BODY TEMPERATURES IN TWO BRAZILIAN PRIMATES [1]

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A considerable literature of temperature data on monkeys exists, but this is largely confined to old world species and several of the larger new world forms (Wislocki, 1933). The current report describes two of the smaller South American species, the night monkey (*Aotus trivirgatus*) and the common marmoset (*Callithrix jacchus*). The latter is a representative species of this typically tropical group, the marmosets (*Callithricidae*) being a large family with many species. These are common in collections and as pets so it is surprising that more is not known of them. While the marmosets are typical diurnal monkeys, *Aotus* is unique as the only nocturnal, new-world, primate. Perhaps in keeping with its nocturnal habit, *Aotus* has a fine thick fur. The light fur and long limbs of the marmosets suggest a limited thermoregulatory ability in the cold, a condition, however, which will not be encountered in its normal environment. Current information on *C. jacchus* has been summarized by Simões (1958).

MATERIALS AND METHODS

The marmosets were captured locally and maintained as a group in a large cage in the Physiology Department. Four individuals, all males (*ca* 190g) were studied. Experimental observations were carried out on singly caged individuals at the Hospital das Clínicas where we

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were indebted to Prof. Roberto Santos for the hospitable provision of facilities in his laboratories. The pair of night monkeys (♂, 660g; ♀ 590g) were made available to us for study from the Zoological State Garden through the kindness of the director, Dr. Valle. They were also caged singly during the series of observations, being maintained in a large general laboratory rather than in isolated quarters.

Body temperatures were measured with a YSI thermister thermometer using the ordinary (3 mm.) plastic coated probes. Metabolic measurements were made using a Manometric apparatus (Morrison, 1952). We are grateful to W. R. Holthaus and B. K. McNab for their assistance in some of these experiments.

RESULTS

Daily Cycles: Figure 1 presents the temperature measurements on *Aotus* as a function of the hour of day. Although only 21 values were obtained a rather well defined daily cycle is manifested. This might be expected in an animal with such a striking behavioral cycle since *Aotus,* like the flying squirrel, stayed curled up and quiet during the daylight hours despite light and disturbance about him. However, it was unfortunate that the subjects should have been subjetc to some

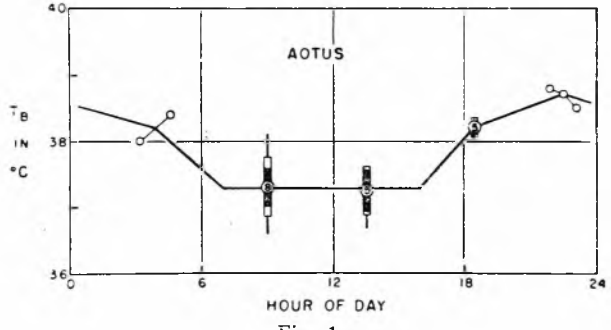

Fig. 1

disturbance during these normally resting hours. It is quite possible that considerable of the dispersion in the daytime points resulted from this abnormal disturbance. Under more favorable conditions a somewhat larger amplitude than the 1.4° observed here might be revealed. Although the data is limited, an equal division of 12 hours each was indicated for the active and resting phases.

Aotus is a very quiet, well-mannered animal which is easy to handle and usually does not try to bite or escape. On the other hand marmosets in general, and *C. jacchus* in particular, are usually excitable and aggressive. They were difficult to capture and struggled incessantly while being held. Part of this difference in behavior can be related to the fact that the nocturnal *Aotus* is in the depressed activity phase during the day when he is normally seen, whereas this is the active period for the marmoset. But while *Aotus* was much more responsive when handled at night, most of this difference relates to a basic contrast in the behavioral characteristics of the species.

