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CHAPTER 10

Husbandry and Management of New World Species: Marmosets and Tamarins

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Animals and natural habitat

Marmosets with the two genera *Cebuella* and *Callithrix*, and tamarins with the two genera *Saguinus* and *Leontopithecus*, plus a fifth genus, *Callimico*, form the primate family of the Callitrichidae. With body weights ranging from 150 g to 850 g, the callitrichid species are the smallest of the simian primates. Eponymous is the occurrence of claws rather than nails on all digits except the big toe. Marmosets and tamarins are arboreal day-active animals with typical characteristics of New World Primates (NWP). Their broad, flat nose with big nostrils is separated by a wide septum. There is no or only little sexual dimorphism between male and female. They live in groups comprising between two and 30 individuals.

Today most of the callitrichid species are endangered in the wild, mainly by destruction of their natural habitat. All Callitrichidae are listed in CITES (Convention on International Trade in Endangered Species on Wild Fauna and Flora). Appendix I includes the highly threatened species, *Callithrix jacchus aurita* and *flaviceps, Saguinus bicolor, leucopus* and *oedipus, Leonthopithecus rosalia, chrysomelas, chrysophygus, caissara* and *Callimico goeldi.* All other callitrichid species are listed in Appendix II.

Good reviews to obtain some information about biology, habitat and behaviour from the field are provided by Coimbra-Filho and Mittermeier (1981),

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as well as Rylands *et al.* (1993). Hershkovitz (1977) covers all aspects of biology in Callitrichidae. Selected topics can also be found in Kleiman (1978) and Rothe *et al.* (1978).

Husbandry and housing

Species

The callitrichid species that are mainly kept in laboratories are the common marmoset (*Callithrix jacchus*), the saddle-back tamarin (*Saguinus fuscicollis*), the moustached tamarin (*Saguinus mystax*) and the cotton-top tamarin (*Saguinus oedipus*). Individuals of these four species are shown in Figure 10.1.

Housing

Like other primates, Callitrichidae should be housed in social groups, either as pairs, family or peer groups. If animals have to be single-housed for experimental reasons, they should have at least visual and olfactory contact to a compatible animal.

Depending on the size of the group, callithrichids are usually kept in cages or rooms. Cages might cover a part of the room or are more limited in size. In general, cages should be built and placed in a way that monkeys can go up or escape above human eye level. The cages should use the full measure of available height rather than width.

Cages are usually made from stainless steel or wire on a wooden frame. Whilst steel cages are more resistant to regular cleaning, they are heavy to move around. Wire on a wooden frame has to be rebuilt often due to frequent cleaning and gnawing and gouging by the animals. Cage walls should be made from meshwire, instead of being solid, to allow animals to use them for climbing. The meshwire should not exceed a measure of 15 × 15 mm since very young babies might crawl out of, or get stuck in, the mesh. The cage base should be solid and covered with sawdust, woodchips or hay. Animals frequently use the ground to forage for food, and to encounter in social play.

The cage size depends on governmental regulations and has to be adapted to the number of inhabitants. The minimum size for a breeding couple should be 1 m × 1m × 1.5 m high. Each additional animal weaned needs an extra 0.25 m^2. Cages can simply be extended by adding a second cage and removing the side walls or connected by simple walkways.

The minimum equipment of a cage for callitrichids consists of a nest or sleeping-box, a sitting shelf, various branches of different size and, on different levels, a water bottle and a feeding bowl. Nest-boxes can either be made of metal or wood. Whilst metal is better for regular cleaning it needs holes for ventilation. Nest-boxes made out of wood are advisable as they absorb the moisture better. The nest-box should be placed higher in the cage than natural sleeping sites. It also has to be large enough to allow all animals of the group to sleep in it. If animals need to be caught regularly, it is worth using nest-boxes that can be closed by a sliding door in order to catch them inside. If possible, cages should have a maximum of furnishing that accommodates callitrichid locomotion and behaviour. Branches have to be placed in both horizontal and vertical lanes and can be either fixed or swinging. Runways on branches can be connected with ropes or hose pipes. Shelves are usually used for resting, grooming and playing.

Although it is possible to keep callitrichids with access to the outside, they need environmental conditions comparable to their natural habitat. Generally three

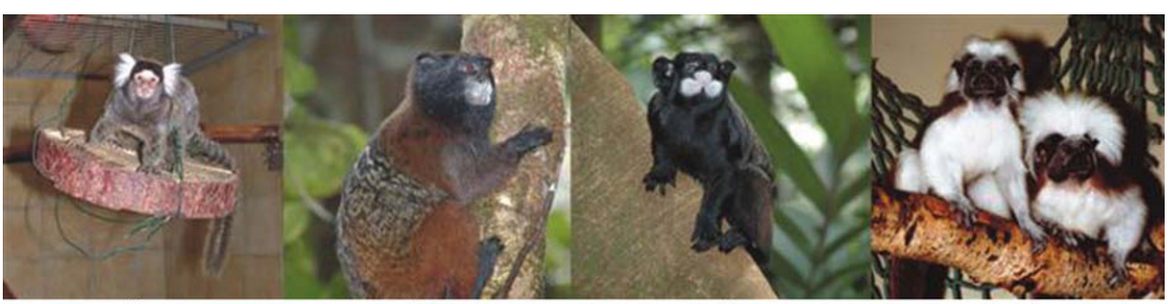

FIGURE 10. 1 Callitrichid species mostly kept as laboratory primates: (a) the common marmoset; (b) the saddle-back tamarin; (c) the moustached tamarin and (d) the cotton-top tamarin.

Figure 10.2 Examples of different housing systems.

factors are important: Temperature: 24°C (25–29); Humidity: 60%; Light: 12 hours light/dark.

Other important factors for callitrichid well-being are smell, noise and view. Since marmosets and tamarins communicate through odour, cleaning should not be so intensive that it removes the family smell of the home cage. Marmosets and tamarins vocalise a lot and it is attractive for them to hear other animals. The monkeys are usually interested in the voices of the personnel and might accept music of low volume. Marmosets and tamarins are nosy and therefore will always try to see as much as they can. Neighbouring groups should be visually separated by foliage, a hanging screen or a curtain, in order to avoid stress. However, single housed animals or young peer groups should be able to see each other.

Handling

Handling of animals is inevitable for quarantine, transport, health checks, routine examinations and experimental procedures. In general, no callitrichid species likes to be handled but can be trained to co-operate by receiving rewards like Nutri-Cal® or marshmallows. As a rule, handling should only be done by skilled persons, in a calm and careful way, to avoid injuries to both animal and handler.

All handling assumes trapping of the animals first. This can be done in several ways depending on cage design and group size. In larger cages and groups, there should be an area which can be used to separate individuals or, as mentioned before, the sleeping box. If there is a passage or corridor that the group has to use, this can also be used for separation of individuals. Animals can also be trained to enter a smaller cage or their sleeping box which will then be closed. Alternatively individuals have to be caught with a net.

Identification of animals

It is necessary to identify animals individually. Microchip, tattoo, chain collar, cutting of hair at the tail or colouring of ear tufts can easily be maintained. Microchips, usually placed under the soft skin in the neck, can get lost by allogrooming or may have to be removed in the case of MRI. Animals have to be restrained for reading both the microchip and the tattoo, since the numbers are not easily visible due to pigmentation of the skin or hair growing. Whilst chain collars have to be checked frequently for the right size, in order to avoid injuries to the animals, cutting or colouring of hair also needs to be repeated on a regular basis.

Feeding and nutrition

General consideration

The nutritional status has a major influence on the growth, reproduction and longevity of nonhuman

primates as well as their ability to resist pathogenic and other environmental stress (Knapka *et al.,* 1995). Due to their small body size, limited gut volume, and rapid rate of food passage (Garber, 1986) callitrichids require a diet high in nutritional quality and available energy. To develop an appropriate diet, the following items should be considered:

- information from feeding in the wild;
- information from published nutrient requirements;
- food available at the facility;
- food preference of animals.

Callitrichids are omnivorous, consuming both insects and plant items such as flowers and fruits. Garber (1992) reported that marmosets spend 30–70% of their feeding time on exudates like gum arabic, with their specially adapted lower anterior dentition and V-shaped mandible. Because of their "long-tusked" dentition, tamarins are called opportunistic exudate eaters which benefit from the bark gouging of marmosets (Ferrari and Martins, 1992). The National Research Council (NRC) recommendations (2003) state that diet of tamarins should consist of 45% insects, 35% fruits, 10% exudates, 7% nectar and 3% seeds, whereas marmosets eat 45% exudates, 16% fruits, 39% insects. Gum arabic provides the marmosets with a source of complex polysaccharides and carbohydrates, certain minerals, especially calcium (Carroll, 1997), and tannin. Trials, in different callitrichid species, with two different diets with or without gum arabic, showed that the addition of gum slowed the gut passage rate in marmosets, without depressing the digestive efficiency (Power and Oftedal, 1996). Marmosets are able to ferment tree exudates with the help of micro-organisms in their bigger cecum (Ferarri and Martins, 1992).

