being, traditional capture and restraint methods must also be employed in emergency situations, or when behavioral training is not successful. For small and medium-sized primates, netting is the preferred method of capture. Handling gloves should be used when removing the animal from the net, in addition to a face mask and eye protection. Immobilization drugs can be administered by hand while the individual is in the net, and then the individual can be removed once the drug takes effect. For larger primates, netting is not recommended; shifting the animal into a smaller confined area (e.g., a chute, squeeze, or isolation cage) for hand injection or darting with an immobilization drug is recommended instead. The method of manual restraint to use for a primate varies with the size of the species. Particular caution must be given to the head and arms, to prevent bites and scratches. For basic restraint and handling methods for a variety of species, see Fowler (1995), Bush (1996), and Christman (2010).

Enrichment

Optimal care for primates requires a program that maintains their clinical health as well as their psychological health and well-being (Cipreste *et al.* 2010), and in some regions this is mandated by regulatory agencies. For instance, in 1991 the US Department of Agriculture/Animal and Plant Health Inspection Service (USDA/APHIS) regulations require primate facilities to develop, document, and carry out a species-specific plan for environmental enhancement to promote the psychological well-being of nonhuman primates. Many enrichment opportunities can be used with primates. Primates are highly social beings, and providing them with compatible conspecifics is the most important social enrichment to consider, as it can stimulate the expression of their behavioral repertoire (Young 2003, Hosey *et al.* 2009).

Providing primates with a complex, stimulating environment is key to a successful husbandry program (Young 2003). Enrichment programs should be well planned to provide the appropriate items and frequency of use to make them most effective. Enrichment items should be chosen with care to prevent exposure to hazardous materials or injury, and to stimulate natural behaviors continually. If enrichment items become permanent fixtures in a primate's enclosure, then they rapidly lose their desired effect of stimulating new behaviors. Enrichment activities fall into different categories, based on the behavior patterns they elicit:

• activities that elicit locomotor behaviors (e.g., using ropes, swings, vines, logs, branches, hammocks, or climbing structures), important for exercise and facilitates the full repertoire of locomotor agility
• activities that elicit increased foraging behaviors (e.g., variation in feeding schedules, food delivery systems, and foraging times) to encourage individuals to spend more time searching, locating, and processing food items
• activities that provide novelty and a variety of objects to stimulate cognitive abilities (e.g., barrels, balls, baskets, boxes, puzzles) and enable primates to explore, be challenged by tasks, and solve problems
• activities that enable primates to exercise preferences and some degree of control in a suitably variable environment.

In the wild, primates are faced with a multitude of choices every day. Providing choice-making opportunities in captive environments can enhance this important aspect of their adaptation (Hosey *et al.* 2009).

Training
All primate keepers should be familiar with the basic tenets of operant conditioning training and should use positive reinforcement techniques wherever possible. Routine husbandry often involves moving and positioning animals for cleaning, exhibit maintenance, and veterinary examinations. It has been demonstrated that these procedures can be greatly facilitated by positive reinforcement training (Laule *et al.* 2003). Primates should be trained to reliably shift between enclosures and exhibits, to station on scales for weighing, to enter crates for transfer between areas, to station for physical inspection and the administering of oral medications, to separate from group members for medical procedures, and to present body parts for hand injections. Housing social groups of primates poses additional challenges for behavioral management, and training techniques can also be applied to facilitate the socialization of conspecifics, reduce aggression, and eliminate abnormal or unwanted behaviors (Prescott and Buchanan-Smith 2007). Cooperative feeding is an effective technique for facilitating the compatibility of conspecifics, the introduction of unfamiliar individuals, and managing the dominance effects in a group by training the dominant animal(s) in a group to allow subordinates to safely approach. Training programs require keepers to work in close proximity with animals, so extra safety protocols should be in place to prevent risks to keepers or animals. It is good practice to avoid hand feeding during training sessions, as the risk for injury to hands and fingers is much greater at that time. Many primate trainers drop food items directly into the primates' hands, use a utensil, or offer only food items greater than six inches in length in order to keep their fingers away from the animal's mouths.