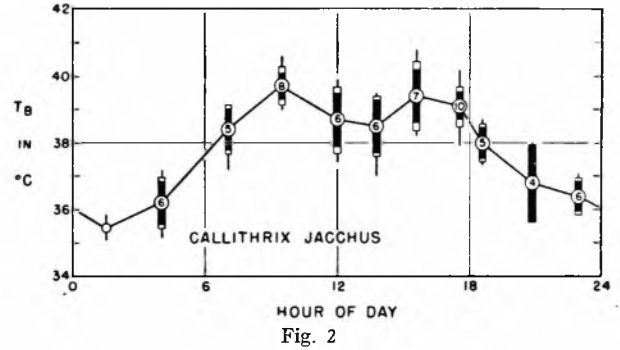

Fig. 2

Figure 2 shows the daily temperature cycle in *Callithrix*. Although there were considerably more measurements (66), the unstable nature of this species introduced considerable dispersion into the data. But the daily pattern is clearly revealed and shows a striking 4.3° amplitude between the minimum of 35.4° at 09^{30} hours and the maximum of 39.7° at 09^{30} hours. The mean temperature over the active period ($0800 — 1800$ hours, 37 values) was 39.1° and the mean value over the quiet period ($21^{00} — 05^{00}$ hours, 14 values) was 36.2°. Again, the two phases were almost equal in duration. An unusual feature was the clear-cut depression in the middle of the active period. Although this phenomenon is sometimes observed in crepuscular animals which are active after night fall and again before dawn, we have not observed it before in a diurnal species.

Activity: The temperature response of *Aotus* in relation to activity is shown in Figure 3. These data are rather unsatisfactory because this species shows almost no range of activity. At night, they were

always awake, but were usually quiet and the small cages used here gave little scope for activity. In the daytime they are always sleeping, or at most wake and very quiet even when disturbed. The *1+* activity values for *Aotus* could be divided into sharply defined upper and lower groups representing day and night. An indication of disturbance to this animal is the fact that so few truly sleeping values were observed. Probably the daytime values should be assigned a value of *0+* even though the eyes were open.

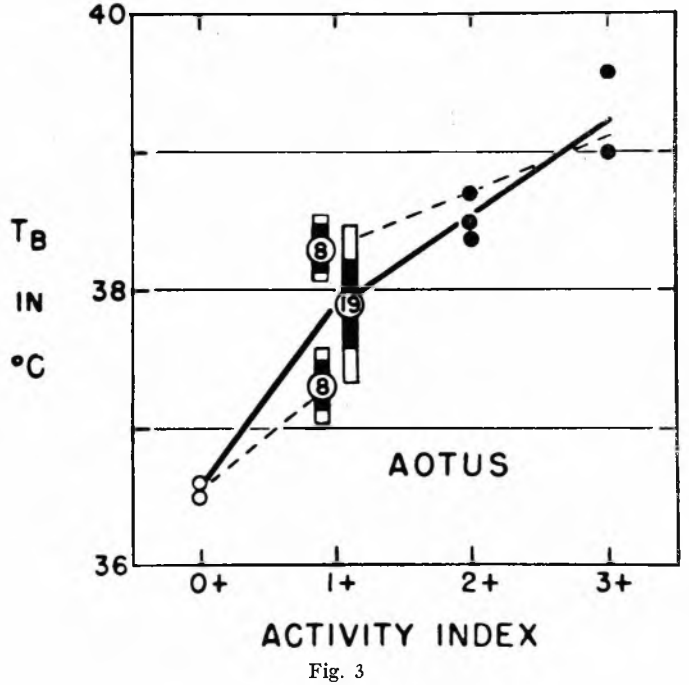

Fig. 3

The data on the marmoset was equally unsatisfactory in this regard to activity (Fig. 4). All sleeping values, were taken during the night. The *1+* activity values fell into three well defined groups of which the lower group included most of the transitional values in early morning of late afternoon between the active and resting periods. The upper group represented daytime values alone. If larger cages had been provided perhaps these waking values would have been more effectively divided.

Response to Ambient Temperatures: Body temperatures for both species following exposures at either high or low ambient temperatures are summarized in Figure 4. There were only three values

