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During the course of studies on renal and adrenal function, followed at the Barro Colorado Island and Gorgas Memorial laboratories, Panama, while the senior author was a John Simon Guggenheim Memorial Fellow, opportunity was taken to secure readings of rectal temperatures of sloths. We desire to acknowledge with appreciation the unfailing courtesies of Mr. James Zetek and Dr. H. C. Clark during these investigations.

It was found that occasionally the temperatures of the sloths vary rather rapidly and widely for no apparent reason. The experimental conditions were not responsible, and activity of the animals did not appear to be involved. Observations were carried out for the most part in the open air, in shade, and the air temperature usually varied only slightly throughout several hours. The occasional wandering of the animals, allowed to go freely, on the grass or in nearby shrubs, into bright sunlight, appeared later to explain the fluctuations. Some direct tests led to evidence of unusual limitations in the temperature-regulating mechanism of the sloth in comparison with other mammalian forms.

Normal temperatures.—The two common Panamanian sloths, the two-toed (*Choloepus hoffmanni*) and the three-toed (*Bradypus griseus griseus*), were studied. These were available in large numbers, and could be maintained in local captivity in good condition. They survived, however, for only a few weeks in midsummer under laboratory conditions in Virginia. A number of sloths employed for histological and other purposes were utilized for normal temperature studies. In table 1, records of stomach, skeletal muscle, and heart temperatures may be compared with rectal readings in the same animals. The latter were taken with the thermometer introduced 4 to 6 cm. into the rectum, and represent deep rectal temperatures. The center of the food mass in the stomach, the larger thigh muscles and the beating left ven-

tricle were used respectively for other readings. Most of the observations were made in the morning; several made in the evening, however, showed no differences.

It is noteworthy that the average rectal temperatures in both two-toed and three-toed sloths were 3 to 4 degrees (Centigrade) lower than in other mammals. There were also wide differences in temperature in both species—in the two-toed over a 1.5 degree range, and in the three-toed over a range of 4 degrees. These facts may be seen in fig. 1. The almost complete lack of

TABLE 1

Body temperatures of sloths

(*Choloepus hoffmanni*)						(*Bradypus griseus*)					
Rectum			Stomach	Skeletal muscle	Heart	Rectum			Stomach	Skeletal muscle	Heart
°C.			°C.	°C.	°C.	°C.			°C.	°C.	°C.
34.5	34.5	34.1	34.0	34.7	34.4	32.8	31.0	32.0	33.8	33.7	33.9
35.5	34.0	34.8	35.5	35.6	35.8	32.9	32.1	32.6	33.3	32.9	32.6
33.4	34.9	35.2	34.3	33.7	34.3	31.7	35.0	33.8	32.8	32.1	33.2
34.0	33.9	34.3	33.9	34.2	34.6	31.5	34.9	34.0	33.0	31.7	33.3
34.2	34.8	34.9	34.8	34.8	35.3	33.0	34.1	32.3	33.7	31.6	33.6
34.8	34.0	34.2				33.5	35.2	33.6	33.2	32.5	33.5
34.2	34.8	34.1	*34.5*	*34.6*	*34.8*	34.8	31.9	34.0	32.2	32.5	34.5
34.3	34.8	34.8				31.5	32.4	31.6			
35.7	34.0	33.8				33.0	33.4	32.8	*33.2*	*32.4*	*33.5*
33.7	33.4	34.2									
33.9	33.8	34.0					*33.0*				
34.6	34.2	34.0									
34.1	33.8	34.8									
34.9	34.2	34.8									
34.8	35.2	34.2									
34.3	34.3	33.8									
34.2	34.9										
	34.4										

Average figures in *italics*.

grouping of values over the four-degree range in the case of the three-toed sloth is especially striking. A lower body temperature in three-toed sloths is also apparent.

The air temperature, it may be noted, varied only slightly from day to day and hour to hour, usually from 28 to 30 degrees between 8 P.M. and 10 A.M., and from 30 to 33 degrees between 10 A.M. and 8 P.M. Readings were taken inside and outside the laboratory from March to May, 1937.