Reproduction
Nonhuman primate females are cyclically or seasonally receptive; and this period of receptivity in many species is associated with visual changes of the anogenital region and conspicuous behavioral changes (e.g., presenting, staring, tongue flicking, head shaking), making it evident to a male when females are in estrus (Strier 2011). Outside of this general pattern, there exists a wide range in reproductive parameters across primate taxa. Most lemurs and lorises are characterized as seasonal breeders, with very short mating seasons which typically last from one to three weeks, with females being receptive for only a few days within this period (Campbell *et al.* 2011). The breeding season is correlated with highly seasonal climatic changes and availability of food resources. In captive environments in the Northern Hemisphere, the breeding season occurs at opposite times of the calendar year than those in the Southern Hemisphere due to the influence of environmental factors such as temperature, rainfall, and day length (Wilson and Reeder 2005). In general, reproductive cycles in monkeys and apes can occur continuously throughout the year with few exceptions (e.g., squirrel monkeys, macaques), although birth peaks are characteristic of species that inhabit environments with marked seasonality of rainfall (Campbell *et al.* 2011). Zoo breeding programs (SSP, EEP) make recommendations for pairings of animals and the resulting transfer of individuals among zoos with knowledge of a species' breeding season, in order to facilitate the introduction of individuals before the next breeding season. Additionally, a variety of reversible contraception methods have been successfully used to prevent conception in managed primate populations while maintaining intact groups. Breeding in primates can be associated with heightened agonistic behavior among group members, and keepers must be vigilant to these changes in group dynamics and individual demeanor, as they could result in overt aggression if not carefully managed. Heightened awareness should be applied during daily husbandry routines to facilitate breeding while mitigating any potential aggressive bouts (e.g., disputes over preferred spaces and food items, or difficulties in shifting individuals).

Gestation and Parturition
Relative to their size, gestation lasts considerably longer in primates than in other mammals. It varies from 54 to 68 days in mouse lemurs, from 110 to 133 days in galagos, from 126 to 168 days in diurnal lemurs, from 130 to 155 days in callitrichids, from 135 to 230 days in cebid monkeys, from 166 to 190

days in lorises, from 150 to 210 days in cercopithecine monkeys, and from 210 days in lesser apes to between 230 and 258 days in great apes (Campbell *et al.* 2011). Pregnancy in most primates can be detected by the absence of the visual signs of estrus and a cessation of breeding cycles, or through more direct means such as vaginal cytology, ultrasound examinations, or hormonal assays of reproductive hormones. Pregnant primates should be closely monitored in preparation for parturition. Primates typically give birth among group members, and females should not be separated from their groups unless the management of a particular species requires alternate management strategies to increase infant survival rates in captive conditions. Upon parturition, privacy for the mother and newborn is paramount to allow the appropriate mother-offspring bond to occur. Keepers must display the appropriate demeanor and maintain a safe distance while observing the mother-infant pair closely enough to see any problems that require intervention.

Infant Care

A newborn primate is born fully furred and with eyes open, and with grasping hands and feet that enable them to cling to their mothers (exceptions to this are some species of lemur and loris; Fleagle 1999; Strier 2011). The first three days of an infant's life are critical to its ultimate survival, the most important factor being the mother's ability to appropriately care for it. Keepers must closely monitor the mother's handling of the infant, noting the mother's positioning of the infant and the mother's reaction when the infant roots to locate the nipple, and they must be able to confirm the frequency and duration of nursing bouts. Nursing does not always occur on day one but should be seen by day two, as the infant will otherwise progressively loose strength and be unable to cling to the mother. There is a significant learning component to maternal behavior in primates. Primiparous females should have the opportunity to watch other females in their group care for their infants to obtain this critical knowledge. The importance of the appropriate social environment for the acquisition of maternal skills, as well as the experience of various breeding programs, necessitates that primates should not be hand-reared as a general rule. In extraordinary circumstances (e.g., death of the dam, needs of the population, genetic value of the individual), hand-rearing may be recommended. When an infant must be hand-reared, a plan should be in place to swiftly integrate it into an appropriate social environment. From the comprehensive experience of captive breeding programs in zoos, hand-rearing protocols are well established for the majority of primate species.

Transportation

The transport of primates must follow the International Air Transport Association (IATA) regulations, which should be referred to before any shipping arrangements are made. In some cases, there may be additional requirements imposed by regional regulatory agencies (e.g., the US Fish and Wildlife Service). A primate must be carried in a closed container that is well constructed to secure the animal safely and protect it from unauthorized access through the entire transit process. Crates used for primates can be constructed of plastic, wood, or metal, depending on the size and strength of the species, and should only include nontoxic materials. Small primates can adequately be shipped in wooden crates or appropriate-sized kennel crates with added tamper-proof locks; large primates like great apes should be shipped in metal crates. Meshed ventilation openings must exist along the sides of the crate, and the front door must include a solid panel with ventilation openings in the top third. Muslin or burlap material should cover all ventilation openings. The crate's floor must be solid and leakproof to prevent excreta from leaking from the crate during transit. Primates must be provided with food and water during transit, and depending on the type of crate and length of transit, their food and water containers will vary.