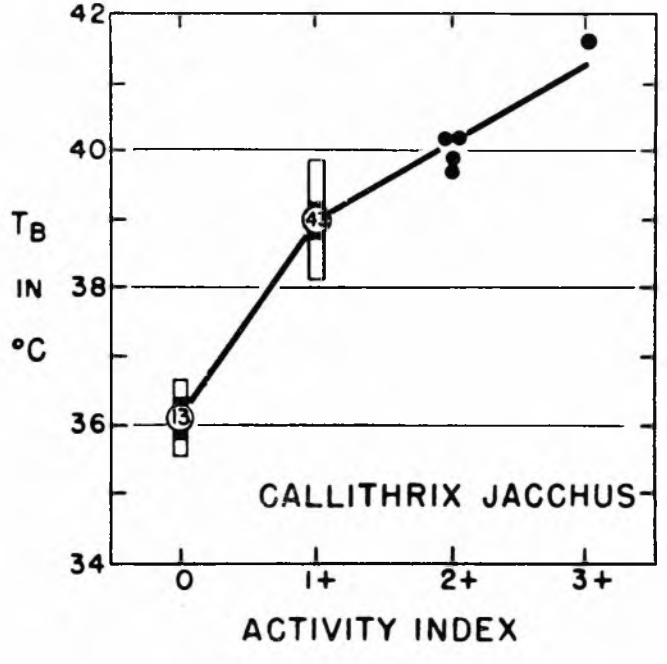

Fig. 4

on *Aotus,* but these showed a very steady, well-maintained body temperature at the level of 38° over an ambient range of 8 to 33°. This value is about midway between the night time and the daytime averages, although these experiments were carried out in the day. It may be presumed that handling and confining the animal to a small chamber elevated the temperature above the normal daytime value.

By contrast, the marmoset showed a definite depression of body temperature when exposed at either 16 or 8°. In the latter the average fall was 1.2° as referred to the average value in animals confined at near room temperature; or 1.7° as referred to the normal daytime average. The former value which is used to draw the average curves in Figure 5 is probably preferable as representing comparable

activity. At higher ambient temperatures (33 and 38°) the body temperature rose steeply, reaching a value of 41° at the latter temperature.

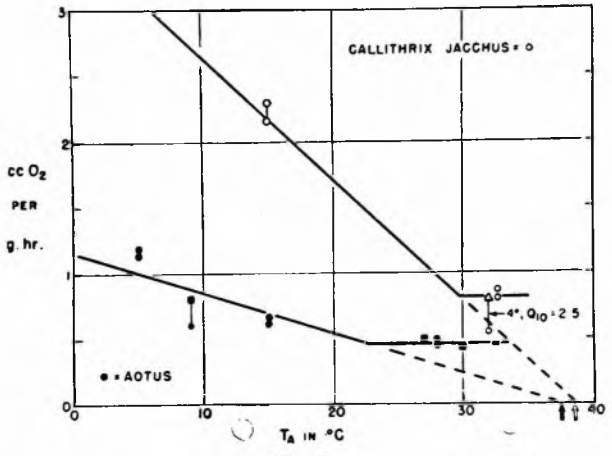

Fig. 5

Metabolism: The limited data on the metabolic response of both species is given in Figure 6. The basal metabolism in *Aotus* lay at a level of 0.45 cc $0_2 g^{-1} hr^{-1}$, equivalent to 2.57 cc $0_2 g^{-}.^{73} hr^{-1}$. Scholander, *et al* (1950) report a slightly higher value of 0.51 cc

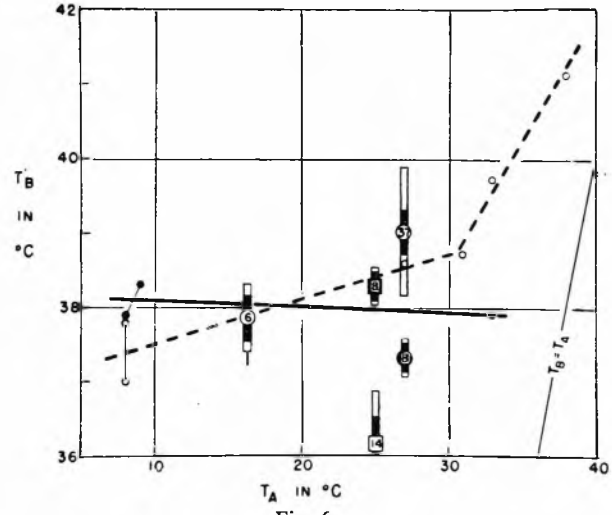

Fig. 6

g $^{-1}hr^{-1}$ for the Panamanian subspecies. This is below the standard value of 2.70 corresponding to the average for mammals (Brodie, 1945). The mean curve describing oxygen consumption below thermal neutrality has a value of 1.16 cc $g^{-1}hr^{-1}$ at 0°. The slope of this curve, 0.031 cc $0_2g^{-1}hr^{-1}C°$, or 0.149 cal $g^{-1}nr^{-1}°C^{-1}$ represents the thermal conductance of the animal and this value is distinctly lower than the average which we have observed in small temperature mammals, in particular, than that of the Franklin ground squirrel, an animal of comparable size (Morrison and Ryser, 1951). The critical temperature for this species lay at 23°.