Exposure to cold.—Both species were found to be unable to withstand exposure to moderate degrees of cold. After spending only a few hours

(4, 5 or 6) in a cold chamber at 10 or 15 degrees, the deep rectal temperature fell markedly, and in some cases a state of cold narcosis very similar to that found in a hibernating animal began at a body temperature of about 20 degrees. The hair of the animals was made moderately wet before exposure, and a cage that allowed free movement was used. Cold was a strong stimulus to muscular activity, and there was marked hypertonus; strangely, however, no shivering, at any temperature, was observed in any of the sloths studied. There was good recovery to a normal body temperature after withdrawal from the cold chamber to room temperature at about 30 degrees (fig. 2). Superficial rectal temperature was lower during the cooling process, and approximated the deep rectal readings during warming-up. One sloth died

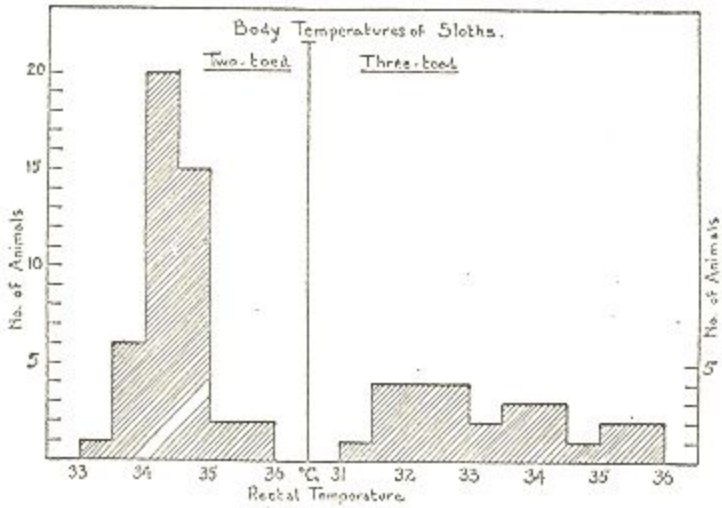

FIG. 1

apparently from the exposure. Its carcass did not cool as rapidly as in many of the living experimental subjects (see fig. 2).

A few other species of tropical animals that were tested—ocelots, marmosets, white-faced monkeys—showed no disposition to lose body heat on similar exposure to cold. The opossum (*Didelphis virginiana*) and the marmot (*Marmota monax*), both rather lowly-organized North American forms, showed practically no reduction in body temperature after exposure to approximately zero temperatures for several days.

Exposure to heat (sunshine).—A number of sloths had been found by accident to show elevations in body temperature after crawling into or resting briefly in the sunshine. Frequently, however, the air temperature in the sun was only a few degrees higher than in the shade, and rarely 6 or 8 degrees higher, undoubtedly because of the high humidity and obscuration in the isthmian tropics.

Shortly after sloths were placed in the sun, they showed increased activity, and within 10 to 20 minutes were vigorously clawing their cages and seeking escape. Two animals placed together in one cage fought viciously, although they were mates. These conditions lasted for only about 30 minutes, however. Rectal temperatures were found to have risen 2 to 4 degrees about this time. At the end of about 90 minutes, panting usually was very marked, and hyperthermia was obviously extreme. Shortly thereafter the animals were removed to the cooler (30 degree) shade of the laboratory. After a period of exposure in the sun of 1 hour, 45 minutes, deep rectal temperatures were usually found to have risen from 4 to 6 degrees above normal. Recovery

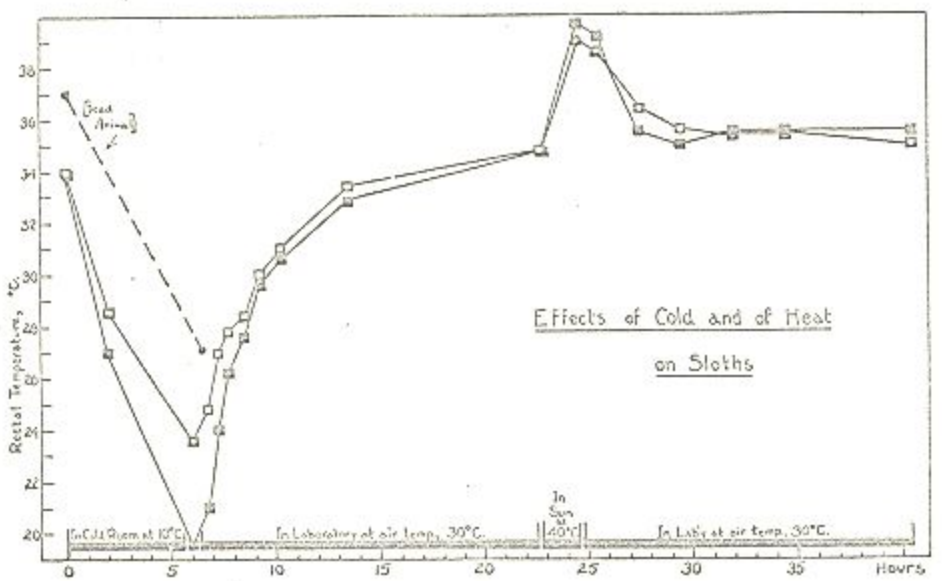

FIG. 2

of normal body temperatures generally followed in 2 to 4 hours, but several animals succumbed within a day or two after an experiment.