The feeding schedule should be orientated to the activity pattern of Callitrichidae. Active periods occur early in the morning, at noon and during early afternoon. Housing conditions are also known to influence the feeding modus like indoors/outdoors group or single housing. When primates are group housed, it is important to ensure that the lowest ranking individual has sufficient access to food and water. Food should be offered in feeding bowls well above floor level. In larger groups several bowls should be offered. Feeding bowls and water bottles have to be cleaned every day.

Pellets represent a combination of all essential nutritive compounds. They are best fed *ad libitum* and should add up to 50% of the total diet. Marmosets eat an average of 20–25 g pellets/day. Many facilities moisten the marmoset pellets with milk or juice, feeding this as "porridge" in the morning. Different commercial pellets are available (SSNIFF, SDS, MAZURI, PMI) and are listed for comparison of ingredients in Table 10.1.

A standard feeding regime in many colonies is a high calory vitamin porridge for breakfast, fruits, vegetables, and a protein source for lunch, and probably insects in the afternoon. Varying extras are offered, like cooked rice, noodles, potatoes, rusks, hardboiled eggs, cottage cheese, boiled chicken, cat food, raisins, sunflower seeds, dried figs or dates, peanuts, carob, grasshoppers, mealworms and waxworms during the week. The feeding intervals should be 4.5 to 6.5 hours. It is difficult to determine how much food an individual consumes on average. On a dry matter basis, an active adult animal consumes approximately 5% of its bodyweight per day.

The following is an overview of special nutrient requirements for nonhuman primates (NHP) with emphasis on callitrichid nutrition (NRC, 2003).

Energy, fat and protein

Energy is required to support the basic life functions. The daily energy intake must be sufficient to meet requirements for basal metabolism and activity. The average amount for callitrichids is 3.9 to 4.2 kcal/g diet. Adult cotton-top tamarins consume, on average, 152 kcal/kg LBW and lactating females up to 260 kcal/kg LBW (Kirkwood and Underwood, 1984).

Fat is an important resource for energy and commercial diets contain about 9% of the essential fatty acids. Dry skin and hair loss are evidence of deficiencies of unsaturated fatty acids in the diet. Experimental diets with high saturated fat and cholesterol concentrations lead to arteriosclerosis and a higher incidence of arterial aneurysm (McIntosh *et al.*, 1987).

Observations in the field, and also in the laboratory, have shown that callitrichids have a big demand for high quality proteins with up to 25% originating from an animal source. Flurer and Zucker (1988) fixed the daily protein requirements between 2.4 and 3.47 g/kg LBW. Ausman *et al.* (1986) indicated that soy protein is half as effective as lactalbumin and also reduces the iron resorption. Essential amino acid requirements for nonhuman primates have not been established (NRC, 2003) but, in 1998, Flurer and Zucker reported that arginine and histidine are essential amino acids in adult *Callithrix jacchus*. Pathological findings due to protein deficiencies are alopecia, facial oedema, diarrhoea, fatty liver syndrome and anaemia.

TABLE 10.1: Comparison of different commercial pellets available

Nutrients	Units	Mazuri marmoset pellets	Ssniff marmoset pellets	SDS trio munch
Crude Protein	%	25.40	26.00	23.80
Crude Oil	%	7.50	7.00	5.30
Crude Fibre	%	3.70	2.50	4.90
Ash	%	10.50	6.00	6.30
Calcium	%	2.16	1.00	1.12
Phosphorus	%	1.46	0.70	0.90
Sodium	%	0.33	0.20	0.29
Magnesium	%	0.29	0.20	0.15
Potassium	%	0.81	0.70	0.69
Water	%	10.00		
N.F.E.	%	42.90		49.70
Met. Energy	%	12.30	14.90	12.40
Vitamins				
A	IU/kg diet	30142.00	18000.00	33462.00
D3	IU/kg diet	11640.00	3000.00	11000.00
E	mg/kg diet	105.60	120.00	123.20
B1	mg/kg diet	27.70	18.00	16.70
B2	mg/kg diet	18.20	24.00	13.50
B6	mg/kg diet	14.10	18.00	11.40
B12	mg/kg diet	39.40	100.00	25.00
Biotin	µg/kg diet	398.00	500.00	220.00
Panthotenic Acid	mg/kg diet	37.30	50.00	25.30
Choline	mg/kg diet	1951.00	1600.00	1070.00
Folic Acid	mg/kg diet	10.20	7.00	5.20
Nicotinic Acid	mg/kg diet	92.70	70.00	45.50
K3	mg/kg diet	5.30	6.00	5.58
Inositol	mg/kg diet	1649.00	60.00	1510.00
Ascorbic Acid	mg/kg diet	2966.00	3500.00	400.00
Trace Minerals				
Manganese (mg)	mg/kg diet	85.00	90.00	74.00
Copper (mg)	mg/kg diet	18.00	14.00	12.00
Zinc (mg)	mg/kg diet	71.00	90.00	89.00
Iodine (mg)	mg/kg diet	3.38	2.00	1.05
Iron (mg)	mg/kg diet	358.00	260.00	152.00
Selenium (mg)	mg/kg diet	0.23	0.20	0.25
Cobalt (mg)	mg/kg diet	2.02	2.00	2.02
Fluorine (mg)	mg/kg diet	54.00		13.00
Amino Acids				
Lysine	%	1.43	1.40	1.23
Methionine	%	0.38	0.40	0.53
Phenylalanine	%	1.04	1.30	1.29
Histidine	%	0.57	0.70	0.55

(Continued)

TABLE 10.1 *(Continued)*

Nutrients	Units	Mazuri marmoset pellets	Ssniff marmoset pellets	SDS trio munch
Tryptophan	%	0.22	0.40	0.21
Threonine	%	0.93	1.00	0.83
Isoleucine	%	0.94	1.10	1.00
Leucine	%	1.82	2.00	2.16
Valine	%	1.18	1.20	1.18
Arginine	%	1.70	1.80	1.13
Tyrosine	%	0.73	0.80	0.83
Cystine	%	0.36	0.40	0.26

Carbohydrates and fibre

Carbohydrates provide about 40% of the metabolised energy in the diet. Crude fibre concentrations in commercial diets vary between 2 and 8% but the addition of 5 to 10% is recommended. Clapp and Tardiff (1985) described a diet for marmosets consisting of 4.2 to 10% fibre, while Power and Oftedal (1996) suggested an addition of 16% of total fibre to the diet. An increase in dietary fibre increases faecal volume and the digestive passage through the gastrointestinal tract, thus reducing the time for digestion.

Vitamins and minerals

Supplementation of fat soluble vitamins must be carried out carefully due to their toxicity in higher concentrations. The NRC recommendation for Vitamin A is 10,000 to 15,000 IU/kg diet. Like all other primates, callitrichids are dependent on an external supply of Vitamin C of 15 mg/kg metabolic bodyweight. With the lack of UV B light, callitrichids can only utilise Vitamin D_3 and so the daily requirement for marmosets is 110 IU/100 g LBW and 33 IU/400 g LBW for tamarins (Knapka *et al.*, 1995). In 1997 Power *et al.*

Figure 10. 3 Marmoset food at the German Primate Centre.

collected blood samples from 18 free ranging cotton-top tamarins. The blood values ranged from 25.5 to 120 ng/ml. Juveniles had higher serum concentrations than adults and pregnant females lower than nonpregnant. The high circulating levels of vitamin D metabolites in captive New World primates are hypothesised to be necessary for their health status because of the low binding affinity of their vitamin D receptor. Serum concentrations below 50 ng/ml may indicate suboptimal vitamin D status. Vitamin B_{12} is important for the function of the gastrointestinal cells, bone marrow and nerve cells. To date, there are no reliable data about the daily requirements of callitrichids. Recommendations for other vitamins are: Retinol: 171 g/kg LBW, Vitamin E + Se: 0.1–0.16 mg/kg LBW and Vitamin K: 2 µg/kg LBW.

Quantitative mineral requirements of nonhuman primates are poorly defined (NRC, 2003) but the following minerals are the minimum suggested for inclusion in a primate diet: Calcium: 0.5%, Phosphorus: 0.3 to 0.4%, Potassium: 0.24 to 1.1%, Sodium: 0.25 to 0.65%, Magnesium: 0.08%, Chloride: 0.27 to 0.62%, Iron: 0.018%, Copper: 12–20 mg/kg diet, Iodine: 2.2 mg/kg, Manganese: 70–100 mg/kg, Zinc: 150 mg/kg, Selenium: 0.01–0.02 mg/kg, Chromium: 150 µg/day.