The basal level for *Callithrix* appears to be at 0.80 cc $g^{-1}hr^{-1}$. One very low value at 0.65 cc $0_2g^{-1}hr^{-1}$ was recorded but in this case the body temperature of the animal was only 33.7°. Adjustment of this value to correspond to 38.0°, the mean body temperature in the day, raised it to the level of 0.80 of cc $0_2g^{-1}hr^{-1}$. Scholander *et al* (1950) reported a somewhat higher value of 1.04 cc $0_2g^{-1}hr^{-1}$ for a related species, *Oedipomidas spixi*. The conductance curve for this species was placed from the data from a single experiment at 15° and gives a value of 0.093 cc $0_2g^{-1}hr^{-1}°C^{-1}$ 0.45 cal $g^{-1}hr^{-1}°C^{-1}$. Although *Callithrix* proved to be a rather poor regulator as judged by the depression of its body temperature at ambient temperatures of only 8 to 17°, this conductance value is at the normal level for temperate forms, being close to that of the 13 lined ground squirrel, a rodent of comparable size.

DISCUSSION

The daily temperature cycle in the marmoset, *Callithrix jacchus*, has a striking amplitude of 4.3°. No member of the Callithricidae have been measured in this regard previously except for a single set of values (12 points) from a tuberculin test on *Oedipomidas spixi* by Fox (1923). His values show a rather close correspondence with those seen here for *C. jacchus*. There are data on several of the other family of new world monkeys. In *Cebus* and in *Ateles*, lesser amplitudes of 2.1 and 2.0 respectively, or less than half the above have been reported (Fox, 1923). Such smaller values appear characteristic of the old world monkeys which have been studied as well.

Further, the form of the daily cycle in *Callithrix* is quite different than that found in the monkeys for which an almost saw-tooth pattern has been reported. *Callithrix* maintained a high level of temperature for about 10 hours, and this active period was clearly divided into two peaks with maxima at 09^{30} and 16^{30} and an intervening minimum at 14^{00}, the time of maximum body temperature in other species. This secondary daytime minimum appears shallow compared to the nocturnal low, but it may be noted that its amplitude was almost as large (1.2 vs. 1.40) as the entire daily cycle in *Aotus*. Such bimodal activity or temperature cycles are sometimes seen in crepuscular animals such as bats which are active at dusk and then again at dawn (Pearson, 1947). The maxima seen here appear either too late (09^{30}) or too early (16^{30}) to qualify for crepuscularity. But in animals such as the marmosets which characteristically live in the dense rain forest, where light levels are greatly reduced, a mid-day cessation of activity has often been described for animals exposed to heat. This might represent a displacement of dawn and dusk.

Aotus trivirgatus shows a temperature cycle that contrasts to *Callithrix* in almost every aspect. The amplitude of 1.40 between minimum and maximum is very modest. The phasing of the cycle, of course, corresponds to the activity of the animal with the maximum at 11^{00}. Insufficient data were available to define the cycle more precisely, but it appeared to represent a rough "square" wave with a maintained lower temperature ($07^{00} \rightarrow 16^{00}$) of 37.3 and a fairly well maintained active temperature, at least much more so than in monkeys in the literature referred to above. *Aotus* may be compared to another primate of similar habit, but of a quite different group, the west African Potto. *Perodicticus potto* is a rather sluggish nocturnal lemur and its temperatures cycle is very similar to *Aotus* with an identical amplitude of 1.4^{o}. It is of interest that both these nocturnal members of an almost strictly diurnal order are of such a quiet habit and show such a reduced temperature cycle. One might speculate that the diurnal habit was so strongly impressed on this order that it was not possible to switch from day to night with a complete (intensity) reversal of the activity pattern. Body temperatures for marmosets and for *Aotus* are summarized in Table 1.

