

PANEL 2: DENNING—CONTROL MECHANISMS, SITE SELECTION AND PHYSIOLOG

Physiological Condition of Three Species of Bears in Winter Dens¹

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SUMMARY

The concepts of this paper include:

A. Winter dormancy of the black and grizzly bear is characterized by a slow heart beat or bradycardia more prolonged than that found during the dive of marine mammals.

B. This dormancy of the black and the grizzly bear seems fairly complete with few of these two species active in midwinter. During this period of dormancy, for nearly six months in Alaska, these animals do not urinate, defecate, eat or drink. In a sense their dormancy is more complete than that found in the typical mammalian hibernator which reduces his body temperature and metabolism, but awakens sporadically every four to ten days and may, then, drink, eat, urinate or defecate.

C. Two male polar bears demonstrated that they too have the capacity to reduce physiological functions in midwinter. This was much harder to prove in these animals than in the other two species. Evidence is cited that many polar bears cannot prepare for this period of dormancy by laying down subcutaneous fat. This probably prevents them from taking on this state of dormancy, although it is quite possible that at least for a month at a time even on the Polar Ice Pack, bears may make use of their ability to reduce heart rate and perhaps body temperature and metabolism.

D. The test of the configuration of the EKG pattern has been applied to three species of bears; this pattern appears to be more like that of mammalian hibernators than like that of other types of mammals.

INTRODUCTION

One of the more interesting aspects of the biology of bears in a cold environment is their success in spending the winter in a den. Biologists for some time have debated whether the physiological condition of bears in winter dens is comparable to the typical hibernation found in some mammals such as the woodchuck, hamster and ground squirrel. Typical hibernation includes a lowering of body temperature, heart rate and metabolism, until the body temperature is within about 1 °C of the ambient conditions. Another characteristic of mammalian hibernation is regular awakening in bouts occurring about every four days in the case of the hamster and about every ten days in the case of the ground squirrel (Folk 1966). There is not enough information about the

¹ Research supported by the Arctic Institute of North America under contract with the Office of Naval Research.

winter denning of bears to allow an exact comparison with the other mammalian hibernators; however, such information as does exist shows that the black bear and the grizzly bear undergo a condition of dormancy which is more extreme than that found in typical mammalian hibernators. When the other hibernators arouse to normal body temperature (at periods varying from four to ten days), they often urinate, defecate and eat. The bear in typical winter dormancy does none of these. Thus, it seem to have a digestive and excretory system better adapted for winter dormancy than do the more typical hibernators. There has been debate as to how to generalize about the dormancy of bears in the winter den, because some of these animals when disturbed in midwinter do become quickly and vigorously active. Because of this and because the female gives birth to her young in midwinter, some biologists have presumed that there is very little decrease in physiological activity. Professor Raymond J. Hock¹ on the other hand believed there was enough reduction to warrant a new term, 'winter lethargy', to be used for bears, instead of hibernation (Hock 1960). It remains to be seen whether this term is justified and will stand the test of time.

The present paper will review our knowledge of the condition of bears as they go into hibernation and their physiological status as they remain there, and will indicate those lines of research which would be most productive for the future. In the facilities of the Naval Arctic Research Laboratory and the Arctic Aeromedical Laboratory, we were able to record by Iowa radio-capsule (Folk 1964) the body temperature, heart rate and the EKG of denning grizzly, black and polar bears. The observations of the first year have previously been reported (Folk 1967). The results from years two, three and four on the same black and grizzly bears, and studies on two polar bears, will be reported here.

DENNING OF BLACK BEARS

Conditions

Black bears in the northern United States are apt to go into dens in early October (Erickson 1964). Most of them appear to remain active until the ground is snow-covered. The location selected varies considerably. Most bears favor dens dug beneath logs, or in holes dug into hillsides. Some of these dens are lined with vegetable matter. Male bears tend to den later than females and young bears. In the sample described by Erickson, the excavated dens and the unprotected ones are the most interesting. Twenty-one per cent dug a hole into a hillside, 46% dug a hole under stumps or logs, and 7% lay down in an unsheltered depression.

¹ Professor Hock was a pioneer worker on the physiology of winter denning of bears and other aspects of hibernation. He built a series of cage-den units at the River Laboratory of the Arctic Aeromedical Laboratory in about 1955 and did a fundamental series of experiments on the metabolism of bears in the winter condition. These cage-den units are still in use for studies on bears. In late summer of 1970, while carrying out a field program in Grand Canyon, Professor Hock was killed by an unusual accident as a portion of a tree fell upon him. It is suitable in this article to call attention to the extensive contributions he made to knowledge of mammalian hibernation.