Environmental enrichment

Why and how

In the wild, callitrichids have a huge home range. They live in social groups which can comprise up to 15 family members. They spend about 60% of their day on foraging. In order to compensate for this high activity of the animals in the wild, it is necessary to provide their environment in captivity with some enrichment devices. A starting point for environmental enrichment is to reproduce some of the main features of their natural habitat and to create opportunities for captive animals to develop skills they might need in the wild. Enrichment can be offered through several ways, like food, play or encounters.

Diet and foraging

Food can become more interesting when fruits and vegetables are offered as large pieces. These food items should ideally be distributed throughout the cage, even at places where animals have to find a way to reach it, e.g. in a container with drilled holes or hanging on a chain from the ceiling. Another possibility is to offer live insects, like crickets and mealworms. Vignes *et al.* (1992) described a mealworm feeder as a foraging enrichment device, made out of 500 ml water bottles with holes of 0.5 cm diameter and hung horizontally.

For species of the genera Callithrix and Cebuella, the mode of feeding of gum arabic can be altered to provide environmental enrichment. Gum is usually provided as a powder to be mixed with water, or as crumbles of different sizes, but gum powder, mixed with water to a thick fluid, can also be painted on clean branches and shelves. More recently, Ventura and Buchanan-Smith (2003) introduced artificial gum trees to stimulate the peculiar feeding skills of marmosets, and De Rosa *et al.* (2002) have observed the use of puzzle feeders.

Cage and furnishing

In order to encourage play and explorative behaviour, toys can be provided easily in the form of available laboratory material that will be used and "destroyed" by the monkeys. Paper rolls, cardboard boxes, plastic tubes or wooden blocks represent perfect toys for marmosets. Majolo and Buchanan-Smith (2003) introduced different novel objects for enrichment such as film cases containing a marble, or a cup containing ten small plastic test tubes. A foraging tree was made from PVC pipe cut into sections and connected with T-shaped PVC tubes (Byron, 2001). Toys that are built for cages have to be checked for safety to avoid injuries.

Social environment

Free ranging callitrichids are usually living as monogamous groups, but can also be encountered as polyandrous or multi-male and multi-female groups. If there is a need for single housing, there should at least be the possibility of visual and olfactory contact with other conspecifics. Different sex pairs can be housed together, e.g. with a vasectomised male. Same sex pairs have to be introduced by giving them visual contact first and the new homecage should be the cage of the subordinate animal. Females are more aggressive than males (Scott, L., personal communications) and female-female pairs do not represent natural group compositions and are therefore less stable, with allogrooming being rarely observed (Majolo and Buchanan-Smith, 2003).

For further information on environmental enrichment see Heath and Libretto (1993), Kitchen and Martin (1996), Poole (1990) and Schoenfeld (1989).

Breeding

Basic information on reproductive biology

Reproduction in callitrichids is characterised by several peculiarities: females show ovarian cycles all year round with a high rate of fecundity, males copulate throughout the cycle and, even during pregnancy, with a higher frequency around the time of ovulation (Kendrick and Dixson, 1983). Callitrichids are the only simian primates with multiple ovulation. Births usually comprise twins, but increasingly triplets or even quadruplets in captivity. Shortly after birth, and despite lactation, callitrichids ovulate (8 to 18 days post-partum) and can conceive again. In cotton-top tamarins, Ziegler *et al.* (1987) determined different post-partum ovulation periods depending on litter size: 27.3 ± 1 days after the birth of twins and only 16 ± 0.75 days after giving birth to a singleton. Information on the length of the ovarian cycle and pregnancy, as well as the time of occurence of post-partum ovulation, is given in Table 10.2.

Another characteristic of callitrichids is the inhibition of reproduction in sub-dominant females. A group usually consists of only one breeding pair. The presence of a dominant female (normally the mother) prevents lower ranking females (the daughters) from reproducing. However, when an unrelated animal is introduced to a group, polygyny or polyandry are increasingly observed. In the common marmoset, up to 50% of daughters can ovulate while living in their natal family, but sexual behaviour with the fathers does not occur (Abbott, 1994; Hubrecht, 1989; Saltzmann *et al.*, 1997). In cotton-top tamarins, none of the daughters ovulates in the presence of the mother (French *et al.,* 1984; Tardif, 1984; Ziegler *et al.*, 1987).

Pregnancy and birth

Pregnancy can be detected by abdominal palpation, ultrasonography with a 7.5–10 MHz probe (Jaquish *et al.*, 1995) or by measuring hormones (e.g. progesterone) in urine, faeces or blood (Harlow *et al.*, 1984). Implantation of the early embryos is superficial. The placenta consists of two discoid parts connected by vascular anastomosese (*Placenta bidiscoidalis*) and is permeable to antibodies (*Placenta haemochorialis*). Thus twins are immunological blood chimers. At conception the litter may comprise a higher number than will be born, since marmosets are capable of resorbing individual embryos without disturbance of the development of the others (Jaquish *et al.*, 1995). Resorption can only occur until the end of the embryonic period. Death of the foetus in later gestation stages might either cause abortion of the whole litter or mummification of the dead foetus.

Birth usually takes place at night. Observations in multiparous females show that the delivery occurs almost always at the same time (Layne, D., personal communications). If the female shows signs of labour during the day something is usually wrong and veterinary examination necessary and a probable caesarian indicated.

Methods for monitoring the reproductive status

For many experimental studies, and also colony management, it is important to know about the reproductive status of the females. Monitoring can be performed using invasive and non-invasive methods.

TABLE 10.2: Reproductive data of callitrichid species kept in laboratories

	Callithrix jacchus	Saguinus fuscicollis	Saguinus oedipus
Cycle length (days)	28	26	21
Gestation period (days)	140–145	150–155	180–185
Post-partum ovulation (days)	10	17–18	17–18

Hormone measurements in blood, urine or faeces are indirect methods since hormone values reflect the function of the reproductive organs. Ultrasonography provides direct results through an immediate view of the ovaries and uterus (Tarantal and Hendrickx, 1988). To determine the time of ovulation, all sample collection for hormone analysis, needs to be performed at least twice, but preferably three times, a week.

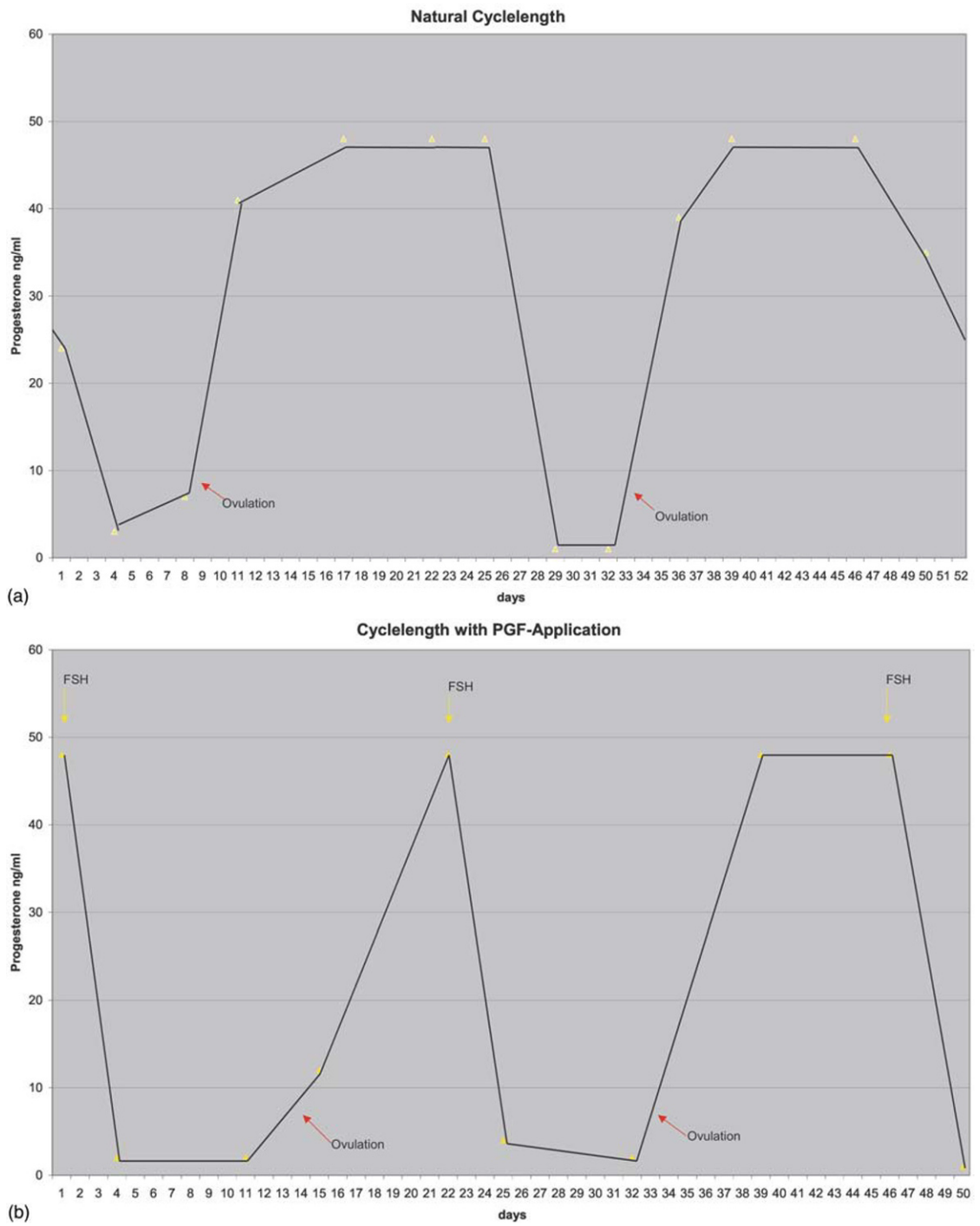

Figure 10. 4a,b Progesterone profile of a common marmoset with natural cycle and with $PGF_{2\alpha}$-application.

