Reports

Diurnal Torpidity in the California Pocket Mouse

Abstract. The California pocket mouse, *Perognathus californicus*, compensates for food supplies which are less than the normal requirement by undergoing a variable period of daily torpor. At an ambient temperature of 15°C, the body temperature of a torpid mouse drops to 16°C, and the metabolism falls to 15 percent of the basal rate. Several other species of pocket mice also show this phenomenon.

Many warm-blooded animals undergo a profound seasonal drop in body temperature and metabolic rate. However, quantitative measurements demonstrating daily cycles of torpidity are available for only a few species. Twenty-four hour measurements of body temperatures or metabolic rates have shown that hummingbirds (*Calypte anna* and *Selasphorus sasin*) (*1*), young swifts (*Micropus apus*) (*2*), bats (*Eptesicus fuscus* and *Myotis lucifigus*) (*3*), and birch mice (*Sicista betulina*) (*4*) have diurnal cycles of torpidity. Although these cycles have not been systematically examined in all these animals, they often appear to coincide with times of reduced food supply.

Bartholomew and Cade (*5*) reported that several species of the genus *Perognathus* (family Heteromyidae) show periods of torpor in captivity. I wish to describe the incidence of torpidity in California pocket mice from the chaparral of the California coastal ranges. The five mice used were trapped in the Santa Monica Mountains, Los Angeles County, California, and weighed between 18.6 and 24.3 g (mean, 20.9 g).

The device used to measure the occurrence and temporal relations of torpidity consisted of a pair of 200-ml glass jars connected by an aluminum tube 20 cm long and 4 cm in diameter. Each jar was fitted with a copper-constantan thermocouple junction. The constantan leads from the pair of jars were connected together, and the copper leads were connected to one channel of a multichannel recording potentiometer. Other pairs of jars were connected to the remaining channels. A pocket mouse was placed in one of the jars of each connected pair. When the mouse's body temperature was normally high, heat from its body raised the temperature of the jar that it was in and caused the potentiometer reading to diverge from the null point. If the animal's body temperature was nearly the same as the ambient temperature, the temperatures in the two jars were essentially the same and the potentiometer reading returned to the null point.

The apparatus was placed in a room kept within 0.5° of 15°C with lights on from 0600 to 1800 hours. In each experiment, the animals were weighed and given a measured daily ration of bird seed (14 percent hulls). California pocket mice do not require drinking water. After 7 days the animals were again weighed and then returned to the apparatus, but this time with food available in excess. During a week with food freely available, the mice regained any weight they had previously lost; and then a new series of experiments, with a different ration, was started. In addition, continuous measurements of oxygen consumption were made for periods of 7 days with a Pauling oxygen analyzer on animals housed in 1-liter containers and given 1.5 g of food per day. The temperature and lighting conditions were the same as for the other experiments.

The incidence of torpidity when the mice were given free access to food was investigated by placing the five mice in the paired jars and recording the periods of torpor for 10 days. During this time, six instances of torpor occurred. When the mice were put on a reduced food ration, they exhibited regular daily periods of torpidity, usually starting on the first morning after food reduction but sometimes not until the third morning. In any one experiment, the duration of the torpor period increased on successive days, due both to earlier entry into and later arousal from torpor. When these daily periods were averaged for a particular experiment, the mean period of torpor increased as the food ration was decreased (Table 1). This increase in the duration of torpor resulted from a change in the mean time of entry into torpor, since the mean time of arousal was always between 1130 and 1330 hours. Included in the range of arousal times are the results of experiments in which food was given at 1200 hours or at 1800 hours, or was present continuously; this indicates that the time of feeding did not affect the time of arousal.

Although some mice lost as much as 30 percent of their original weight on the reduced food rations, severe weight loss was not prerequisite to torpor. All five mice showed the typical torpor pattern during a 7-day experiment in which their weight loss was less than 10 percent, and one mouse showed regular diurnal torpor even though its

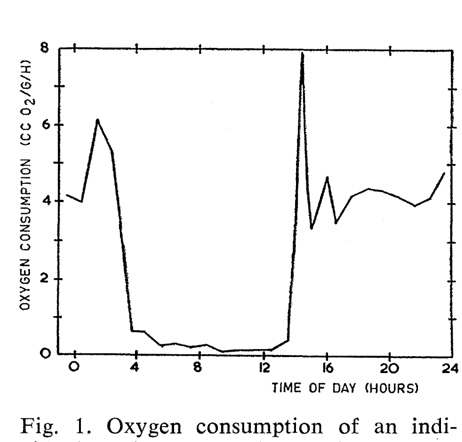

Fig. 1. Oxygen consumption of an individual pocket mouse for 24 hours on a food ration of 1.5 g per day.

Instructions for preparing reports. Begin the report with an abstract of from 45 to 55 words. The abstract should *not* repeat phrases employed in the title. It should work with the title to give the reader a summary of the results presented in the report proper.

Type manuscripts double-spaced and submit one ribbon copy and one carbon copy.

Limit the report proper to the equivalent of 1200 words. This space includes that occupied by illustrative material as well as by the references and notes.

Limit illustrative material to *one* 2-column figure (that is, a figure whose width equals two columns of text) or to *one* 2-column table or to *two* 1-column illustrations, which may consist of two figures or two tables or one of each.

For further details see "Suggestions to contributors" [*Science* **125**, 16 (1957)].

Table 1. Mean time of day for entry into and arousal from torpor. The standard error of the mean is given in minutes in parentheses. The sample size varied from 15 to 35. Weight maintenance in the absence of torpor requires about 3.5 g of seeds each day (17.5 percent mean body weight).