Some observations of black bear denning in Alaska will be helpful. Most dens which have been described have been under logs, but Dr. Robert Weeden guided us to a den dug in the south side of a hill outside of Fairbanks (Figs. 1, 2). The digging of a den by a black bear has more significance in this area because of the presence of permafrost. Because of the ambient temperatures encountered in Alaska, it is more likely that black bears would seek deep shelter than in the lower 48 states. The radiant contribution of heat from the earth must be much more important in Alaska than in other locations; this contribution to the comfort of the animal in extreme cold seems important enough to include the following physical measurements:

- a. In the Weeden den the ground temperature without the animal occupant was repeatedly -9°C when the air temperature was -46°C .
- b. In a simulated den made from insulation material, the radiation from the earth warmed the air six inches from the ground to -8°C when the outside air temperature was -47°C
- c. When ground temperature was measured under the snow alone and the air temperature was -40°C , the ground temperature remained at -9°C .

This radiant heat from the earth would be as important in a grizzly bear den in Alaska as in a black bear den.

Physiological State

The body temperatures of large animals such as bears can drop only with difficulty if they remain quietly resting in a reasonably warm location in hibernating position (Fig. 3). Even with cellular metabolism reduced to the minimum because of lack of specific dynamic activity and exercise, still the surface mass ratio of a large animal would delay cooling under the conditions of maintained cellular metabolism and a very heavy insulation. It is not surprising that the lowest figures obtained for body temperature of denning bears are as follows: Morrison 37.9°C , Hock 31.0°C , Rausch 33.0°C . By radio-telemetry we confirmed these readings, showing a body temperature drop of the same order of magnitude. Part of the reason that investigators have obtained high body temperatures in midwinter may be the time of day of locating the animals. It could be that a lower body temperature might be found at midnight. We reported earlier the day-night rhythm of body temperature of the black bear during the month of October and during the month of December; there was a high during the day and a low during the evening. As the winter progressed there was only a slight drop in average body temperature but the daily rhythm showed a lower amplitude.

The most striking and important results from the radio-telemetry were the changes in heart rate of the bears as winter dormancy progressed. The summer sleeping heart rate was usually higher than 40 beats/minute. As fall progressed this heart rate in three individual black bears became lower at least during part of the day and eventually during most of the 24 hours. Sequentially over several weeks, heart rates below 30, then 20, then 10, and finally 8 heart beats per minute were recorded. These particular black bears did not urinate or defecate for at least three months. After this time they were artificially aroused. The significance of these physiological observations will be discussed later.



Fig. 1 View of den excavated by black bear, Fairbanks, Alaska, on the Weeden property. The den is on the south slope of a hill in a hardwood forest.



Fig. 2 Interior of the black bear den showing claw marks. Den was two meters deep and one meter in diameter. Tracks in snow provided proof that the bear wintered there.

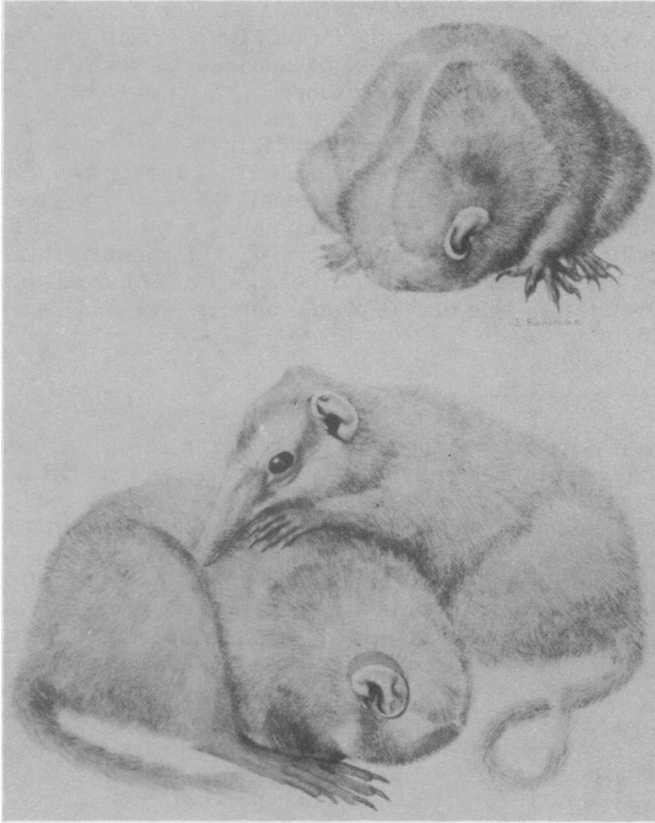


Fig. 3 Sleeping and hibernating position of mammals, illustrated by the Phillipine Tree Shrew (not a hibernator). Note especially the single shrew. We have no photographs, but our 250 lb black bear was observed (unobscured by bedding) in hibernating position all winter. On some occasions he lifted his head.