Breeding management and raising of offspring

New pairs should only be made up of fully grown animals in good condition, not younger than 24 months. In immature females, pregnancy may restrict normal growth and very young mothers more often fail to rear their first offspring. It is advisable to place the new pair away from their natal groups in order to prevent stress and the suppression of ovarian cycles by the mother.

Infants are carried by all members of the family, but participation varies between the different species. This co-operative rearing system is important for the breeding success of the offspring. Hearn and Burden (1979) developed a rotation system of collaborative rearing of marmoset triplets without depriving them of the maternal and family influence. If available, a foster mother can also raise the new-borns, after marking the babies with urine of the new mother prior to presentation. Infants start to eat solid food from week 3–4, stealing the food from the mouths of family members. At the age of 90 days, infants are completely weaned. Twin fights can be observed with a higher incidence at the age of eight months. Offspring should be removed from their family at the age of eighteen months.

Irreversible control of fertility can be performed by sterilisation or castration of the male or female. Pregnancy can be prevented by injecting the female with Prostaglandin $F_{2\alpha}$ every three weeks or implanting melengestrol-acetate between the shoulder blades. This MGA implant can last for two years (Moehle *et al.*, 1999).

TABLE 10.3: Physiological data of common marmoset and cotton-top tamarin

		Common marmoset	Cotton-top tamarin
Bodyweight	g	350–450	550–650
Sexual maturity	months	24	24
Estrus lengths	days	28	21
Gestation period	days	144	180–185
Post-partum ovulation	days	10	17–18
Birthweight	g	26–32	40–45
Weaning age	days	60–90	60–90
Life span	years	13	15
Body temperature	Celsius	36.8–38.6	39.3–40.1
AF	/min		
HF	/min	194–242	
Daily pellets intake	g	20	25
Urine/24 hours	ml	16.99	

Source: Fortman *et al.* (2002); Savage (1995).

Physiological data

Body mass differs significantly between species. Marmosets are the smallest of these four laboratory species, weighing between 350 and 400 g, and moustached tamarins are the largest, weighing between 650 and 700 g. In comparison to free ranging animals, those in captivity are up to 20% bigger (Kingston, 1969).

Haematological and blood chemistry data

Many New World Primates are trained to allow routine blood sampling without anaesthesia. Some values like AST, LDH and CK are elevated after Ketamine application. The following gives an overview of blood chemistry values of different callitrichid species.

Experimental procedures

Urine and faeces can best be collected early in the morning when the light is switched on. A container or a mat can be placed under the cage where the sample will be collected. Anzenberger and Gossweiler (1993) described a procedure where animals are trained to go into a small compartment of the cage and pee for a reward. Hearn (1975) collected 24-hour urine samples from marmosets, measuring 3–47 ml (16.99 ml). Faeces samples can be coloured by feeding nutrient colour. If urine or faeces have to be sampled for 24 hours, animals have to be single housed in a metabolism cage for this period.

Intramuscular injections, of no more than 0.2 ml, can be given into the quadriceps muscle. Subcutaneous injections are ideally introduced under the skin of the dorsum, with a maximum volume of 2 ml on each side. The average blood volume of animals is 7–8% of the bodyweight and a maximum of 10% of the blood volume can be taken in 14 days (0.7 ml/100 g LBW) without expecting health problems. If more is required, up to 15% fluid has to be substituted. Blood samples

TABLE 10.4: Normative haematological values of marmosets and tamarins

		Common marmoset	Cotton-top tamarin	Moustached tamarin	Saddle-back tamarin
WBC	x 1000/Ul	6.1 ± 2.2	11.2 ± 5.2	12.3 ± 2.8	8.7 ± 4.06
RBC	x 1000000/Ul	5.6 ± 0.78	6.3 ± 0.61	6.06 ± 0.65	5.39 ± 1.02
HGB	mg/dl	15.0 ± 1.4	15.9 ± 1.7	14.3 ± 1.9	14 ± 2.5
HCT	%	44.6 ± 7.1	47.9 ± 5	48.2 ± 6.5	44.4 ± 6.6
MCH	mg/dl	25.8 ± 2.7	25.4 ± 1.5	24.2 ± 0.7	26.4 ± 3.3
MCHC	g/dl	34.2 ± 4.5	33.1 ± 2.3	30.1 ± 2.6	33.1 ± 3.9
MCV	fl	74.3 ± 10.9	76.3 ± 5.4	78.2 ± 5.7	78.9 ± 7.6
SEGS	x 1000/Ul	3.2 ± 1.5	7.03 ± 4.5	5.1 ± 1.8	8.2 ± 4.5
BANDS	x 1000/Ul	0.17 ± 0.08	0.33 ± 1.7	0.08 ± 0.01	
Lymphocytes	x 1000/Ul	3.0 ± 1.6	3.3 ± 1.7	6.4 ± 2.5	1.9 ± 0.92
Monocytes	x 1000/Ul	0.25 ± 0.18	0.54 ± 0.44	0.85 ± 0.52	0.3 ± 0.12
Eosinophils	x 1000/Ul	0.23 ± 0.14	0.21 ± 0.17	0.39 ± 0.26	0.28 ± 0.17
Basophils	x 1000/Ul	0.16 ± 0.15	0.1 ± 0.06	0.22 ± 0.2	0.18 ± 0.08
NRBC	/100 WBC	3.0 ± 2.0	1.0 ± 1	3.0 ± 2	9 ± 19
Platelets	x 1000/Ul	609 ± 200	361 ± 74	840 ± 142	546 ± 113

Source: Abou-Madi (1999); Fortman *et al.* (2002); Savage (1995).

can be taken from alert animals from the femoral or lateral tail vein with a 1–2 ml syringe and a 25–26 gauge needle.

Hearn (1977) developed a restraining device to allow a single person to carry out routine procedures. Intravenous injections or fluid administration can be given into the Vena saphena, V. cephalica or V. coccygea, using a 24–26 gauge catheter. If the animal's veins are collapsed, fluid can be given intraosseally, directly into the bone-marrow of the tibia or femur, using a 20 G disposable intraosseus infusion needle with a T-handle. This needle can also be used to collect bone marrow from the trochanteric fossa, iliac crest or proximal humerus. Vascular access ports can also be implanted into marmosets to deliver compounds intravenously, e.g. the V. femoralis (Dalton, 1985).

Oral gavage can easily be maintained. Semen can be collected by penile stimulation (Kuederling *et al.*, 2000) or electroejaculation (Cui *et al.,* 1991). Osmotic pumps can be placed subcutaneously between the shoulder blades, or intraperitoneally (Fortman *et al.*, 2002) to deliver drugs continuously for up to four weeks without restraining animals. Geretschläger *et al.* (1987) described a method to collect cerebrospinal fluid from anaesthetised marmosets with a 25 gauge scalp vein set, Venofix®, and a 1 ml syringe, collecting 0.1 ml per puncture from the cisterna magna.