Food ration (g)	Mean time (hr)	
	Entry	Arousal
0.4	2018 (39)	1142 (22)
1.0	2324 (30)	1212 (21)
1.5	0148 (48)	1324 (26)
2.0	0424 (28)	1224 (12)
2.5	0436 (30)	1230 (22)

weight did not change and some of its food was uneaten. All mice remained in good condition during the experiments and survived collectively more than 150 periods of torpor.

The mice showed the same responses during oxygen consumption experiments that they did in the paired jars. Figure 1 is a record of the oxygen consumption of one mouse for 24 hours. All the mice followed this pattern, showing a moderate increase in oxygen consumption prior to the beginning of torpor, and a large increase during arousal. With a few exceptions, oxygen consumption declined smoothly as a mouse entered a period of torpor. This decline continued at a decreasing rate for more than 5 hours before a minimum oxygen consumption of about 0.15 cm^3 per gram of body weight per hour was attained, corresponding to a body temperature of 16°C.

Experiments with other *P. californicus* have demonstrated that mice which maintain high body temperatures (38°C) behave as typical homeotherms. Their metabolic rate reaches a minimum of 0.97 cm^3 of oxygen per gram per hour at an ambient temperature of 32.5°C. Above and below this temperature, metabolism rises. A comparison of the minimum metabolic rate at a body temperature of 16°C and the minimum metabolic rate at a body temperature of 38°C yields a Q_{10} of 2.4, indicating that the depression of metabolism from the basal level to the level in torpor is temperature dependent in the manner typical of biological systems. During arousal at an ambient temperature of 23°C, the body temperature of two mice increased at a maximum rate of 0.67°C per minute.

The major advantage of diurnal torpor appears to be energy conservation. Energy conservation could be of critical importance to a small animal such as *P. californicus* which lives in a region of severe seasonal drought. The effectiveness of diurnal torpor when food is scarce was shown by one mouse which was able to maintain its original weight on a food ration that was only 43 percent of the food required when it maintained a continuously high body temperature.

The genus *Perognathus* contains many desert dwellers. Diurnal torpor should be as advantageous for the desert species as it is for *P. californicus*. I have obtained quantitative measurements of diurnal torpidity in *P. baileyi*, *P. fallax*, *P. flavus*, *P. formosus*, and *P. longimembris*, and other species are known to enter torpidity. Thus, diurnal torpor may be characteristic of the genus (*6*).

VANCE A. TUCKER
Department of Zoology,
University of California, Los Angeles

References and Notes

1. O. P. Pearson, *Condor* **52**, 145 (1950).
2. J. Koskimies, *Experientia* **4**, 274 (1948).
3. O. P. Pearson, *Ecology* **28**, 127 (1947).
4. K. Johansen and J. Krog, *Am. J. Physiol.* **196**, 1200 (1959).
5. G. A. Bartholomew and T. J. Cade, *J. Mammal.* **38**, 60 (1957).
6. These studies were aided in part by a contract between the University of California and the Office of Naval Research, Nonr 233 (61), administered by G. A. Bartholomew.

6 November 1961

Platinized Silver Chloride Electrode

Abstract. A hybrid electrode made by platinizing silver–silver chloride has been found to combine the stable potential and low direct-current resistance properties of a silver–silver chloride electrode with the low high-frequency impedance characteristic of a platinized platinum electrode.

The silver–silver chloride electrode made by slow plating of silver chloride from KCl solution onto silver can be a convenient and satisfactory potential electrode. Its resistance at low frequencies and direct current may reach about 5 ohm cm^2 for a deposit of about 2 coul/cm^2 but increases rapidly with either more or less plating. Platinum black plated onto platinum or other metals is a most satisfactory and widely used electrode for alternating current and transient purposes and may have an impedance less than 1 ohm cm^2 at 1 kcy/sec after a deposition of about 10 coul/cm^2. However, it does not have either a definite electrode potential or direct-current resistance as ordinarily used.

The hybrid electrode was made by first depositing a heavy layer of silver chloride on silver in 0.5*M* KCl with 10 or more coulombs per square centimeter at 2 ma/cm^2 to give a resistance of more than 300 ohm cm^2. It was then platinized in Kohlrausch solution (*1*) with 1 to 5 coul/cm^2 at about the same current density. The electrode was then returned to 0.5*M* KCl, and a small charge was passed in the direction to deposit silver chloride.

The completed electrode then had an equilibrium potential within a few millivolts of that of the original silver–silver chloride with an impedance of a few ohm square centimeters at 20 cy/sec or less, approaching that of a good platinized electrode at higher frequencies.

As additional chloride was deposited from a KCl solution the potential remained undisturbed but the impedance increased rapidly, as if an additional layer of silver chloride were being laid down. With the current flow reversed (that is, in the direction to remove silver chloride), the potential remained reasonably constant until a charge was passed approximately equal to that used to deposit the original silver chloride layer. Beyond this point the impedance remained unchanged at high frequencies but rose at low frequencies and the electrode potential was poorly defined and unstable, as if the silver chloride had been completely removed, leaving the platinum black intact. When the electrode was again plated with chloride, the stable resistance and potential were promptly restored. Cycles of chloride deposition and removal have been repeated, within and about the ends of the useful range, without obvious deterioration of the electrical or mechanical characteristics of the electrode.

The electrode thus approaches the best properties of both silver–silver chloride and platinized electrodes for use from direct current to high frequencies so long as the silver chloride content is not exhausted or does not exceed that at which the platinum black was deposited.

The electrode development was stimulated by the work of Teorell and Wersäll (*2*) in which they used platinized silver electrodes. But their removal of any possible silver chloride by ammonia suggested, contrariwise, that the chloride might serve a useful purpose. Marmont (*3*) described a