DENNING OF GRIZZLY BEARS

Conditions

There is remarkably little information about the denning of grizzly bears in Alaska. Many hunters have disturbed these animals in winter dens but have not described in the open literature the dens themselves. The grizzly bears of McKinley Park appear to behave as a marmot or groundhog and dig directly and deeply into a hillside. All dens described and measured by Adolph Murie (1963) were constructed this way. Dens of a similar type have been reported by Lentfer (1967) and Pearson (1968). The bottle-shaped dens are much alike so that we may call their construction an inherited stereotype den-construction pattern like that found in rodents and birds. It appears to be a characteristic of the grizzly bear species. Presumably, the animal benefits a great deal

from the earth as a heat sink to the outside environment. The time of denning in northern Alaska may extend from about the first of October until the end of April. Considering the lack of use of the kidney, bladder and digestive tract, this does indeed represent a remarkably long time of dormancy. The three grizzly bears studied both at Point Barrow and at the Arctic Aeromedical Laboratory were allowed to remain in dormancy until they came out of the dens spontaneously. We demonstrated that these grizzly bears for two winters did not urinate or defecate for periods of time extending from four to five months. We do not know exactly how often such animals get out of the so-called hibernation position, but it was certain on some occasions that these bears as well as black bears did not raise their heads when we moved close to the cage noisily. We were even able to take photographs with flashbulbs without the animals raising their heads.

Physiological State

The heart rate change in dormancy of the grizzly bears was similar to that of the black bears. With three of these individuals we were able to study this condition for three consecutive winters. One animal was left undisturbed for each of two winters for as long as five months (Figs. 4 and 5). The heart rate changes and daily rhythms were very similar to those of the black bear. Our usual handicap in this program was the failure of the implanted transmitters as the winter progressed. During one winter an experiment was done to test the complete reliability of the radio-transmitters implanted in these animals. Twice during the winter the grizzly bears which were in dormancy together

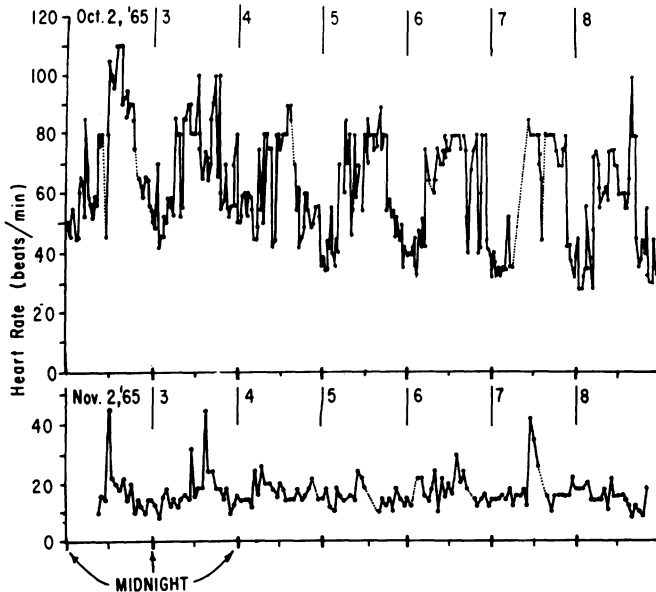


Fig. 4 Heart rates recorded daily every 30 minutes showing the dormancy stages as grizzly bear ('Blondie', 175 lb) went into winter-den condition. Sleeping heart rates began at 40 b/m, became 30 b/m, and by November, were 8-10 b/m.

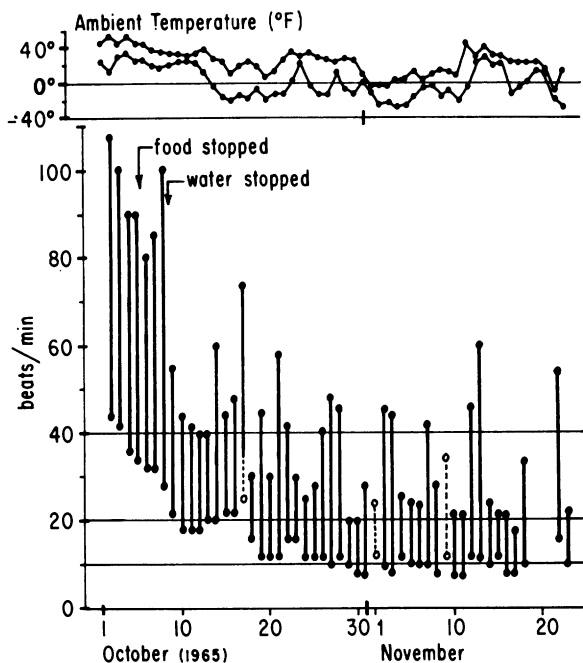


Fig. 5 Example of graphing of maximum and minimum heart rate to represent daily activity of a grizzly bear. Note that the animal went into dormancy in the middle of October. To obtain such records, 48 half-minute records were made each day all winter, on 4 bears.

were awakened and stimulated to test for maximum heart rate recording from these capsules. The capsules provided as high values in winter as in summer.