Veterinary care

Health management

Health checks should be made by care takers during feeding schedules, once or, preferably, twice daily, but it should definitely be the first duty, in the morning, to see if an animal is down, in labour or healthy. Observations should be made of behaviour and general condition of the animals, such as appetite, attentiveness, locomotion, bodyweight, coat quality, faecal quality, stress between group members and how the animals go to the food, which might be quite difficult in larger groups. If necessary, the veterinarian should be consulted to decide if the animal requires a proper physical examination, including body temperature, rectal and vaginal swab, faecal sample, blood sample, palpation of the abdomen, auscultation of heart and

TABLE 10.5: Normative blood chemistry values of marmosets and tamarins

		Common marmoset	Cotton-top tamarin	Moustached tamarin	Saddle-back tamarin
Glucose	mg/dl	177 ± 65	179 ± 82	117 ± 63	173 ± 66
BUN	mg/dl	19 + 5	15 ± 8	13 ± 5	14 ± 5
Creatinine	mg/dl	0.7 ± 0.2	0.7 ± 0.3	0.7 ± 0.4	0.5 ± 0.2
Uric Acid	mg/dl	0.5 ± 0.2	1.0 ± 0.7		0.8 ± 0.1
Calcium	mg/dl	9.5 ± 1.1	8.9 ± 0.9	8.7 ± 1.2	8.9 ± 0.9
Phosporus	mg/dl	5.3 ± 1.9	4.8 ± 1.5	8.0 ± 3.0	5.2 ± 1.1
Sodium	mEq/l	147 ± 8	150 ± 8	154 ± 7	154 ± 1
Potassium	mEq/l	4.9 ± 2.6	4.0 ± 0.8	4.9 ± 1.6	3.4 ± 0.7
Chloride	mEq/l	103 ± 11	104 ± 8	104 ± 8	110 ± 1
Iron	mg/dl	129 ± 1	127 ± 73		
Magnesium	mg/dl		2.4 ± 0		
Cholesterol	mg/dl	176 ± 73	121 ± 42	106 ± 79	65 ± 12
Triglyceride	mg/dl	160 ± 43	69 ± 32		80 ± 0
Total Proteins	mg/dl	6.8 ± 1.0	6.6 ± 0.7	6.5 ± 0.7	7.5 ± 1.0
Albumin	mg/dl	5.1 ± 0.6	3.8 ± 0.5	3.5 ± 1.0	4.2 ± 0.2
Globulin	mg/dl	1.7 ± 0.5	2.8 ± 0.5	2.3 ± 1.3	2.5 ± 0.1
AST	I.U./l	112 ± 112	157 ± 56	56 ± 85	491 ± 892
ALT	I.U./l	13 ± 24	38 ± 41	7 ± 14	26 ± 32
GGT	I.U./l		21 ± 21		
Total Bilirubin	mg/dl	0.2 ± 0.3	0.2 ± 0.2	0.1 ± 0.1	0.3 ± 0.4
Direct Bilirubin	mg/dl	0.0 ± 0.0	0.0 ± 0.1		
Indir. Bilirubin	mg/dl	0.1 ± 0.0	0.2 ± 0.1		
Amylase	µg/l	337–1523	575 ± 400	496 ± 0	
alk. Phosphatase	I.U./l	125 ± 64	184 ± 110	358 ± 341	129 ± 68
LDH	I.U./l	551 ± 429	460 ± 319	594 ± 326	390 ± 226
CK	I.U./l	543 ± 0	645 ± 706		
Lipase	I.U./l		40 ± 16		
CO2	mMol/l		18.1 ± 8.3	24 ± 0	11.7 ± 3.5
Cortisol	µg/dl		570 ± 0		

Source: Abou-Madi (1999); Fortman *et al.* (2002); Savage (1995).

lungs, ultrasound and x-ray if indicated. Sick animals should be kept warm (e.g. heating lamp or pad) and, if necessary, the individual should be isolated from its group for intensive care.

Anaesthesia

Drug of choice for mild anaesthesia is Ketamine (50 mg/kg), with a maximum of 25 mg/animal because of its myotoxicity (Davy *et al.*, 1987). Saffan® is also very safe (12–18 mg/kg). For longer surgery, a combination of Saffan (18 mg/kg) and Valium® (0.25 mg/animal) is reliable in common marmosets, and Ketamine (25 mg/kg) + Midazolam (25 mg/kg) for cotton-top tamarins. The combinations, with an inhalation narcotic (e.g. Isoflurane) for longer lasting surgery is very effective either with a modified tubus (2.0 mm) or a face mask.

Quarantine

Most imported animals arrive in a stressed condition, dehydrated and underfed and should therefore be rested (Deinhardt, 1967). Quarantine duration depends on national regulations but should be a minimum

TABLE 10.6: Drugs recommended for Callitrichidae

Drug	Dosage mg/kg	Application Route	
Analgetics			
Aspirin	20	PO	TID
Flunixin	10	IM	SID
Buprenorphine	0.01	IM/IV	TID
Oxymorphone	0.075	IM/IV	TID
Antibiotics			
Amikacin	2.5	IM	SID
Amoxicillin	10	IM	SID/QOD
Ampicillin	5	PO/IM	BID
Cefazolin	25	IM	BID
Cefotaxime	75–100	IM	TID
Chloramphenicol	25–50	IM/PO	BID
Clindamycin	11	PO	SID
Doxycycline	8	PO	SID
Enrofloxacin	2.5–5	PO	SID
Erythromycin	40–75	IM/PO	BID
Gentamycin	2	IM	BID
Kanamycin	7.5	IM	BID
Neomycin	10	PO	SID
Oxytetracycline	10	IM	QOD
Trimethoprim/ Sulfadiazine	12	IM	QOD
Antimycotic			
Amphotericin B	0.25–1.0	IV	SID
Griseofulvin	20	PO	SID
Ketoconazol	20–30	PO	TID
Antiparasitic			
Albendazol	25	PO	SID
Fenbedazol	50	PO	SID
Ivermectin	0.2	IM/PO	SID
Metronidazol	35–50	PO	BID
Paramomycine	50	PO	BID
Miscellaneous			
Dexamethasone	0.25–1.0	IV/IM/PO	SID
Furosemide	2	IV/IM/PO	BID
Kaolin	0.5–1.0 ml	PO	SID
Oxytocin	1–2 IU	IV/IM	SID
Prednisolone	10	IV	SID
Baypamune		SC	QOD
Atropine	0.05	IV	
Epinephrine	0.2–0.4	IV	

of 30 days. Animals should be totally isolated from the rest of the colony. Two days after arrival, each animal should undergo a general health examination including a tuberculin-test. This examination is repeated at the end of the quarantine period, and can be done either with alert or anaesthetised animals, depending on the animal.

Diseases

Only a short overview can be given about the most common diseases in callitrichids, and for further details see Bennett *et al.* (1995, 1998), Potkay (1992) and Savage (1995). The occurrence of diseases can differ a lot with different housing conditions, and whether animals are imported from the wild or bred in a laboratory, housed outdoors/indoors or behind a barrier system with restricted access of personnel.

Viral diseases

Herpes simplex or hominis can be transmitted to all callitrichids from humans with an active Herpes infection, e.g. via saliva. It produces severe ulceration in the facial area, oral cavity and oesophagus and can lead to death within 48 hours with an incubation period of seven days. Many facilities therefore recommend that people with cold sores should not work with the animals. The reservoir host for Herpes tamarinus is the Squirrel monkey. It is transmitted via saliva, bite wounds, capture nets and gloves. After an incubation period of 7–10 days, the animals develop multiple ulcerations of lips, eyes and oesophagus and nasal discharge, apathy and anorexia, death occurring from between 2 and 3 days. Callitrichids and cebids should therefore not be housed together (King, 1967). Herpes saguinus was described by Melendez (1971) as not leading to clinical symptoms. Cytomegalovirus (CMV), which occurs very often as a latent infection in Old World Primates (OWP), seems not to be relevant in marmosets, and has been isolated from the salivary gland of tamarins without clinical symptoms (Nigida *et al.*, 1979). Herpes saimiri is latent in Squirrel monkeys without symptoms but leads to malignant lymphomas in callitrichids and Old World Primates. Herpes ateles is also known to produce lymphomas. Inoculation with Varicella zoster evokes delayed antibody titres but no clinical symptoms. Epstein-Barr-Virus is an established animal model in callitrichids but it does not occur naturally. Ramer *et al.* (2000) described a syndrome of weight

loss, loss of appetite, diarrhoea and palpable abdominal mass with grossly large mesenteric lymph nodes. Cho *et al.* (2001) isolated, from these spontaneous B cell lymphomas, an EBV related Lymphocryptovirus called CalHV-3. It is the third Herpes virus isolated in Callitrichidae.

Monkeypox is a zoonosis, transmitted through direct contact with lesions on the skin and mucosa of the oral cavity. Smallpox, vaccinia and monkeypox infection can be fatal diseases in marmosets characterised by cutaneus erythemateous papules on the tail, hands and feet, anogenital region and abdomen. They are also associated with weight loss (Gough *et al.,* 1982), and can even be lethal.

The role in gastroenteritis of Rotavirus, which occurs more often in captivity than in the wild, has not been verified (Kalter, 1982). Mansfield *et al.* (2001) and Thomson and Scheffler (1996), isolated Coronavirus from animals with watery diarrhoea and an acute *Escherichia coli* infection.

Para-influenza Virus Type I produces symptoms from nasal discharge to pulmonary lesions whereas Type II and III have been isolated from cotton-top tamarins without symptoms (Murphy *et al.,* 1972). Paramyxovirus saguinus, in combination with gastroenterocolitis and a high mortality rate, in cotton-top tamarins have been described. Clinical symptoms include apathy, kachexie, diarrhoea and death within 24 hours.

