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The Theories and Physiology of Hibernation

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ONE of the most interesting phases of the life history of any animal is its life in the winter when conditions of temperature and food supply are generally very adverse. The fact that some animals have the ability to meet these conditions by hibernating gives them a particular interest to not only the naturalist, but the physiologist and anatomist as well. In recent years a great deal of interest has been given to this field in respect to its surgical application, especially in the field of cardio-vascular and cerebral surgery.

THE PHENOMENON OF HIBERNATION

The life processes of a hibernating animal are slow. They take little or no food and only a fraction of their normal requirement of oxygen. There is a comparable summer dormancy, called estivation, resorted to by various animals during periods of excessive drought and heat.

Very distantly-related animals may respond similarly to winter temperature. Whirligig beetles and black bears agree in being "light sleepers," though their mid-winter stirrings hardly compare in results. Closely related species, on the other hand, may react very differently to temperature. Chipmunks may remain continuously dormant through their whole hibernating period; red squirrels now and again awake from their sleep and come out in mid-winter, while grey squirrels are out and about the entire season.

True hibernators appear to be in a deep sleep. While they are dormant, chipmunks and ground squirrels lie with their eyes closed and their bodies tightly curled up. On the other hand, dormant wasps hold themselves strictly straigtened out, their bodies, legs and wings held stiffly parallel. Hibernating animals breath slowly and unevenly, their temperatures approaching that of the environment and fluctuating with it. In his studies of the 13-lined squirrel, Johnson in 1928 found that during ordinary active life this squirrel respires 100 to 200 times per minute; its heart beats 200 to 350 times per minute; and its body temperature ranges from 32 to 41° C. However, during hibernation it may breathe as seldom as once or twice per minute or even less; its heart beats only about five times per minute and its temperature drops almost as low as that of the air surrounding it.

Although they may appear entirely lifeless, hibernators are in general quickly sensitive to handling and to changes of temperature or other stimuli. Torpid woodchucks grasped suddenly and thrown into water have begun to swim immediately. According to one worker, hibernating bats that were brought into a warm room began drinking water before their temperature had risen to that of the room.

A loss in the water content of the body is a characteristic preparation for hibernation and has been rather widely observed. In insects this preliminary drying out of the tissues is apparently a necessary preparation for dormancy. Insects can endure continuous freezing. Snails, spiders and insects that have been encased in ice crystals and solid masses of frozen soil for weeks at a time become normally active when thawed out. But they cannot survive alternate freezing and thawing as well. No vertebrates have been known to survive having been completely frozen. Frogs frozen into the solid ice of shallow ponds have often been known to survive; however, in experimental tests the bodies of those similarly frozen into blocks of ice have been found to be only incompletely frozen.

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PHASES OF HIBERNATION

The Entering Phase. The process of entering into hibernation is not a rapid one. It does not take place within an hour or two, and the attainment of the actual deep hibernating state may take anywhere from a few days to a month. Benedict in his book, *Hibernation and Marmot Physiology*, mentions some observations made on woodchucks which were entering into hibernation. It was found that the animals first became lethargic and uninterested in the general surroundings, as long as they were not in danger. Usually the animal's eyes were open and it was not in the characteristic curled-up or ball-shaped position of deep hibernation. Frequently the animal would appear to be sleeping but the noise of someone entering the room would cause it to raise its head.

The process of entering hibernation may be considered to take place in steps, for the woodchuck returns to its original awake condition at least once after its initial drowsiness. The period of initial lethargy varied from a few hours to four days, after which the animals returned to the normal awake state. Usually the second step into the semi-hibernation state occurred from one to five days after this first drowsy period. Some of the woodchucks maintained this second drowsy state for only a day or two and thereafter the condition reappeared every two or three days. The time after the initial period, until the animals went into deep hibernation, varied from three days to a month. At no time did the animals hibernate before food was removed from their cages.

Benedict, from his experience with the woodchuck in hibernation, would base his definition of hibernation on a lowering of the body temperature to within a few degrees of the environmental temperature and accompanied by a profound decrease in the heat production. Deep torpor representing these conditions is usually found only with small animals ranging from the ground squirrel to the woodchuck. True hibernators in deep hibernation remain in a comatose condition throughout their period of confinement.

Bears differ greatly from the woodchuck. Even when asleep and unirritable, they cannot be in true hibernation because they do not have a low body temperature and low heat production.

The Awakening Phase. The process of awakening from hibernation involves a marked increase in metabolism. In the ground squirrel, the body temperature may rise from 2° to above 30° C., respirations may increase from one per minute to about 150 per minute and the pulse rate may rise from 5 per minute to about 300 per minute. The anterior part of the body recovers from lethargy earlier than the posterior part. There is violent trembling and shaking. The awakening phase is completed within one or two hours from its initiation. The animal is considered to be fully awake when the eyes are opened; however, they appear to gain control of their other senses by as much as five or six minutes earlier.