Fat Storage for the Winter

Part of the preparation for winter dormancy by the black bear and the grizzly bear consists of increasing food consumption and laying down adipose tissue. There have been no careful observations of how much is deposited where it would act as an insulating material and how much is laid down in other areas such as around the kidney. One would presume that this harboring of energy reserves is essential to bears before becoming dormant. In those cases of black bears and grizzly bears being found in midwinter in an active wandering state, they have been thin and without depots of fat. The essential point for the development of this paper is that black bears and grizzly bears usually find the resources to accumulate calories in the form of fat. This does depend upon the availability of food which has certain seasonal and year by year variations. For example, the inland grizzly bear is presumed to make use of berries, roots and grass in the fall to accumulate fat, although berries are the most important. If these are in scarce supply, it would be harder for both of these species to lay down fat for the winter. This concept of food availability and accumulation of fat is important in the comparison of the biology of the polar bear with these two species.

DENNING OF POLAR BEARS

Conditions

The first question to ask about the polar bear is whether its diet is ever comparable to the other two species. Its range must partly decide diet. There are several reports of polar bears nearly 1,100 miles from Point Barrow in the vicinity of the North Pole (Table 1). It is apparent that some polar bears are found at all times of the year at long distances from land. It is also true that some polar bears wander inland at all seasons, not only just before the season of dormancy. It is reasonable to suppose that the population of bears found well out on the ice do not travel the distance of perhaps 300 to 400 miles to a different habitat when winter approaches. For convenience we may refer to ice polar bears as one group, and shore polar bears as another. According to Perry (1966) many shore polar bears prepare for winter in the same way as black bears and grizzly bears; they wander inland and eat large quantities of vegetable matter. Then they return to remain along the shore all winter. Presumably, this population has accumulated much fat as winter approaches. This is not always successful. Peter Sovalik, of Barrow, describes several incidents of very thin polar bears found in midwinter on the shore so hungry that they would attack and eat dogs regardless of the presence of a hunter. It would appear that they had not accumulated the necessary threshold quantity of fat in order to become dormant, when food was scarce.

The ice bears at some distance from land may be quite successful in stalking seals so that they, too, put on depot fat, but this must be difficult compared to the ease with which black bears and grizzly bears fatten up on vegetable matter. It is possible that most ice bears are male bears and non-breeding females. If this is true, then the cubs listed in Table 1 were over a year old. Perhaps the situation of these ice bears is a vicious circle in which they find it difficult to lay down fat and therefore must keep active most of the winter.

There are more descriptions of polar bear dens than there are of grizzly bear dens. Harington (1968) reports that these dens along the shore are apt to contain two-year-old young males or females, and with or without the mother. Peter Sovalik describes, as many other have, the den of a mother and two cubs, in the Colville Delta, approximately 30 miles from the ocean shore. An Eskimo family had camped very near this den all winter without any clue to the presence of the mother and cubs. Sovalik's description of den size, and lack of fecal matter or urine, coincides with those published by Perry. Two questions now remain. What is the physiological condition of those polar bears which do remain in the den most of the winter, and how many polar bears make use of such a physiological mechanism?

Physiological State

The physiology of polar bears is of particular interest because of their extreme adaptations, uncertain status as a species, and because of questions concerning their relationship to grizzly bears and black bears. As stated above, we had determined that a conspicuous bradycardia (reduction in heart rate) exists in the grizzly bear and black bear when in a condition of dormancy in the winter den. We looked for the same phenomenon in two captive male polar bears maintained together under winter den conditions during the winters of 1967-68 and 1968-69. This study was technically difficult to make because of the value of the specimens and lack of information on how to predict the behavior of the animals. They were deprived of food and water, the standardized procedure for inducing dormancy in these experiments with bears. During

TABLE I. UNUSUAL SIGHTINGS OF POLAR BEARS IN MID ARCTIC OCEAN*

Time	Observer	Ice Island	Position ‡	Position	Type of Bear
Spring	Hanson (1963)	Arlis II	86. 5	175E	Female
October	Hanson (1963)	Arlis II	88. 5	160W	Female, cubs
May	Hanson (1966)	T3	75. 5	155W	Female, cubs
September	Hanson (1959)	Alpha II	77. 8	171. 5W	Adult bear
September	Hanson (1959)	Alpha II	78	171. 5W	Female, cub
September	Hanson (1959)	Alpha II	78	171. 5W	Seventh bear collected on this station.
—	Perry† (Page 117)	—	88	—	Female, cubs
—	Peary*	—	86	—	Adult
—	—	Alpha I	84	—	Adult
—	Malmson (1970)	—	84	—	Adult
—	Malmson (1970)	—	83	—	Adult
May	Buck (1970)	Arlis V	74	161W	Female (fat)
May	Buck (1970)	Arlis VI	75	168W	Male, adult. Nine other sightings (N = 3) seen here.

* Data provided by Dr. Mzx C. Brewer from the logs of several floating ice islands.