Preparing an individual for transport is critical for its acclimation to a new environment. Primates can be readily trained to voluntarily enter crates and accept hand-injections for immobilization for preshipment examinations, thus reducing the stress involved in these events. Additionally, the transfer of all pertinent information to the receiving institution is a critical role of keepers in any transfer of collection animals between zoos. Primates being moved to a new facility are faced with new surroundings and keeper staff. In some cases, particularly with ape species, keepers can accompany the animals through the transfer to ensure a more successful acclimation to the new environment.

Veterinary Care

The medical management of primates involves clinical practices to protect the animal collection from common zoonoses affecting primate species, to protect the keeper staff that provides their daily care, and to prevent disease transmission. Primates are susceptible to a variety of bacterial, viral, parasitic, and fungal zoonoses that are infectious or contagious, and different diseases have varying degrees of prevalence among certain primate taxa (ILAR 2003; Fowler and Miller 2003). Common primate gastrointestinal bacterial pathogens can include: *Salmonella*, *Shigella*, *Campylobacter*, *Klebsiella*, *Yersinia*, and *Clostridium*. Clinical signs include diarrhea, weight loss, vomiting, and lethargy; treatment is often an antibiotic therapy. Successful administration of oral antibiotics requires individually medicating the affected animal, and this need underscores the importance of operant conditioning training in primate medical management. The best methods for the prevention of bacterial diseases are the implementation of biosecurity measures (footbaths, gloves, face masks) and general cleanliness in food preparation and enclosure disinfection. Perhaps the most commonly known bacterial pathogen of concern in primates is *Mycobacterium* (i.e., tuberculosis or TB). There are many different species of mycobacteria; however, clinical signs may not be detectable and TB testing, radiographs, blood sampling, and cultures may be required for diagnostic confirmation (Fowler and

Miller 2003). Preventative measures require all primates entering a facility to be tested for TB, to prevent introducing individuals infected with *Mycobacterium* into the collection.

Different primate species are known to carry different viruses; and it is important to note that not all viruses cause disease in the host species. Herpes virus, similar to that found in humans, is common in prosimians and callitrichids; and great apes are susceptible to the same viruses as humans. Many viruses are carried by cercopithecine monkeys, including Foamy Virus, Simian Immunodeficiency Virus (SIV), Herpes B, and Herpes B-like virus; these have varied etiologies and clinical signs (e.g., lethargy, respiratory or gastrointestinal infection, and ulcers on the mouth or face; Murphy *et al.* 2006). Most viral diseases are not treatable; preventative measures are the focus instead, and they include knowing the health status of individual primates entering a collection and ensuring best practices in biosecurity.

The potential for the transfer of diseases between humans and nonhuman primates should always be considered a risk factor, and protocols should be in place to prevent zoonotic disease transmission both to and from nonhuman primates (McCann *et al.* 2007). The transmission of disease can be substantially reduced by ensuring good personal hygiene (e.g., frequent sanitization of hands and the use of footbaths between areas housing primates) and management protocols that include personal protective equipment (e.g., face shields, goggles, masks, and gloves). Information on known primate zoonotic diseases and their prevention should be made available to all keepers who work with primates and they should be familiar with preventive measures that are in place to reduce risk factors. Additionally, primate care staff should be screened annually for tuberculosis. It is also recommended that they be vaccinated against tetanus, polio, rabies, measles, and hepatitis. Facilities housing macaque species should have preventive measures in place to protect keepers from the risk of infection by Herpes B virus which may be carried by macaques. The Centers for Disease Control and Prevention (CDC 1987, 1999), the Institute for Laboratory Research (ILAR 1996, 2003) and regional zoological associations can be used as resources for best practices in primate management guidelines.

Specific diseases will manifest in primates at different stages in their lives. Metabolic bone disease often prevails early in the growth process due to insufficient calcium and vitamin D, and presents as poor growth rate and inability to locomote appropriately (commonly described as "bunny hopping"). Treatment can include oral or injectable calcium, appropriate vitamin D levels in the diet, and exposure to full-spectrum light (Wolfensohn and Honess 2005, IPS 2007). Providing young primates the opportunity for exposure to full spectrum light for vitamin D synthesis, for as little as 10 minutes per day, is of critical importance for normal growth processes. At the opposite end of the spectrum in the developmental process are diseases that commonly manifest in aged primates. Of particular concern are degenerative diseases such as arthritis, spondylosis (spinal osteoarthritis), and heart and renal disease.

The last particular concern is sepsis as a result of trauma. The social nature of primates and the management of their group dynamics will often necessitate the clinical management of wounds due to aggression from conspecifics. These wounds can be in the form of lacerations, punctures, or fractures, and clinical signs of sepsis can include lethargy, depression, lameness, anorexia, and drowsiness (somnolence). Keen observation and inspection of individuals for wound sites is basic to prevention, as treatment of sepsis requires early medical intervention with antibiotics.