Spread as an aerosol, measles is a very contagious disease with high morbidity and mortality up to 95%. This Morbillivirus infection starts with swollen eyelids, fever, nasal discharge, facial oedema and exanthema, ending up with interstitial pneumonia. Secondary complications include septicaemia, abortion, metritis, severe dysentery and disseminated intravascular coagulopathy. Human measles vaccine and gamma globulin can be used prophylactically.

Christe *et al.* (2002) immunised juvenile rhesus monkeys successfully with a canine distemper vaccine. The incubation period for Hepatitis A Virus, a picornavirus, is 30–40 days but animals do not develop clinical symptoms. It is of more importance as an anthropozoonosis, transmitted via urine or faeces, and personnel should be vaccinated. Callitrichid Hepatitis Virus (CHV), transmitted by mice, is closely related to the murine Lymphocytic Choriomeningitis Virus (LCMV). Clinical findings are anorexia, lethargy and dyspnoea and levels of aspartate aminotransferase, alkaline phosphatase and bilirubin are elevated. Outbreaks in different colonies have shown that it is connected with a high incidence of morbidity and mortality (Asper *et al.,* 2001; Montali *et al.,* 1993).

Bacterial diseases

Bordetella bronchiseptica causes death in juvenile marmosets and tamarins and clinical symptoms are mucopurulent nasal discharge, fever and pneumonia. Antibiotic treatment with Doxycycline works well. Vaccination is indicated if there is a manifest infection in the colony (Brack *et al.,* 1997). Campylobacter spp. is one of the most frequently isolated organisms from NHP with diarrhoea, or even from asymptomatic animals. Campylobacter jejuni is a cause of diarrhoea and enterocolitis in tamarins (Paul-Murphy, 1993) producing yellowish, soft mucoid faeces that can also contain occult blood. Faecal-oral route is the primary mode of transmission. It is of higher prevalence in wild caught animals and is a sign of poor hygiene in captivity (Gozalo *et al.,* 1991). Erythromycin is the antibiotic of choice (Johnson *et al.,* 2001). Brack *et al.* (1998) reported cases of Erysipelothrix insidiosa septicaemia in red bellied tamarins and common marmosets. Pathological lesions were gastrointestinal haemorrhages, hepatitis and myocarditis. A vaccination with porcine Erysipelothrix insisdiosa vaccine terminated the infection. Pathogenic strains of Escherichia coli are an important cause of diarrhoea although not well documented as a cause of diarrhoea in NHP. The enteropathogenic (EPEC) strain induces watery, non inflammatory, non bloody diarrhoea while the EHEC (enterohaemorrhagic) strain induces life-threatening haemorrhagic diarrhoea due to the production of a shiga-like toxin, associated with anaemia and neutrophilic leucocytosis (Thomson and Scheffler, 1996). Animals become anorexic, inactive, lethargic and develop a recognised clinical dehydration (Mansfield *et al.,* 2001). Treatments are Enrofloxacine and supportive fluids.

Klebsiella pneumoniae is an opportunistic pathogen that is very common in callitrichids, leading either to sudden death, without prior clinical signs, or pneumonia, septicaemia, peritonitis, lymph node abscessation and enteritis (Berendt *et al.,* 1978). The strains can quickly develop multi drug resistance due to plasmid-transfer.

Bronchopneumonia can be related to a Pseudomonas aeruginosa infection, with associated conditions including endocarditis, myocarditis, empyema and septicaemia (Deinhardt, 1967).

Salmonella spp. can be manifested as gastroenteritis with watery diarrhoea, anorexia and fever with severe dehydration. Transmission is via the faecal–oral route or contaminated food and rodents or insects can also be vectors (Savage, 1995).

Shigellosis doesn't seem to play such as an important role in New World Primates as it does in Old World Primates, but Potkay (1992) mentioned Shigellosisas as an important pathogen in callitrichids, seen in concurrent infections with Salmonella.

In comparison to Old World Primates, New World Primates are not very sensitive to infections with Mycobacterium tuberculosis. Michel and Huchzermeyer (1998) described a case of an anthropozoonosis in a common marmoset, kept as a pet in South Africa, with loss of condition and palpable mass in the abdomen, identified as an abscessed mesenteric lymph node.

Yersinia pseudotuberculosis is of great importance in facilities with outdoor housing. This enterobacterium is spread by rodents. Infected animals develop diarrhoea, ulcerative enterocolitis and mesenteric lymphadenitis, associated with hepatosplenic necrosis (McClure *et al.,* 1986). A polyvalent vaccine should be administered in colonies at higher risk.

Parasitic diseases

The Acanthocephalan Prosthenorchis elegans penetrates into the wall of small and large intestines, mainly the lower ileum and caecum as far as the serosa, resulting in ulceration, necrosis, perforation and peritonitis. Trichospirura leptostoma is a spiroid nematode that inhabits the pancreatic duct of common marmosets. Animals with high parasitosis have moderate to severe fibrosis in the pancreas (Hawkins *et al.,* 1997). Clinical symptoms are weight loss and increased faecal volume. 50 mg/kg Fenbendazol SID for 14 days is the most effective treatment.

Severe pterigodermatitis (Rictularia nycticebus) is manifested by diarrhoea, weakness, hypoproteinaemia and anaemia. This spiroid is attached to the small intestines and may be treated with Mebendazol or Ivermectine. Cockroaches are the reservoir hosts and should be eliminated (Potkay, 1992).

Giardia lamblia is a flagellate protozoan found world-wide, infecting humans and animals. Clinical signs range from none to watery bloody mucoid diarrhoea, associated with abdominal cramps, bloating, anorexia and nausea (Kalishman *et al.,* 1996). Other protozoal infections are Balantidium spp. and Entamoeba spp. Entamoeba histolytica produces cysts in the liver, whereas E. dispar is apathogenic but can also result in diarrhoea, anorexia, weakness, abdominal pain and nausea. Natural infections are very uncommon. Drug of choice is Metronidazol or Paramomycinsulfate.

New World Primates are very sensitive to infections with Toxoplasma gondii. Transmission is mostly by ingestion of sporulated oocysts shed by felidae, or diaplazentar (Potkay, 1992). Death occurs after 5–6 days with non-specific clinical symptoms like anorexia, weakness, fever, coughing, dyspnoe , leukopenia and abortion.

Filariasis can be overwhelming with thrombus-like occlusions of small vessels in the lung, heart muscle and liver.

Mycotic diseases

There are not many case reports of mycotic infections in callitrichids. They can be observed after long and repeated antibiotic treatment. Candida sp. is a normal inhabitant of mucous membranes and skin (Savage, 1995). Juan-Salles *et al.* (1998) described a case of intestinal Cryptococcosis in a common marmoset with fibrinonecortizing enteritis.

Non-infectious diseases

Geula *et al.* (2002) reported that 60% of marmosets, older than seven years, have deposits of β-amyloid in the brain, liver and kidney, without having clinical symptoms.

Dental abscesses, recognised by a typical swelling beneath the eye**,** are very common and not only in aged monkeys. The oral cavity should be carefully examined for cracking, splitting or looseness of teeth, exposed pulp cavity or peridontitis. Antibiotics should be administered prior to tooth extraction under general anaesthesia.

In 1988 Brack carried out a retrospective study of all Callitrichidae at the German Primate Centre, revealing that 91% of tamarins and marmosets, older than six months, had an IgM-mediated mesangioproliferative glomerulonephropathy. Clinical signs can be proteinuria and haematuria. Eitner *et al.* (2001) considered that it is an IgA-mediated nephropathy.

Hemosiderosis is the deposition of the iron pigment, hemosiderin, in the liver, and is a common finding in many New World Primates (Miller *et al.,* 1997). They found 100% incidence of hemosiderosis in animals with Wasting Marmoset Syndrome. There is also evidence of immune dysfunction and increased susceptibility to infection in affected individuals (DeSousa, 1989). Spelman *et al.* (1989) hypothesised that the clinical disease associated with hemosiderosis in captive lemurs is caused by excessive dietary iron intake, high dietary ascorbic acid and low amounts of tannin. Sergejew *et al.* (2000) treated iron overloaded marmosets successfully with different chelations.

Osteomyelitis can occur after bite wounds on the digits or tail. Disinfection with poviodine and antibiotic administration are the best prophylactic measures. Amputation of digits may be necessary.