PHYSIOLOGY OF HIBERNATION

Body Weight. Many references in the literature indicate actual gains in weight have been made during deep hibernation when the animal is not partaking of any food. These earlier observations implied that there is a great consumption of oxygen during hibernation, so great that there is an absorption and retention of oxygen in the body. Later, it was shown that any gain in weight is primarily due to adsorption of water on the fur of the animals. Benedict measured the weight loss of woodchucks during the time the animals were actually hibernating and found that it amounted to 0.2 grams per day per kilogram of body weight.

Body Temperature and B. M. R. The rectal temperature of hibernators when not in hibernation is quite labile. In the woodchuck it ranges from 34-39° C. On the other hand, in normal hibernation the rectal temperature of the woodchuck, at a constant environmental temperature, is always found to exceed the surrounding temperature by from one to three degrees. The body temperature may go as low as 3° C. after which it is possible for the animal to return to its warm-blooded state. It reacts slowly to the environmental temperature, but follows it in a general way.

The minimum basal metabolism of the non-hibernating animal is 410 calories per unit of body surface per 24 hours. During hibernation the absolute minimum heat production is 17 calories per unit of body surface per 24 hours; although, 27 calories per unit of body surface is the average minimum attained by most of the animals. The low values of the heat production are not accompanied by the lowest rectal temperatures, but frequently are observed at rectal temperatures of 8 to 12° C.

Insensible Water Loss. The water loss due to insensible perspiration in the normal non-hibernating animal at an environmental temperature of about 17° C. averages 7.2 grams per kilogram of body weight per 24 hours and 15.7 grams per kilogram of body weight at 31° C. For the woodchuck in deep hibernation the insensible water loss is approximately 0.2 grams per kilogram of body weight per 24 hours. Although an average is given here for the insensible water loss it is so small that it is of little significance since it is profoundly influenced by changes in the humidity.

Heart and Respiration Rate. The non-hibernating woodchuck has a minimum heart rate of 80 beats per minute and an average minimum respiration rate of from 25 to 30 per minute. In deep hibernation the minimum heart rate is 4 to 5 beats per minute and the minimum respiration rate is 0.2 per minute, the average being not more than 1 per minute.

Respiratory Quotients. In the non-hibernating woodchuck 48 hours must elapse after the animal eats to insure respiratory quotients of 0.71 which is the quotient one observes when fat is the sole source of energy. A respiratory quotient of 0.70 is obtained in the hibernating woodchuck which would indicate that the sole source of energy is fat.

PREDISPOSING FACTORS TO HIBERNATION

Environmental Temperature. Of all the major contributing factors inducing hibernation, cold and the lack of food or hunger have received the most attention. It is agreed by all workers that the animals must be placed in a cold environment. The optimum temperature is commonly stated to be from 10 to 11° C. However, animals have been kept for weeks and even months at temperatures of 10 degrees without hibernating. This emphasizes the point noted by many writers that cold is not certain to produce hibernation and that some other factor or factors enter into the initiation of this phenomenon. The conclusion can be drawn that cold, per se, is in general a contributory factor but not of itself sufficient to cause hibernation.

Lack of Food. The second most generally accepted condition is that the animal should be without food. This is almost invariably mentioned as a cause, yet, the opposite point of view is frequently held. It is a well-known fact that animals rarely hibernate in zoological parks. The normal explanation of this is that the animals always have plenty of food before them. This would suggest that when food is available there would be no hibernation. A close study of the natural habits of the woodchuck shows that they frequently take edible material such as hay into their burrows for bedding. In fact, they have been known to bring hay to the mouth of their den to be eaten on awakening, thus anticipating the need for food. Present evidence indicates that the absence of food is probably on the whole contributory, but not absolutely essential to hibernation.

External Stimuli and CO_2. The absence of external stimuli, either touch or sound, has been advanced as a contributory cause to induce or maintain hibernation. The theory that the accumulation of carbon dioxide in the burrow, producing an autonarcosis, as an important factor in hibernation has largely been refuted by Benedict as has the theory of complete darkness being a facilitating factor.

THEORIES OF HIBERNATION

Many theories have been offered on the phenomena of hibernation. Early workers believed there was a so-called "hibernating gland" in the vicinity of the thymus in the cervical region. This is now generally regarded as adipose tissue which aids the animal to survive the long confinement period. Some investigators have associated hibernation with the nervous system, while others consider an inefficient heat regulating mechanism to be the true explanation. Others have thought certain anatomical peculiarities such as the enlarged character of the heart, thorax and central blood vessels or the smallness of the peripheral vessels and lungs to be the cause. More recent evidence would indicate that the endocrine glands probably should be included under a general theory of a hypo or hyperfunction as the cause of hibernation. However, there is no convincing evidence that the endocrines exert a dominant role in the onset of hibernation. It is quite obvious that scientists do not have any adequate explanation of the mecanism of this phenomenon, nor how it became established in certain animals.

