

**THE PHYSIOLOGY OF HIBERNATION AND SOME
KINDRED PROBLEMS.**

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When as a boy I learned that woodchucks slept for the winter, going without food during the entire time, I was curious to know how they could do it. Some thirty years passed by before science was able to offer a satisfactory answer to my boyhood enquiry.

To properly understand the physiology of hibernation, emaciation, starvation and the source of metabolic water during hibernation, one needs to keep in mind the modern story of the changes in the food as it gradually and inevitably is transformed into living protoplasm.

The complex foods eaten by animals are greatly simplified in the digestive canal as they come in contact with the several ferments or enzymes. The older term, ferment, from *ferveri*, to boil up, is at present being set aside for the more technical word, enzyme. Whatever term is used for these peculiar substances is unimportant. They are able to act apart from the gland or cell which produces them. Each enzyme is specific in its action. After the digestive enzymes have simplified the several foods, they probably are of little further use to the living organism that produced them. It is believed that the larger amount of the several digestive enzymes passes off with the undigested residue. This is cited as one of the economical wastes in the living body.

After the food has been digested, it passes through the inner membrane of the intestinal wall into the blood. While the food is circulating in the blood, it is in a chemical form quite distinct from that of the digestive canal, even after digestion is completed. Just what the agents are that cause these changes we do not fully understand at present.

This naturally brings us to refer briefly to one of the brilliant discoveries of modern physiology. I refer to the discovery of the internal secretions. We now believe that no set of cells is free from the production of its own internal enzyme. These internal enzymes serve to make the combinations of the nitrogenous and nonnitrogenous food molecules more and more like those that exist in the living protoplasm. This does not mean that we know exactly the molecular composition of living protoplasm, but rather that some of the more elementary relations are

being comprehended. The action, then, of the internal enzymes is just the reverse of the digestive enzymes.

With this brief resume, we may now come directly to our problem. During hibernation, the muscle tissues are the ones that become lighter in weight. The muscle is largely protein with more or less of fat intercolated between the fibers. Hence there must be some agent that circulates in the blood that acts in a manner distinct or characteristic for this period. For during the summer and early fall, the muscles are becoming heavier.

Without going into the historical development of the series of remarkable experiments and researches associated with this problem, we may say that the general conclusion is that the internal enzymes act like digestive enzymes with the result that the protein and fat in the muscle are torn from their summer relation and set free to be used in that part of the body demanding energy. This action of the part of the enzymes is described as the reversibility of enzyme action.

I may illustrate their similar action in starvation by a personal experiment that was tried on *Amia calva*, the bow fin, an inedible fish that is common in the Great Lakes. The experiment started accidentally when one year I had a few live fish left over as the class finished studying this phase of the course. They were simply left in the basement aquarium in a tank of running water and without food. On my return in the fall, there were a number of the fish alive. This suggested a number of problems that have not yet been completely worked out. From time to time, unfed specimens were killed and their tissues examined. There was no difficulty in keeping *Amia* a year without food, and one was kept twenty months. During this long period of enforced fasting, the fish were at all times active and swam freely. The main external change was a great reduction in the muscle tissue of the tail and back regions. When the muscles were studied in detail, it was found that the cell walls of many of the individual fibers were entirely empty, while adjacent to these empty cells were complete and partly complete muscle cells.

A chemical examination of the normal and starved fish showed the same general proportions of the proteins in each. Nor did a chemical analysis of the blood of normal and starved animals show any marked differences in composition.

The explanation is the same as in hibernation. The fact that some of the muscle cells were destroyed does not change the method by means of which they were broken down. Here there

was a severe drain for the necessary energy to keep the body alive.

These two phenomena make it easy to understand how the human body can lose so much weight in a few days when suffering from a high fever. Here the body is taking no food and is utilizing an unusually large amount of energy. The energy that causes the high body temperature must come from some material substance. It does not come from the food as none is taken to speak of. There is a stress and high tension throughout the body. In imagination, we can picture these unknown chemical bodies, the internal enzymes, running hither and thither searching for more fuel to burn. There is an abundance of it in the fat of the body. This is seized first as the most readily accessible supply. If the demand continues after the fat is gone, the protein in the muscle is torn down to furnish the necessary vital energy. Truly, modern physiology has become as interesting as a story.

Intimately associated with food energy for hibernation is the source of the metabolic water. I believe that it may be safely assumed that the hibernating animal takes neither food nor water. We know how necessary water is to the living protoplasm. Where does it come from? The necessary metabolic water comes from the same source that it does during the active summer life of hibernating animals. As the carbohydrates and in part the proteins are finally utilized, one of the by-products of the splitting up or off process is water which is then taken into the living protoplasm. The usual water drunk is utilized to carry off wastes rather than to enter into the living relation.

MAKING AN ARTESIAN WELL PUMP ITSELF.

The field men of the United States Geological Survey, in their investigations of the ground-water resources of the Virginia Coastal Plain, have observed that the flows from many artesian wells in that region are utilized to drive hydraulic rams for the purpose of lifting the water to higher levels. Along the lower courses of the Potomac and Rappahannock and along the shores of the many inlets that run back from Chesapeake Bay above the James, there are hundreds of artesian wells that supply a perennial flow of beautifully clear water which is, as a rule, excellently adapted to all domestic uses and is largely utilized by the canning factories and other industrial establishments that abound in that part of the country. Though the pressure of the water from the wells is ample at the shore level, the head diminishes so quickly with increase in elevation that no flow can be obtained along the higher banks above the shores where the water is most needed. One method of obtaining it at these higher levels is to use the force developed by the artesian flow to operate hydraulic rams, which in turn raise the water to the heights desired along the bluffs above the river and inlets. Thus it may be said that the artesian wells pump themselves.—*U. S. Geological Survey Bulletin.*