† Perry, 1966

‡ Degrees north

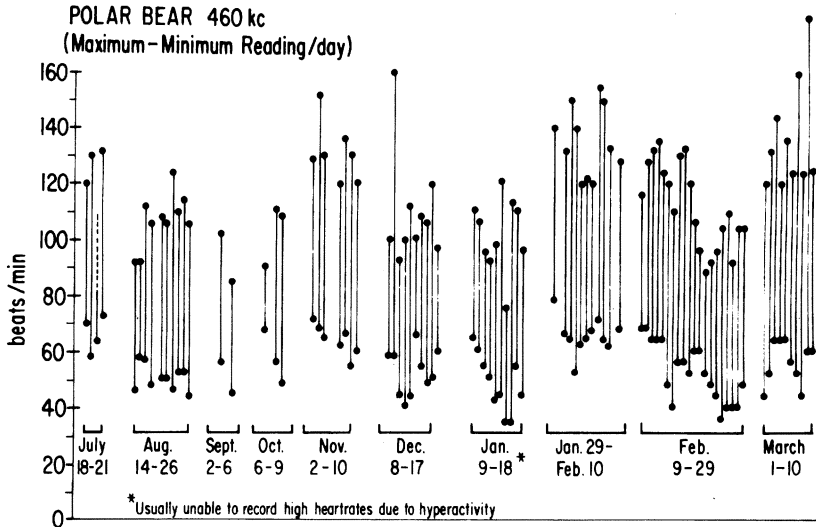


Fig. 6 Polar bear maximum and minimum heart rates during their first experimental winter; they were frequently disturbed by accidental visitors.

the first summer, sleeping heart rates of one specimen were seldom as low as 50 b/m. During the winter, bradycardia was gradually acquired by this specimen until a rate of 35 b/m was achieved (Fig. 6). At this point the experiment was terminated because of uncertainty as to whether one animal might attack the other. During the second summer, the other male polar bear (weight 260 kg, 570 lbs) was instrumented. This specimen showed no sleeping heart rates below 60 b/m during the months of July, August, and September. From October to the end of January the animals were observed by closed circuit television and were provided with minimal food. Their behavior indicated the possibility of dormancy, and during the month of February rigid conditions to simulate denning in the outdoor environment were followed (complete darkness, isolation from camp noise, abundant hay in which to prepare winter dens, and removal of food). The temperature of the enclosure varied from -20°C to -50°C . The instrumented animal once again initially demonstrated sleeping heart rates of 60 b/m which changed slowly week by week until rates of 27 b/m were obtained. The steady downward trend undoubtedly would have continued since both animals remained in the position of dormancy (head under belly near tail). However, on 1 March, one month after the experiment began, the radio-capsule in the abdominal cavity of the animal failed. The results from these two winters are strong evidence that the polar bear has the capability of reducing its circulatory activity in dormancy in the same fashion as the grizzly and black bear.

Discussion of Special Case of Polar Bears

Our physiological observations show that the polar bear is capable of the same dormancy as the other two species (in spite of the deplorable instrumentation hazards which always beset the individual who uses radio-telemetry). It should be emphasized that during the next winter (the third) with reasonable conditions of quiet and isolation and lack of light (although with a warmer temperature

than desirable), the same two polar bears did not go into dormancy. A few feet away there was another building with the same noise conditions, about the same temperature conditions, and the same conditions of lighting, in which a 750 lb grizzly bear did become dormant for approximately five months. This observation and similar data lead us to believe that it may not be as usual or as easy physiologically for a polar bear to enter dormancy. If we once again contrast ice polar bears as a population and shore polar bears, one must consider that at least for a month at a time, the ice bears could dig a snow tunnel or cavern that would be suitable for dormancy. As a rule, probably the ice would shift about this den after about a month had passed. A longer time of denning is unlikely because the storage of fat for insulation and reserve energy supply is probably very different in the ice compared with shore populations. This was specifically checked by Ken Bennington, who necropsied seven polar bears which came upon the ice island, Station Charlie. These bears were collected throughout the year, from April to January. What impressed him the most was the complete lack of adipose tissue under the skin. Only one skin needed a small amount of work to flesh off the subcutaneous fat. These observations and others (see Perry) lead us to believe that ice bears are not prepared for winter dormancy and must usually continue hunting. Shore polar bears both male and female, on the other hand, undoubtedly possess the insulation and stored fat to remain many months in the winter den. Although we have shown metabolic and circulatory reduction in both male and female captive bears, the physiology of a female bear which is nursing young is completely unknown. At times our dormant bears of all three species did show a day-night rhythm of variation, although at other times the readings were flat. Probably the female while nursing her young shows the same day-night variation or at least a cycle determined by the nursing periods. Note especially, however, that no nursing polar bear den has contained evidence of feces or urine. It is remotely possible that the mother would eat the feces, but surely not the urine. Apparently the female polar bear in dormant condition — complete lack of use of kidney, bladder and digestive tract from October to April (Harington 1968) — will give birth to young and nurse them.

DISCUSSION OF THE PHYSIOLOGICAL CONDITION OF WINTER DORMANCY IN ALL THREE SPECIES OF BEARS

What is the advantage of a reduction in heart rate during winter denning? We must report a complete lack of success so far in measuring blood pressure, cardiac output and blood flow in a bear in dormancy. Professor Van Citters and his team, of the University of Washington, did the appropriate operations to determine this on two of our grizzly bears, but after receiving the transducers and while wearing the radio packs, the animals did not get into the dormant condition.