Keepers play a vital role in the medical management of primates. Their responsibilities include providing a clean, enriched, and safe environment; closely observing the behavior and appetite of individuals; knowing the animal's preference for medical compliance (e.g., form of medications, frequency of dosing, individual administration); and training individuals for voluntary participation in clinical health procedures (e.g., regular weighing, entering of anesthesia induction boxes, and accepting hand injections). In summary, sound primate management strives to prevent disease transmission both to and from nonhuman primates. Cleanliness and biosecurity are the two most important factors in the prevention of infectious and contagious diseases in primate collections. A keeper's observation and communication skills are imperative for identifying illness in an animal and preventing the spread of disease.

Conservation and Research

Primates are humankind's closest biological relatives; humans share 98.4% of their DNA coding with chimpanzees. The majority of primates live in tropical forests, where they play an integral role in ecosystem function as plant pollinators, seed predators, and seed dispersers. Increasing forest fragmentation, human encroachment, and illegal capture of primates for the bush meat and pet trades have resulted in more isolated populations. According to the International Union for the Conservation of Nature (IUCN) Primate Specialist Group (PSG), there are currently 612 recognized species and subspecies of primates (www.iucn.org). Since 2000, 46 new species have been discovered or redescribed, and many more isolated populations have yet to be discovered by scientists (Lehman and Fleagle 2010). Due to their reliance on tropical forests and due to human extraction activities, primates are considered to be amongst the most endangered taxa worldwide, and in most urgent need of conservation measures.

In situ conservation efforts are aimed at mitigating threats to fragile populations and protecting the integrity of the landscapes they inhabit. As the majority of primate species have evolved specialized dietary and habitat preferences, the destruction of their forests and the depletion of key plant species

Table 29.2. A sample of primate societies across various regions of the world

American Society of Primatologists
Associacjao Portuguesa de Primatologia
Associacion Primatologica Espanola
Associazione Primatologica Italiana
Sociedade Brasileira de Primatologia
Congolese Society of Primatologists
Deutsche Primatologische Gesellschaft
European Federation for Primatology
Groupe detude et de recherche sur les primates de Madagascar
International Primatological Society
Mexican Association of Primatology
Pan African Sanctuary Alliance
Primate Conservation Inc.
Primate Ecology and Genetics Group
Primate Society of Great Britain
Primate Society of Japan
Societe francophone de primatologie
South East Asian Primatological Association

make them exceptionally vulnerable to these unprecedented environmental perturbations. The advancement of our understanding of a species' ecological requirements from primate behavioral ecology studies provides critical information necessary to inform conservation management plans (see Rowe and Meyers 2013 for a comprehensive online database of primates).

Ex situ primate research ranges in topic from a species' basic biological description to assisted reproduction and management techniques. Captive breeding programs at zoos provide an opportunity for describing the life history traits of species that may not be known from studies in the wild; and basic biological parameters provide the foundation for understanding species' unique adaptations (e.g., Beehner and McCann 2008; Villers *et al.* 2008; Shelmidine *et al.* 2009). Managing captive primates requires continued enhancement of husbandry practices, and many research efforts are focused on ways to evaluate and improve current standards (e.g., Stoinski *et al.* 2004; Ballou *et al.* 2010). Research initiatives are often collaborative efforts administered through regional zoological association species programs and local universities. There are many primate organizations whose mission includes scientific research, educational outreach, and conservation of primate species (Table 29.2). Keepers are encouraged to become members of primate organizations and their regional zoological associations to become involved in the broader aims of primate research and conservation.

Summary

The primates are a diverse order, with a wide range of ecological and behavioral adaptations that make the techniques used in their husbandry care equally diverse. Best practices for their management and care can be achieved when key elements of primate natural history are incorporated into daily husbandry routines. The complexity of primate behavior and social structure makes them popular species for zoo exhibition; and it is this aspect of their behavior that presents the most challenges to keepers who are charged with their daily care. The key to becoming a proficient primate keeper is acquiring the observational and technical skills needed to manage the social and clinical health of primates on a daily basis. These include a general knowledge of primate natural history and of each species' ecological adaptations, an understanding of their species-typical behavior and the complexities of their social interactions, and acquisition of the technical skills needed to develop a rapport with individual primates and facilitate operant conditioning training in order to provide optimal care.

Keepers should be encouraged to become members of their regional zoological associations. They should become educated about population management of the species in their care, ongoing research projects relating to primate taxa, educational outreach programs, and ways to contribute to in situ conservation efforts. There are also many primate associations working on various aspects of primate research, education, and conservation in which membership would provide keepers with a means for professional development in the field of primatology.

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