Wasting Marmoset Syndrome (WMS) is a disease of poorly understood aetiology. It may be related to stress, malnutrition (e.g. protein deficiency, too much fruit in the diet), parasitic, bacterial or viral infections or colitis. Clinical symptoms are rapid weight loss (>30% of LBW/week), dull fur, alopecia, particularly on the tail and breast, muscle atrophy, diarrhoea or obstipation colitis. Clinical pathology includes normochromic anaemia, thrombocytosis, hypoproteinaemia, hypoalbuminaemia, and elevated alkaline phosphatase levels (Logan and Khan, 1996; Tucker, 1984). Lewis *et al.* (1987) compared the faecal microflora of healthy marmosets with animals who developed WMS. The latter showed an increase of bacteriodes and fewer lactobacilli. The value of dietary lactobacilli in NHP is a largely unexplored area. A chronic inflammation may be the primary insult in the development of WMS in many marmosets. Treatment with antibiotics and supportive care with fluids, immune modulators, Vitamin D_3 and Calcium, Ensure®, Nutri-Cal® may help.

There are very few cases of Diabetes mellitus in NWP (Howard and Yasudu, 1990). Metabolic Bone Disease is mostly associated with a diet low in Vitamin D_3 and calcium and the lack of sunlight, followed by osteomalacia and secondary hyperparathyroidism (Hatt and Sainsbury, 1998). Clinical findings are bone fractures. Multiparous females are of higher risk because of their high demand for Calcium and D_3 during pregnancy and lactation.

Nasopharyngeal Squamous Cell Carcinoma was described in two related marmoset colonies by Betton (1983) and McIntosh *et al.* (1985), and characterised by conjunctivitis, mucoid nasal discharge and exophthalmos.

Gozalo *et al.* (1993) described a case of a renal hemangiosarcoma in a moustached tamarin.

In captivity, cotton-top tamarins develop colon adenocarcinoma spontaneously, with a high incidence of up to 35% of adult animals aged 5–10 years. If chronic diarrhoea and weight loss are present, colon carcinoma should be considered. Animals respond to Sulfazalazine treatment given for more than two months (Clapp, 1993).

Dystocia is frequently observed in callitrichids and not only in primiparous animals. Caesarean section is indicated if the female shows signs of labour for more than one hour. It is also possible that the females deliver one or two babies without problems and the last baby has to be delivered via c-section. Retentio secundinaria has been observed very rarely. A case of Placenta previa is described by Lunn (1980).

Abbreviations

BID	=	Twice Daily
CITES	=	Convention on International Trade in Endangered Species on Wild Fauna and Flora
IM	=	Intramuscularly
IU	=	International Units
IV	=	Intravenously
LBW	=	Live Bodyweight
MRI	=	Magnetic Resonance Imaging
NCR	=	National Council Research
NHP	=	Nonhuman Primates
NWM	=	New World Monkeys
NWP	=	New World Primates
OWM	=	Old World Monkeys
OWP	=	Old World Primates
PO	=	Orally
QOD	=	Every Other Day
SID	=	Once Daily
SC	=	Subcutaneously
TID	=	Three Times Daily
WMS	=	Wasting Marmoset Syndrome

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References

Abbott, D.H. (1984). *Am. J. Primatol.* 6, 169–186.

Abou-Madi, N. (1999). In Sodaro, V. and Saunders, N. (eds) *Callitrichid Husbandry Manuel,* pp 127–141. Neotropical Primate Taxon Advisory Group.

Anzenberger, G. and Gossweiler, H. (1993). *Am. J. Primatol.* 31, 223–230.

Asper, M., Hofmann, P., Osmann, C., Funk, J., Metzger, C., Bruns, M., Kaup, F.J., Schmitz, H. and Guenther, S. (2001). *Virology* 284, 203– 213.

Ausman, L.M., Gallina, D.L., Hayes, K.C. and Hegsted, D.M. (1986). *Am. J. Clin. Nutr.* 43, 112–127.

Bennett, B.T., Abee, C.R. and Henrickson, R. (1995). In Bennett, B.T. (ed.) *Nonhuman Primates in Biomedical Research: I Biology and Management*. Academic Press, San Diego, USA.

Bennett, B.T., Abee, C.R. and Henrickson, R. (1998). In Bennett B.T. (ed.) *Nonhuman Primates in Biomedical Research, II. Diseases.* Academic Press, San Diego, USA.

Berendt, R.F., Knutsen, G.L. and Powanda, M.C. (1978). *Infect. Immun*. 22, 275–281.

Betton, G.R. (1983). *Vet. Pathol*. 21, 193–197.

Brack, M. (1988). *Vet. Pathol*. 25, 270–276.

Brack, M., Reimbrodt, R., Tschaepe, H., Gilhaus, H. and Rensing, S. (1997). *Erkrank. Zootiere* 38, 317–321.

Brack, M., Rensing, S. and Gatesman, T.J. (1998). *Infect. Disease Review* 1, 15–19.

Byron, J.K. and Bodri, M.S. (2001). *Lab. Animal* 30, 42–48.

Carpenter, J.W., Mashima, T.Y. and Rupiper, D.J. (1996). In Carpenter, J.W. (eds) *Exotic Animal Formulary,* Greystone Publications, Kansas, USA.

Carroll, J.B. (1997). In Pryce, C., Scott, L. and Schnell, C. (eds) *Handbook: Marmosets and Tamarins in Biology and Biomedical Research*, pp 102–109. DSSD Imagery, Salisbury, UK.

Cho, Y., Ramer, J., Rivailler, P., Quink, C., Garber, R.L., Beier, D.R. and Wang, F. (2001). *Proc. Natl. Acad. Sci. USA* 98, 1224–1229.

Christe, K., McChesney, M.B., Spinner, A., Rosenthal, A.N., Allen, P.C., Valverde, C.R., Roberts, J.A. and Lerche, N.W. (2002). *Comp. Med*. 52, 467–472.

Clapp, N.K. and Tardiff, S.D. (1985). *Dig. Dis Sci.* 30, 17–23.

Clapp, N.K. (1993). *A Primate Model for the Study of Colitis and Colonic Cancer: the Cotton-top Tamarin (Saguinus oedipus)*. CRC Press, Boca Raton, Florida, USA.

Coimbra-Filho, A.F. and Mittermeier, R. (1981). In Coimbra-Filho, A.F. and Mittermeier, R.A. (eds) *Ecology and Behavior of Neotropical Primates,* Vol. 1, p 496. Rio de Janeiro: Academia Brasileira de Ciencias.

Cui, K.H., Flaherty, S.P., Newble, C.D., Guerin, M.V., Napier, A.J. and Matthews, C.D. (1991). *J. Androl.* 12, 214–220.

Dalton, M.J. (1985). *Lab. Anim*. 14, 21–22.

Davy, C.W., Trennery, P.N., Edmunds, J.G., Altman, J.F.B. and Eichler, D.A. (1987). *Lab. Anim*. 21, 60–67.

Deinhardt, F. (1967). *Lab. Anim. Care* 17, 11–29.

De Rosa, C., Vitale, A. and Puopolo, M. (2002) *Lab. Anim*. 37, 100–107.

DeSousa, M. (1989). *Clin. Exp. Immunol*. 75, 1–6.

Dietz, J.M. and Baker, A.J. (1993). *Anim. Behav*. 46, 1067–1078.

Eitner, F., Ostendorf, T., Kitahara, M., Rensing, S., Hofmann, P., Maetz-Rensing, K., Kaup, F.J., Groene, H.J. and Floege, J. (2001). *Kidney Blood Pressure Res.* 24, 332.

Ferrari, S.F. and Martins, E.S. (1992). *Am. J. Phys. Anthropol.* 88, 97–103.

Flurer, C.I., Krommer, G. and Zucker, H. (1988). *Lab. Anim. Sci.* 38, 183–186.

Flurer, C.I. and Zucker, H. (1989). *Z. Ernaehrungswiss*. 28, 49–55.

Fortman, J.D., Hewtt, T.A. and Bennett, B.T. (2002). In Fortman, J.D. (ed.) *The Laboratory Nonhuman Primate*. CRC Press, Boca Raton, Florida, USA.

French, J.A., Abbott, D.H. and Snowdon, C.T. (1984). *Am. J. Primatol*. 6, 155–167.

French, J.A., Inglett, B.J. and Dethlefs, T.M. (1989). *Am. J. Primatol.* 18, 73–86.

Garber, P.A. (1986*). Am. J. Phys. Anthropol*. 69, 202.

Garber, P.A. (1992). *Am. J. Phys. Anthropol*. 88, 469–482.

Geretschläger, E., Russ, H., Mihatsch, W. and Przuntek, H. (1987). *Lab. Anim.* 21, 91–94.

Geula, C., Nagykery, N. and Wu, C. (2002). *Acta Neuropathol*. 103, 48–58.

Gozalo, A., Block, K., Montoya, E., Moro, J. and Escamilla, J. (1991). *Primatol. Today,* 675–676.

Gozalo, A., Chavera, A., Dagle, G.E., Montoya, E. and Weller, R.E. (1993). *J. Med. Primatol.* 22, 431–432.

Gough, A.W., Barsoum, N.J., Gracon, S.I., Mitchell, L. and Sturgess, J. (1982). *Lab. Anim. Sci*. 32, 87–90.