The rate and extent of cooling and warming, and phases of recovery, are represented in fig. 2. Data are taken from two protocols.

Discussion.—Many considerations set the sloth apart as a lowly form of mammal. Most sloths show extremely sluggish habits compared to other forms. Observed in captivity, it may take from 30 minutes to one hour to eat a banana, and then (usually) it will fall asleep for two or more hours—if it does not do so between bites. A great deal of the day appears to be spent in sleep, the animal clinging back downward with body curled in a tight ball. About two-thirds of the time appears to be spent in this manner. In the wild, under conditions of exigency, it may be more active. The three-

toed form is much more sluggish than the two-toed, and it also shows a lower and more variable body temperature.

In captivity in a large open-air pen in the tropics, sloths were observed almost invariably to seek the deepest shade. In the profound depths of the jungle, the temperature is said to vary but little from 80 degrees F. throughout the year, and here the sloth abounds. Its very thick skin and long, coarse, hairy coat are remarkably protective. Such conditions would be ideal for maintaining a uniform body temperature, if little effort were expended in the daily round.

Some dissections that were carried out on sloths proved very interesting. The weight of the stomach (three-chambered in both species studied) and its contents varied between 20 and 25 per cent of the total weight. Even after fasting for several days, the stomach appeared from one-half to three-quarters full, and weighed about 15 per cent of the body weight. All the skeletal muscles, surprisingly, totalled only about 25 per cent of the body weight, in contrast to about 45 per cent in higher animals. Again, the conditions would seem to be related to a rather torpid habit of life. The relatively small amount of muscle tissue would also suggest an explanation of the relative thermal incapacity of the sloth. The long-protracted nursing period of the young sloth—apparently from one to two years, at the end of which time the offspring may be almost as large as the mother—is again in keeping with the above facts.

Wislocki (1933) has discussed the variable body temperatures of sloths and other forms. Gibbs (quoted by Wislocki) and also Kredel (1928) have observed wide fluctuations in the temperature of sloths with outside temperature changes. The contrasting remarkable ability of true homoiothermic animals to withstand cold has been shown (Britton, 1922, 1930), and the importance of glandular mechanisms in recovery from cold has also been emphasized (Britton, 1928).

The sloth is generally found to be extremely hardy under ordinary conditions. It appears, however, to be very poorly adapted to withstand even moderate variations in outside temperature in excess of those of its normal habitat. It may, indeed, be considered as poikilothermic in character. Probably it is not far removed thermogenically from a reptilian ancestry.

SUMMARY

The average rectal, stomach, muscle, and cardiac temperatures in two-toed and three-toed sloths in Panama are 3°–4°C. lower than in most higher mammalian types. The three-toed form, which is much more sluggish, shows a very variable rectal temperature.

Exposure of sloths to moderately cold air (10°–15°C.) results in a rapid loss of body heat. Within a few hours (4–6.5) the rectal temperature may be reduced to about 20°C., and a state of cold narcosis similar to a hibernating

condition may set in. No shivering has been observed. Recovery of normal temperature was possible on exposure to warmth.

Sloths that were placed in ordinary sunshine (35°–40°C.) showed a sharp rise in body temperature to approximately the lethal level (40°C.) in about two hours. Panting and other evidences of hyperthermia were extreme. Several animals succumbed from these experiences. A dead sloth did not cool or warm as rapidly as many of the live animals.

The very sluggish habit of life of the sloth is discussed. It is shown especially that its muscle tissue represents only about 25 per cent of the body weight, i.e. about one-half the amount found in higher animal types. This explains in part its thermotaxic inadequacy.

A number of other tropical animals examined showed no notable temperature-regulating incapacity.

The extremely limited and low-grade thermo-regulatory mechanism shown by two-toed and three-toed Panamanian sloths indicates that these mammals are approximately poikilothermic in nature.

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