First we must accept the situation that the bear is showing a bradycardia which is similar to the diving bradycardia seen in swimming mammals including man. Scholander (1964) has shown that stroke volume does not change during diving bradycardia, that this bradycardia is under the control of the vagus and can be blocked by atropine, and the blood pressure does not rise. In addition, if diving bradycardia is prevented, a seal will quickly die under water in a very few minutes. We reconstruct the situation then that the bradycardia-associated mechanism which permits an Arctic seal to remain under water for 15 minutes, is also helpful to the bear in dormancy. Although the bear's body temperature is not reduced very far, this high percentage of reduction in circulation would be reflected in a lower oxygen consumption if the suppositions

and experiments of Whalen (1965) are correct. This hypothesis is supported by the direct measurements of Raymond Hock (1960), who demonstrated a 50% reduction in oxygen consumption by his bears in dormancy in spite of the fact that the body temperature reduction was only 4°-7°C.

The present state of development of electronic equipment will not yet permit the measurement of blood flow and cardiac output of bears in dormancy; we intend to pursue the subject by means of body temperature radio-capsules distributed throughout the body. The explanation of this experimental approach is that associated with the bradycardia of diving marine mammals is a compartmentalization of the circulatory system (Folk 1966). Circulation is mostly restricted to the anterior half of the animal's body (Folk 1966); the animal in a sense makes itself into a heart-lung-brain preparation. This is also the case in the mammal when in hibernation and while awakening from hibernation. We presume that this compartmentalization would be of advantage to the bear in dormancy.

SPECIAL CONSIDERATION OF LIPID METABOLISM

One of the more important and profitable areas to be investigated in the winter dormancy of bears concerns fat deposition in the fall, because apparently dormancy depends on it. The scanty data which exist are mostly based upon weighing bears before and after a period of dormancy. The loss of weight during this time could be mostly due to insensible water loss.

Weighing fat masses is also unsatisfactory because over the winter the mass can slowly be replaced in part by water, yet the weight might remain roughly the same. More observations are needed by biologists because we lack information on where lipid stores accumulate. There are numerous patterns of fat distribution in animals preparing for winter: the seal apparently accumulates fat only under the skin; the sea otter apparently does not add any fat at all under the skin; some mammals accumulate large inguinal fat pads (hamster), while other mammals do not (opossum). One must ask also whether the accumulation of fat depots are really intended for utilization during the winter or are primarily important for the animal when it emerges in the spring.

Is fat used during dormancy of the typical mammalian hibernator? At least fat metabolism as a source of energy during periods of stress produced by starvation and cold-exposure has been established. A respiratory quotient of 0.7-0.85 has been reported in bears, bats and marmots during cold-exposure. This figure is indicative of fat catabolism.

The utilization of stored lipid from adipose tissue during hibernation or long periods of dormancy is not well understood. There are discrepancies in the amount of winter body loss, amount of depot fat mass loss, and above all the quality of depot fat loss (weight of fat masses may not be a clue). It appears that animals capable of hibernation or dormancy may not all undergo a period of fall fattening prior to winter. Some rodents which are termed hibernators hoard food, while still others fatten *and* hoard food (Cade 1964). Still other hibernators (bats (Ewing 1970), marmots, black bears, 13-lined ground squirrels) do not hoard food, but increase their weight by fall fattening. Morrison has reported data on one dened bear in which adipose tissue was over 40 per cent of the body weight (Hock 1960). Many more measurements should be made through the skin with a depth gage (Fig. 7).

The increased amount of adipose tissue has been presumed to serve two functions: a) a stored energy source is available and b) the insulation of the animal is effectively increased. It is known that hibernators such as the Arctic ground squirrel lose 30 per cent of their body weight during hibernation, but it is not known what per cent of this loss is water or lipid (Hock 1960; Landau 1960). The black bear may lose 15-20 per cent of its total weight while in its winter den (Hock 1957; 1960). In these animals this loss could be due to mobilization of stored fat for energy, but there are few figures for known loss of just adipose tissue. Beer (1956) states that his bats lost 70 per cent of their fat in mid-November.