Harlow, C.R., Hearn, J.P. and Hodges, J.K. (1984). *J. Endocrinol*. 103, 17–24.

Hatt, J.M. and Sainsbury, A.W. (1998). *Vet. Rec*. 143, 78–80.

Hawkins, J.V., Clapp, N.K., Carson, R.L., Henke, M.A., McCracken, M.D., Faulkner, C.T. and Patton, S. (1997). *Contemp. Top. Lab. Anim. Sci.* 36, 52–55.

Hearn, J.P. (1977). *Lab. Anim*. 11, 261–262.

Hearn, J.P. and Burden, F.J. (1979). *Lab. Anim*. 13, 131–133.

Hearn, J.P., Lunn, S.F., Burden, F.J. and Pilcher, M.M. (1975). *Lab. Anim*. 9, 125–134.

Heath, M. and Libretto, S.E. (1993). *Anim. Technol.* 44, 163–173.

Hershkovitz, P. (1977). In Hershkovitz, P. (ed.) *Living New World Primates (Platyrrhini), with an introduction to Primates, Vol. I*, pp 397–911. The University of Chicago Press, USA.

Howard, C.F. and Yasuda, M. (1990). *J. Med. Primatiol*. 19, 609–625.

Hubrecht, R.C. (1989). *Primates* 30, 423–432.

Jaquish, C.E., Toal, R.L., Tardiff, S.D. and Carson, R.L. (1995). *Am. J. Primatol.* 36, 259–275.

Johnson, L.D., Ausman, L.M., Rolland, R.M., Chalifoux, L.V. and Russel, R.G. (2001). *Comp. Med*. 51, 257–261.

Juan Salles, C., Marco, A. and Domingo, M. (1998). *J. Med. Primatol*. 27, 298–302.

Kalishman, J., Paul-Murphy, J., Scheffler, J. and Thomson, J.A. (1996). *Lab. Anim. Sci*. 46, 116–119.

Kalter, S.S. (1982). *Vet. Pathol*. 19 (Suppl. 7), 33–43.

Kendrick, K.M. and Dixson, A. (1983). *Physiol. Behav*. 30, 732–742.

King, N.W., Hunt, R.D., Daniel, M.D. and Melendez, L.V. (1967). *Lab. Anim. Care* 17, 413–423.

Kingston, W.R. (1969). *Lab. Anim. Handbooks* 4, 243–250.

Kirkwood, J.K. and Underwood, S.J. (1984). *Folia Primatol.* 42, 180.

Kitchen, A.M. and Martin, A.A. (1996). *Lab. Anim.* 30, 317–326.

Kleiman, D.G. (1978). In Kleiman, D.G. (ed.) *The Biology and Conservation of the Callitrichidae.* Smithsonian Institution Press, Washington DC, USA.

Knapka, J.J., Barnard, D.E., Bayne, K.A.L., Lewis, S.M., Marriott, B.M. and Oftedal, O.T. (1995). In Bennet, B.T., Abee, C.R. and Henrickson, R. (eds) *Nonhuman Primates in Biomedical Research: I Biology and Management*, pp 211–248. Academic Press, San Diego.

Kuederling, I., Schneiders, A., Sonksen, J., Nayudu, P. and Hodges, J.K. (2000). *Am. J. Primatol.* 52, 149–154.

Lewis, D.H., Stein, F.J., Sis, R.F. and McMurray, M.N. (1987). *Lab. Anim. Sci.* 37, 103–105.

Logan, A.C. and Khan, K.N.M. (1996). *Tox. Pathol.* 6, 707–709.

Lunn, S.F. (1980). *Vet. Rec.* 106, 414.

Majolo, B. and Buchanan-Smith, H.M. (2003). *Lab. Animal Europe* 3, 25–33.

Mansfield, K.G., Lin, K., Xia, D., Newman, J.V., Schauer, D.B., MacKey, J., Lackner, A.A. and Carville, A. (2001). *J. Infect. Dis.* 184, 803–807.

McClure, H.M., Brodie, A.R., Anderson, D.C. and Swenson, R.B. (1986). In Benirschke, K. (ed.) *Primates: The Road to Self-sustaining Populations,* pp 531–556. New York: Springer-Verlag.

McIntosh, G.H., Giesecke, R., Wilson, D.F. and Goss, A.N. (1985). *Vet. Pathol.* 22, 86–88.

McIntosh, G.H., McMurchie, E.J., James, M., Lawson, C.A., Bulman, F.H. and Charnock, J.S. (1987). *Arteriosclerosis* 7, 159–165.

Melendez, L.V., Daniel, M.D., Barahona, H.H., Fraser, C.E., Hunt, R.D. and Garcia, F.G. (1971). *Lab. Anim. Sci.* 21, 1050–1054.

Michel A.L. and Huchzermeyer, H.F.A.K. (1998). *J. S. Afr. Vet. Ass.* 69, 64–65.

Miller, G.F., Barnard, D.E., Woodward, R.A., Flynn, B.M. and Bulte, J.W.M. (1997). *Lab. Anim. Sci.* 47, 138–142.

Moehle, U., Heistermann, M., Einspanier, A. and Hodges, K. (1999). *J. Med. Primatol.* 28, 36–47.

Montali, R.J., Scanga, C.A., Pernikoff, D., Wessner, D.R., Ward, R. and Holmes, K.V. (1993). *J. Inf. Diseases* 167, 946–950.

Murphy, B.L., Maynard, J.E., Krushak, D.H. and Berquist, K.R. (1972). *Lab. Anim. Sci.* 22, 339–343.

National Research Council, Committee on Animal Nutrition (2003). In *Nutrient Requirements of Nonhuman Primates.* National Academy of Science, Washington DC, USA.

Nigida, S.M., Falk, L.A., Wolfe, L.G. and Deinhardt, F. (1979). *Lab. Anim. Sci.* 29, 53–60.

Paul-Murphy, J. (1993). In Fowler, M.E. (ed.) *Zoo and Wild Animal Medicine: Current Therapy 3*, pp 344–351. WP Saunders. Philadelphia, USA.

Poole, T.B. (1990). *Anim. Technol.* 41, 81–86.

Poole, T., Hubrecht, R. and Kirkwood, J.K. (1999). In Poole, T. and English, P (eds) *The UFAW Handbook on the Care and Management of Laboratory Animals*, pp 559–573. Blackwell Science, Oxford, UK.

Potkay, S. (1992). *J. Med. Primatol.* 21, 189–236.

Power, M.L. and Oftedal, O.T. (1996). *Am. J. Primatol.* 40, 131–144.

Power, M.L., Oftedal, O.T., Savage, A., Blumer, E.S., Soto, L.H., Chen, T.C. and Hollick, M.F. (1997). *Zoo Biology* 16, 39–46.

Ramer, J.C., Garber, R.L., Steele, K.E., Boysen, J.F., O´Rourke, C. and Thomson, J.A. (2000). *Lab. Anim. Sci.* 50, 59–68.

Rothe, H., Wolters, H.J. and Hearn, J.P. (1978). In *Biology and Behaviour of Marmosets.* Proceedings of the Marmoset Workshop Göttingen, Germany, September, 2–5, 1977. Mercke-Druck, Göttingen, Germany.

Rylands, A.B., Coimbra–Filho, A.F. and Mittermeier, R.A. (1993). In Rylands, A.B. (ed.) *Marmosets and Tamarins,* pp 11–77. Oxford University Press, UK.

Saltzmann, W., Schultz-Darken, N.J. and Abbott, D.H. (1997). *Am. J. Primatol.* 41, 159–177.

Savage, A. (1995). In Savage, A. (ed.) *The Cotton-top Tamarin Husbandry Manuel.* Roger Williams Park Zoo, Providence, RI, USA.

Schoenfeld, D. (1989). *Am. J. Primatol.* (Suppl.1): 45–51.

Sergejew, T., Forgiarini, P. and Schnebli, H. (2000). *Br. J. Hematol.* 110, 985–992.

Spelman, L.H., Osborn, K.G. and Anderson, M.P. (1989). *Zoo Biology* 8, 239–251.

Tarantal, A.F. and Hendrickx, A.G. (1988). *J. Med. Primatol.* 17, 105–112.

Tardif, S.D. (1984). *Am. J. Primatol.* 6, 199–209.

Thomson, J.A. and Scheffler, J.J. (1996). *Lab. Animal. Sci.* 46, 275–279.

Tucker, M.J. (1984). *Lab. Anim.* 18, 351–358.

Ventura, R. and Buchanan-Smith, H.M. (2003). *Int. J. Primatol.* 24, 399–413.

Vignes, S., Newman, J.D. and Roberts, R.L. (1992). *Contemp. Top. Lab. Anim. Sci.* 40, 26–29.

Ziegler, T.E., Savage, A., Scheffler, G. and Snowdon, C.T. (1987). *Biol. Reprod.* 37, 618–627.