of the ratio of the numbers of bacteria retained: (experimental/control). This calculation is designated the relative retention ratio. The differences between the results obtained with the mice subjected to the experimental conditions and those obtained with the corresponding control mice were all highly significant ($p < .001$). Hypoxia, cigarette smoke, and alcohol were introduced and maintained for the first 4 hours following bacterial deposition. Mice, in an atmosphere of 10 percent oxygen (90 percent nitrogen), showed 70 percent clearance and a relative retention ratio of 2.5 (that is, they retained 2.5 times as many bacteria as the controls). Inhalation of cigarette smoke at subtoxic (nicotine) concentrations reduced clearance to 50 percent, and the retention ratio was 4.5. Intraperitoneal injections of 1 ml of 12 percent ethyl alcohol rendered mice stuporous, and clearance dropped to 62 percent, with a retention ratio of 3.6. Cortisone was administered in three divided doses to mice prior to exposure; and at a total dose of 1.22 mg of hydrocortisone (injected subcutaneously) per gram of body weight the animals appeared sick and lost weight. However, they showed 80 percent clearance with a retention ratio of 2.4.

This study offers an effective method for estimating quantitatively pulmonary resistance to airborne bacteria. The method includes: (i) the production of bacterial aerosols of controlled concentrations and particle size from which predictable numbers of bacteria can be implanted in the lungs of experimental animals; (ii) the demonstration of the rapid clearance of the bacteria; and (iii) the measurement (assay) of significant reduction in clearance produced by certain conditions which are often implicated as contributory factors in pulmonary damage and infection. The use of an organism of low virulence which clears rapidly provides a convenient system in relation to time, avoids complicating infection, and lends greater significance to conditions which reduce clearance. In this study, smoke inhalation and alcohol caused most interference; cortisone and hypoxia caused less, but significant, impairment. The disposal of foreign particles from the bronchopulmonary tree is most often attributed to the cleansing actions of the muco-ciliary stream (*3*) and alveolar phagocytes (*4*). With bacteria, immunologic mechanisms must also be considered. Studies of bacterial clearance during the selective blockade of these mechanisms may help to clarify their relative roles in resistance to pulmonary infection (*5*).

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Temperature Regulation and Metabolism in Mexican Freetail Bats

Abstract. *Body temperatures of* Tadarida mexicana *in their natural cave environment were usually maintained at high levels, even when ambient temperatures were low. Oxygen consumption rates were correspondingly higher in low environmental temperatures. However, in laboratory tests, body temperatures and metabolic rates are fairly dependent on ambient temperature.*

Bats of the suborder Megachiroptera have been reported to regulate their body temperatures at fairly constant levels (*1, 2*). In contrast, body temperatures and metabolic rates of resting Microchiroptera can drop to lower levels (*3, 4*). Microchiroptera have even been referred to as poikilothermic (*5*). Although there has been some suggestion that they are not always so temperature labile (*2, 4, 6*), a detailed study of the temperature response of Microchiroptera in nature, particularly of species which appear not to hibernate, seems lacking. The following data were collected on a migratory species, the Mexican freetail bat, *Tadarida mexicana,* under laboratory and field conditions.

Bats from a variety of Texas and Oklahoma caves were studied throughout most of the year 1959. Rectal temperatures (*7*) were usually obtained within 30 seconds after the bat was removed from the cave ceiling. The bat was killed by dislocation of the cervical vertebrae just prior to the measurement. In spite of variations in the ambient temperature between 12° and 36°C, the *Tadarida* usually had resting temperatures (during the day) between 32° and 42°C (Fig. 1). Field observations during the freetail's stay in the southwestern United States and in the winter in Mexico also indicated that body temperatures are usually sufficiently elevated to permit flight. Young bats, incapable of flight, also had rectal temperatures well above the environmental temperature (Fig. 1). Measurements over a 24-hour period in the cave did not reveal any pronounced depression of body temperatures. Although the temperature of freetails is not as stable as in many mammals, it appears to be less labile than previously considered.

Oxygen consumption was measured throughout a 12-hour period in the cave and was found to be consistent with the pattern obtained for the body temperature. Determinations were made by a direct volumetric technique (*8*). Bats were captured as they returned to the cave in the morning and placed in metabolic chambers situated within the cave. The chambers were subject to normal changes in air temperature, noise, and light within the cave, but they were shielded from disturbances created by the operator. Average metabolic rates were higher at colder temperatures; the lowest rates were recorded in the summer months when environmental temperatures were be-

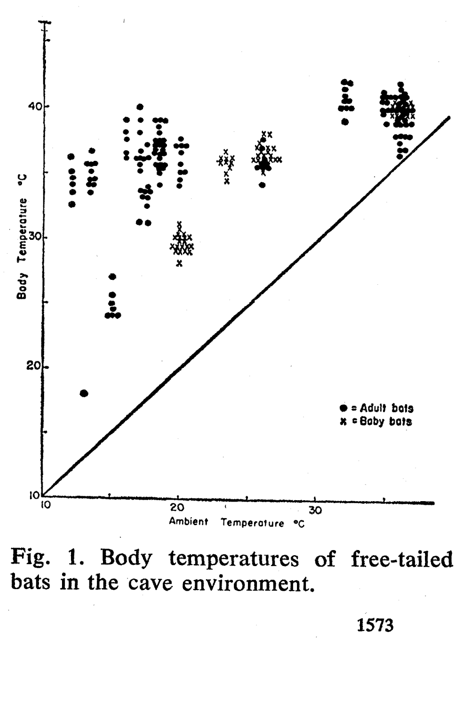

Fig. 1. Body temperatures of free-tailed bats in the cave environment.