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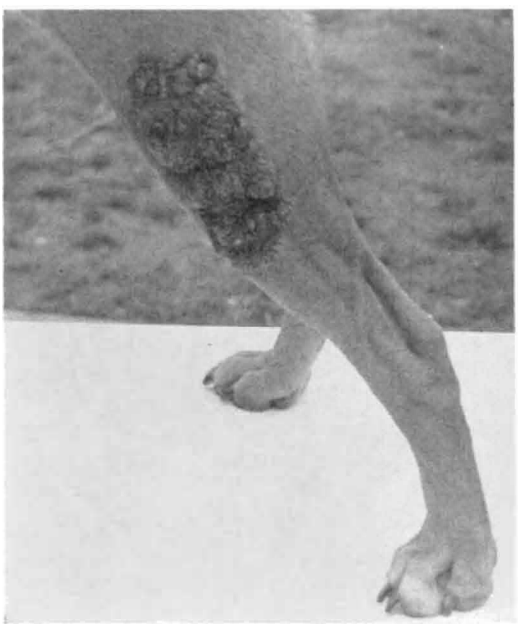
4. Subcutaneous tissue: lipoma.

Skin Manifestations in the Course of Infectious Diseases.

1. Virus infections: pox, virus papular dermatitis in horses, contagious ecthyma, infectious goat dermatitis, foot and mouth disease, vesicular stomatitis, vesicular exanthema of swine, coital vesicular exanthema in horses, rinderpest, cutaneous strangles, hog cholera, distemper complex, pemphigus, scrapie.
2. Bacterial infections: impetigo, pyogenic dermatitis, contagious dermatitis in horses, swine erysipelas, anthrax, malignant edema, tuberculosis, glanders, ulcerous lymphagitis in horses and dogs (Nocardiosis).



Pyogenic dermatitis

Skin Disorders Caused by Fungi. Dermatoses of fungal origin may be classified as follows:

1. Blastomycoses: equine blastomycosis, canine blastomycosis.
2. Dermatomycoses: ringworm—tinea. Microsporum group: Microsporum canis, M. gypseum, M. audouini. Trichophyton group: Trichophyton equinum, T. mentagrophytes, T. verrucosum, T. schoenleini, T. gallinae.
3. Cutaneous moniliasis: Monilia albicans.
4. Mycetomycoses. actinomycosis, actinobacillosis, farcy of cattle, streptothricosis in dogs, botryomycosis.
5. Sporotrichosis.

Skin Manifestations of Protozoal Origin.

1. Babesiosis. 2. Surra. 3. Mal de Caderas. 4. Dourine. 5. Leshmaniosis. 6. Spirochaetosis.

Dermatoses Associated with Helminthes.

1. Nematodiases: rhabditidiasis, ancylostomiasis, bunostomiasis, parafilariasis, stephanofilariasis, habronemiasis, dirofilariasis, dracunculiasis, onchocerciasis.
2. Trematodiasis.

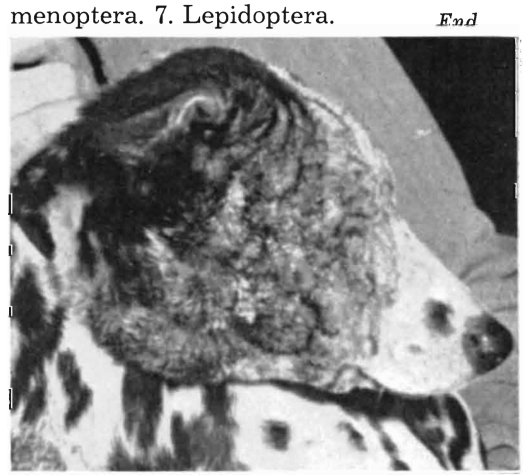
Acarine Dermatoses Associated with Ticks and Mites.

1. Ixodes acariasis. 2. Dermanysus acariasis. 3. Trombiculidiasis. 4. Sarcoptic acariasis: Genus sarcoptes, genus cnemidocoptes, genus notoedres, genus psoroptes, genus chorioptes, genus otodectes. 5. Demodectic acariasis.

Dermatoses Caused by Insects.

1. Pediculosis. 2. Siphonaptera. 3. Diptera. 4. Hemiptera. 5. Coleoptera. 6. Hymenoptera. 7. Lepidoptera.

End



Pustular and phlegmonous form of Demodectic mange.

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