TABLE 1

Body temperatures in Marmosets and Night monkeys

Species	TB	#	*S.D.*	*Hour*	TA	*Sex*	*Reference*
Oedipomidas spixi	38.8	(8:?)	—	Day	(25)		Britton and Klein, 1939
" "	39.1	(9:1)	0.33	15^{00}			Fox, 1923
	37.0	(3:1)	—	Night			
Callithrix jacchus	39.1	(?:2)	—	Day	19	♂	Brown, 1909
" "	39.1	(37:4)	0.88	Day	27	♂	this study
	36.2	(14:4)	0.72	Night	25		this study
A. trivirgatus	38.0	(?:2)	0.80	15^{00}	19	♂,♀	Brown, 1909
A. t. griseimembra	38.5	(3:?)	—	Day	(25)		Britton and Klein, 1939
A. t. trivirgatus	37.3	(13:2)	0.40	Day	27	♂,♀	this study
	38.4	(10:2)	0.25	(Night)	25		this study

A contrast between the two species is also seen in the influence of cold on body temperature. The data indicate that *Aotus* is a quite adequate regulator, at least within the rather modest test limits of 8°, since there was no fall in body temperature. By contrast, *Callithrix* was quite thermolabile over the whole temperature range showing a slope of 0.10 (Δ_1 TB/Δ TA) between 8 and 31°; and a slope of above 31. *C. jacchus* is confined to eastern Brazil where a uniform temperature is the rule. *A. t. trivirgatus* is also found over about the same range, but other subspecies range into the lower Andes at altitudes up to 5.000' where cold of a degree appropriate to its dense fur is encountered. The metabolic measurements gave a conductance value for *Aotus* which was, in fact, lower than that seen in some "temperate" mammals of comparable size (Morrison and Ryser, 1951). The value for *Callithrix* was comparable to that seen in "temperate" rodents, and it would appear that either huddling or the development of an axial temperate gradient (Scholander, 1957) had compensated for the longer limbs and greater surface area.

SUMMARY

1. The daily body temperature cycle in the common marmoset, *Callithrix jacchus,* (4 ♂) had and amplitude of 4.3°C, about twice that observed in other primates and higher than that seen in any other mammal. The maximum was at 09^{30} hours (39.7 ± 0.98°) and the minimum was at 01^{30} (35.4 ± 0.4°).

2. The night monkey, *Aotus trivirgatus,* (1 ♂, 1 ♀) showed a reversed (nocturnal) temperature cycle with an amplitude of 1.4°, less than is seen in most monkeys. The maximum was at 23^{00} (38.5°) and a minimum of 37.3° was maintained between 07^{00} and 17^{00} hours. The ♂ averaged 0.6° higher than the ♀.

3. *Aotus* maintained its normal body temperature on cold exposure down to 8°, while in *Callithrix* the body temperature fell continuously from 38.8 at 31° ambient to 37.3 at 8° ambient.

4. Metabolic measurements in the cold gave values of thermal conductance of 0.149 for *Aotus* and 0.45 cal $g^{-1}hr^{1}°C^{-1}$ for *Callithrix;* (0.031 and 0.093 cc 0_2 $g^{-1}hr^{1}°C^{-1}$) and critical temperatures of 22.5 and 29.7 respectively. The basal metabolic rate was 0.80 in *Callithrix* and 0.45 cc 0_2 $g^{-1}hr^{-1}$ in *Aotus*.

SUMÁRIO

1. O ciclo de temperatura corpórea diário do saguí *Callithrix jacchus* (4 ♂) tem uma amplitude de 4,3°C, cêrca de 2 vêzes a observada em outros primatas e mais elevada em qualquer outro mamífero. O máximo foi às 9,30 horas (39,7 ± 0,98°) e o mínimo foi às 1,30 horas (35,4 ± 0,4°).

2. O macaco noturno *Aotus trivirgatus* (1 ♂, 1 ♀) exibiu um ciclo de temperatura reverso (noturno) com uma amplitude de 1,4°, menor do que a vista na maioria dos macacos. O máximo foi às 23 horas (38,5°) e um mínimo de 37,3° foi mantido entre 7 e 17 horas. O macho teve uma média 0,6° mais elevada do que a fêmea.

3. *Aotus* manteve sua temperatura do corpo normal na exposição ao frio até 8°, enquanto que em *Callithrix* a temperatura do

corpo caiu contìnuamente de 38,8 a 31° ambientais para 37,3 a 8° no ambiente.

4. Medidas metabólicas no frio deram valores de condutância térmica de 0,149 para *Aotus* e 0,45 $g^{-1}h^{1o}C^{-1}$ para *Callithrix;* (0,031 e 0,093 cc 0_2 $g^{-1}h^{1o}C^{-1}$) e temperaturas críticas de 22,5 e 29,7 respectivamente. A taxa metálica basal foi de 0,80 para *Callithrix* e 0,45 cc 0_2 $g^{-1}h^{-1}$ para *Aotus*.

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