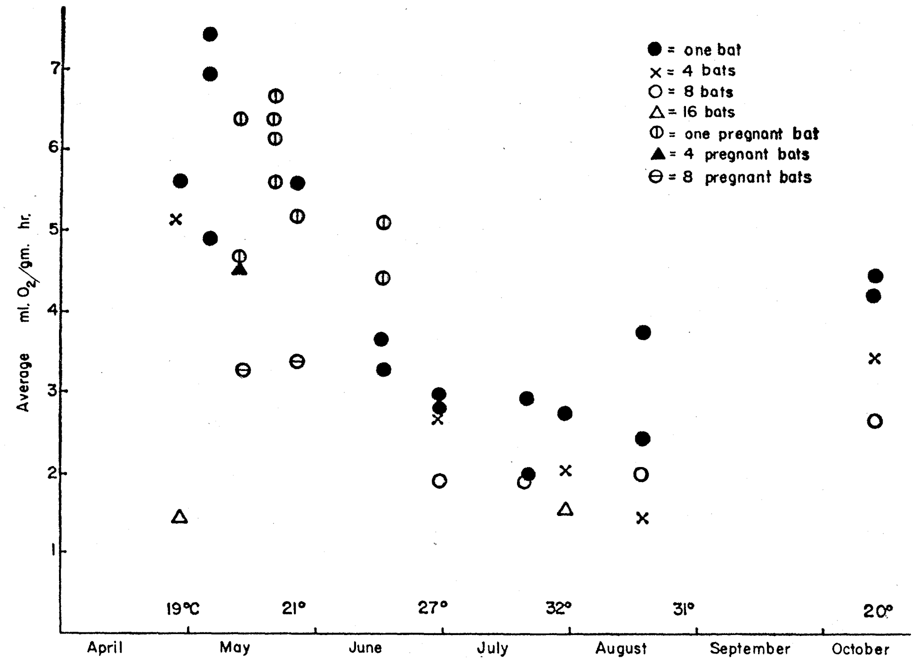

Fig. 2. Oxygen consumption of free-tailed bats in the cave environment at different temperatures and at different times of the year. Measurements were obtained on individual bats and on bats in various size groups.

tween 27° and 32°C (Fig. 2). Additional data on metabolism at temperatures above 32°C might establish the presence of a thermoneutral zone. The zone would include the minimum body temperature which the freetail needs for flight, 31°C (*9*). It would appear that the maintenance of high body temperatures in the cold (Fig. 1) is accomplished by an increase in metabolic rate.

The effects of clustering are probably important in maintaining high temperatures in the cave. Measurements within clusters of bats at various depths showed temperatures between 36° and 41°C during most of the year. The edges and surface of the cluster were generally several degrees cooler than deep within the group. Clustering would reduce heat loss, but this behavior alone is not sufficient to explain the elevated body temperatures of the freetail, since many hibernating bats also gather in large clusters.

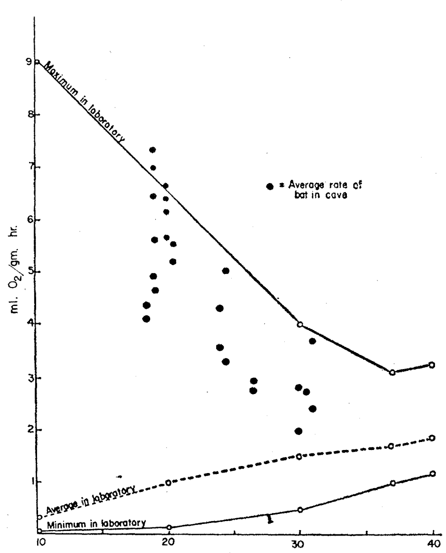

Fig. 3. Average oxygen consumption of individual freetail bats in the cave compared to values in the laboratory (*8*).

Clustering also appears to be responsible for the lower metabolic rates of bats in groups (Fig. 2). This might be interpreted as supporting evidence for Twente's conclusion that clustering keeps hibernating bats cold (*10*). However, this is difficult to reconcile with the fact that bats in groups had higher metabolic rates at colder temperatures than they did at warmer temperatures. Furthermore, Twente's statement that the bats deep in the cluster have colder temperatures than those on the periphery was not borne out by this study, nor has the hibernating form *Myotis sodalis* been noted to have this temperature response (*11*).

When tested in a post-absorptive state in the laboratory (June–November, 1958), *Tadarida* responded differently. Body temperatures were often within a few degrees of the environmental temperature after the bats had been exposed for several hours to the cold (*9*). The average and minimum metabolic rates were directly dependent on the ambient temperature (*8*). The average metabolic rates obtained in the cave were invariably higher than the average rates in the laboratory (Fig. 3). Usually the difference in magnitude was considerable, particularly at the lower temperatures where high metabolic rates were maintained in the wild. The exclusion of the pregnant bats from consideration does not affect the pattern; metabolic rates were not markedly increased by pregnancy. This observation agrees with laboratory results on *Myotis lucifugus* (*12*). A variety of stimuli were present in the cave experiments which were absent in the laboratory tests, for example, the presence of food in the digestive tract. Also, light, sound, and temperature changes within the cave during the day undoubtedly served to stimulate the animals and elevate their metabolic rates. Furthermore, under conditions of mild food deprivation that existed in the laboratory studies, the freetail may be more thermolabile. Such a situation has recently been noted for several species of pocket mice, *Perognathus* (*13*).

The thermolability of the Microchiroptera has been, perhaps, overemphasized and our views should be tempered by the knowledge that the majority of bats are tropical. It seems likely that studies of the latter will reveal a considerable number of species that maintain high body temperatures and metabolic rates over a wide range of ambient temperatures (see *14*).

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