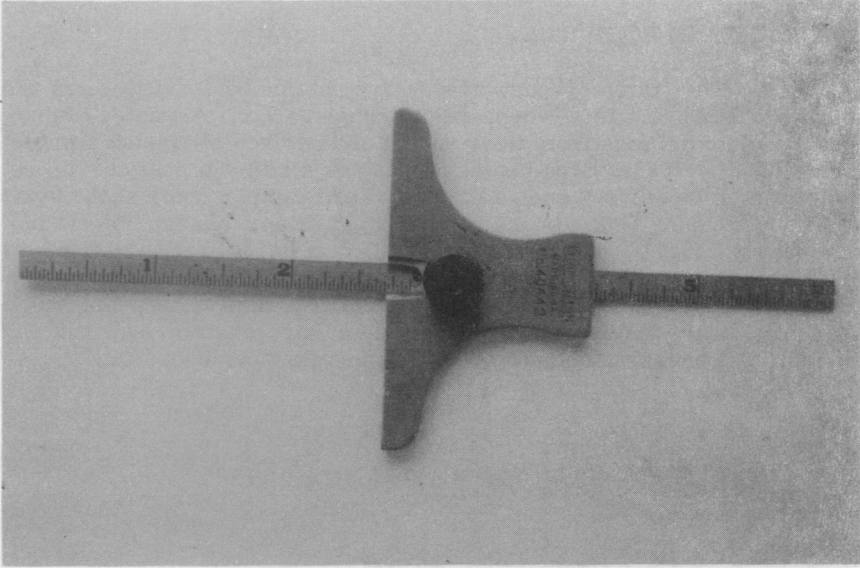


Fig. 7 Machinists depth gage as used for measuring back-fat on live animals. An incision is made through the skin, the ruler is slipped through the fat to the muscle, and the slide is run down to the skin. The procedure was totally satisfactory on seals and polar bears. The standard positions for measurements on live hogs is 2 inches from the mid-line, at the first and last ribs, and last lumbar vertebra.

An interesting point is the observation by hunters which indicates bears do not become very lean and hungry until after 2-3 weeks following arousal from their dens. This must indicate that fall fattening serves yet a third purpose: that of protection from starvation following arousal before food is secured. This leaves in question the importance which has been attached to fattening in relation to survival of long periods of dormancy.

It is apparent from the literature that a more extensive study of lipid utilization by bears during dormancy is needed. Many of the analytical procedures (thin-layer and gas-liquid chromatography) which have been used successfully with other hibernators (hamster, bat, etc.) are readily adaptable to bear adipose tissue (Kodama 1963; Kodama 1964; South 1967; Williams 1967). Both qualitative and quantitative utilization of individual fatty acids could be followed

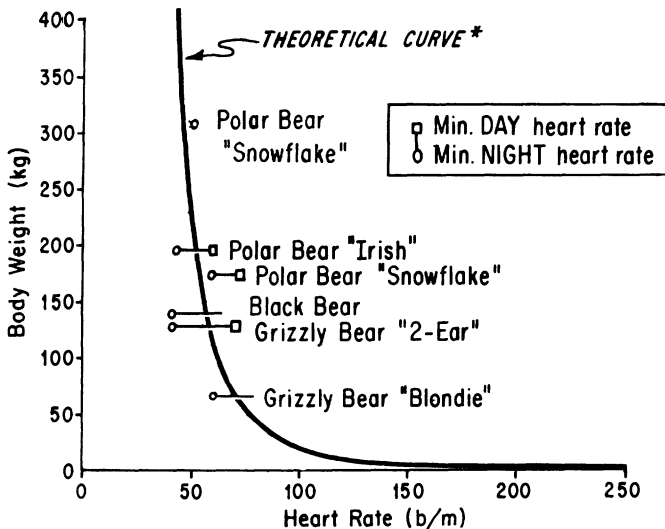
throughout the year on wild caught or killed bears of different species. It is quite possible a study such as this might reveal the true value of fall fattening to a 'hibernating' bear.

In summary several questions can be posed with respect to the value of fat deposition to a hibernator. Is there a preferential utilization of certain adipose depots during different physiological conditions of the animal? Is this preference extended to certain saturations or chain-lengths of fatty acids? Finally can an animal's activity during winter be predicted from his fall metabolic behavior?

HEART RATE AND BODY WEIGHT

When resting heart rates of a new animal are obtained, it is customary to fit them to previous heart rate-weight relationships. Clark attempted to predict the heart rate of animals from their weight and derived the formula presented in Fig. 8 (Kleiber 1961). Even before plotting on his theoretical curve, one suspects there will be curious contradictions. For example, many of the heart rates of our sleeping 500 lb bears were 50 b/m. Many human subjects of approximately 150 lbs who are not athletic have a heart beat of 50 b/m. The summer sleeping beat of our woodchucks is 50 b/m (weight approximately 12 lbs). Another problem is that none of the studies in the literature of heart rate and weight of bears takes into account whether they were thin bears in mid-summer or fall bears which had put on 100 lbs of subcutaneous fat.

HEART RATE VS. BODY WEIGHT IN BEARS



* $beats/min. = 1400W^{-0.27}$ (Clark, 1927)

Fig. 8 An expanded end of the curve which shows the relationship between heart rate and body weight.

A further problem in the measurement of basal heart rates is the time of day at which the measurements are made. The sleeping heart rate of the bear is undoubtedly lowest both in the free environment and in captivity from approximately 10 p.m. in the evening until perhaps 6 a.m. However, bears can sleep deeply during the daytime. We believe that there is a physiological setting for most mammals by day and by night so that all physiological readings may be higher at one time of the day than they are 12 hours later. Therefore, it is difficult to accept from the literature sleeping heart rates unless one knows the day-night rhythm of the animal. To be specific, we are certain that at times we observed our grizzly bears to sleep with a heart rate of 50 b/m near midnight but to be in a deep sleep with a heart rate of 70 b/m near noontime. We have, however, made use of what information is at hand by plotting noon and midnight values of some of our bears. There is a reasonably good fit of this data with Clark's theoretical formula. We had mentioned earlier that totally different mammals may have a sleeping heart rate between 40 and 50 b/m, and I presume that it is the smaller animals that are the exception to the rule, and not the larger bears.

IS THE BEAR A HIBERNATOR

One may judge at this point that the extreme reduction in heart rate, digestion and excretion, and a partial reduction in body temperature and in metabolism, indicate that the bear at least semi-hibernates. There is one more bit of evidence to explain the relationship of the three bear species to other mammalian hibernators. It is accepted that hibernators have a very short Q-T segment on the EKG pattern. This means that if we consider that the EKG pattern is made up of three spikes for each heart beat, then the third spike is closer to the second one in mammalian hibernators than it is with the rest of the mammals. There is one exception to this generalization which is that mice and rats also have a short Q-T segment. We have begun to look for evidence in the three species of bears for the presence of a short Q-T segment. Since this segment might change with increased heart rate in the individual, we have attempted to accumulate data only from mammals which are resting or asleep. Most of the species have been tested by radio-telemetry in our own laboratory. Results are expressed as the QT : RR ratio; the line of best fit through the origin represents a constant ratio in spite of variable heart rates (Fig. 9). Points off the line represent a Q-T segment which is shorter than that found in typical mammals. This is apparent in the EKG record of a polar bear (Fig. 10). One hibernator (Arctic Ground Squirrel), the bears and their relatives (the raccoons) depart from the constant ratio. There are two departures from this generalization. The bats are hibernators and although they fall on the line, they may represent the beginning of a hibernator line representing a different ratio from that of ordinary mammals. The other exception is the Arctic fox, a non-hibernator. There is a reasonable explanation for this. The heart beat of the fox, and the daily work of the heart of the fox is entirely different from that of other mammals. This relationship has been discussed in detail in an earlier paper (Folk 1963). The heart of the fox must rest approximately every half hour, then it may change to a heart beat of five times resting value for a brief time and then return to baseline. So far we have found no other 'heart' which shows this behavior; perhaps it explains the occurrence of the fox Q-T segment which is similar to that of hibernators and the bear group rather than that of typical mammals.

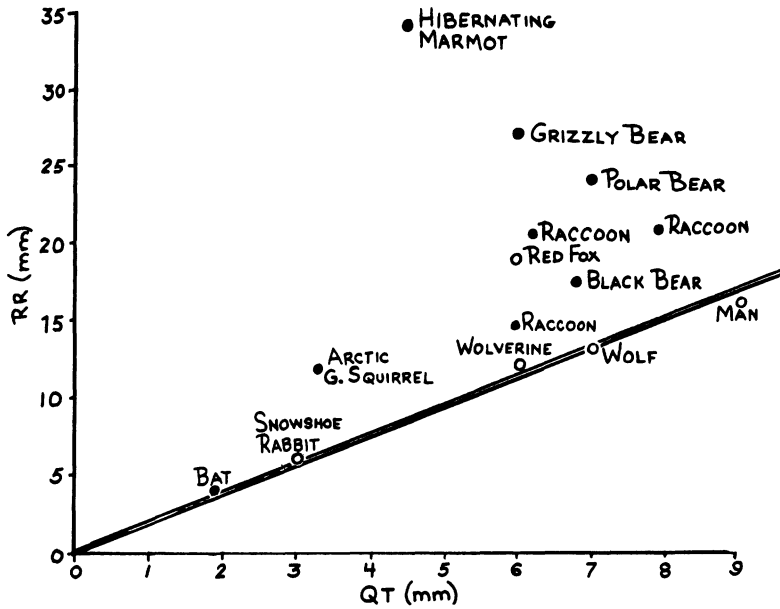


Fig. 9 EKG intervals of mammals. Note departures from the usual constant ratio between heart rate (RR interval) and QT interval. Hibernators have an unusually short QT interval.

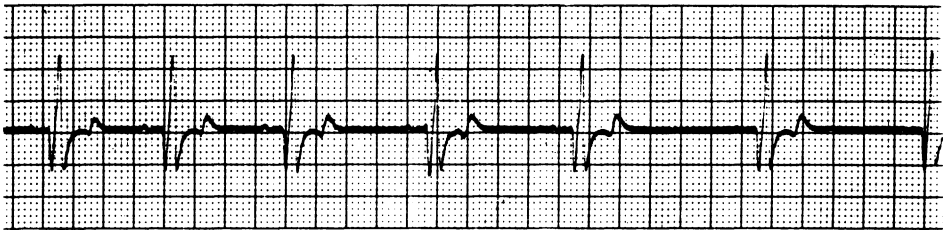


Fig. 10 EKG pattern of polar bear weighing about 660 lbs recorded by Iowa radio-capsule (long-life, short range, implanted in peritoneal cavity).

We conclude that this evidence from the Q-T segment supports the position of the bears having an intermediate relationship between hibernators and non-hibernators.

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