CORRESPONDENCE

TEMPERATURE TOLERANCE OF BIRDS' FEET

THE EDITOR OF THE AUK:

We love our mysteries. On the one hand, a scientist does his best to reduce mystery to commonplace fact, by research. On the other hand, the same scientist reads mystery stories. This is quite all right, as long as the two interests remain separated. Zoologists, including ornithologists, are warm-blooded animals. If they walk barefooted in subzero snow or dangle their bare feet in ice water, they soon suffer acute discomfort. Birds are also warm-blooded. Some birds walk barefooted in subzero snow and others dangle their feet in ice water. Since we would be uncomfortable, so must they be. We love our mysteries.

During the past many months, while making library and other studies of metabolism and animal-heat loss, I have repeatedly encountered scientists who interpret the animal's thermal adaptations and responses in terms of their own (that is, man's) adaptations and responses. For this and other reasons, the literature dealing with the thermal lives of animals is crowded with serious error. The mystery of the barefoot bird in wintertime points to some of the error.

In The Auk for July, 1945, under General Notes, Norris-Elye writes of Canada Jays that joined the hot-stove league. The jays would fly into a tent, land on a stove top, and stand there for from five to eight seconds. "The heat was sufficient to make a drop of water flash into steam." This is an interesting and valuable observation, and we need more like it. The trouble comes in the analysis and interpretation. Norris-Elye, speaking of this phenomenon, and of ". . . why the feet of birds do not freeze in subzero temperature," assumes a ". . . marvelous insulation against the transfer of heat possessed by these birds." He says: "The answer is obviously insulation against heat loss. . . ." This interpretation simply makes a bad matter worse. The mystery will be heightened rather than cleared up by looking for marvelous but nonexistent heat insulation in or on bare toes and tarsi.

A few statements of fact are in order.

1. If a bird succeeded in maintaining bare toes and tarsi at body temperature when getting about in subzero weather or when the feet are in ice water, the rate of heat loss would be so great that the bird could not eat enough energy in the form of food to make up for the loss and also maintain bodily functioning. This is not an opinion. It is a fact, based on computations the writer may some day publish elsewhere.

2. The bird is under no necessity for maintaining body temperature (or anything like it) in the feet. In fact, it is under the absolute necessity of permitting these parts to adopt nearly the temperature imposed by cold surroundings; otherwise, it would die from excessive heat loss.

3. Adaptation to cold exposure requires, and is in part accomplished by, a complete or nearly complete stoppage of blood circulation in the feet. This statement is supportable from all standpoints: (a) very little muscle or other tissue requiring a blood supply is to be found in these parts: (b) when these parts drop to low temperatures, metabolism in them almost ceases; (c) if much blood continued to flow, much heat would be lost.

4. Survival of the bird's tissues at low temperatures can be better appreciated by knowing what human tissue can stand. Human tissue, removed from the

body, can live for long periods at 4° C. (39.2° F.). In the 'whole' human being, limbs can go for long periods, with little or no circulation, at a refrigeration-anasthesia temperature down near 0° C. (32° F.). The longest record of this sort, recently reported, was that of a limb so maintained for 79 days. The limb was saved. If we wish, we might think of the bird foot in winter as being in a state of refrigeration anasthesia, but still operable as a tool—with its tendons pulled on by muscles sufficiently warm in their location closer to the body.

5. Bats survive a *body* temperature of —1.7° C. (29° F.) without injury (G. M. Allen, 'Bats': 274, Harvard Univ. Press, 1939).

6. With the blood supply withdrawn, little water is present in the bird foot and tarsus. No damage can be done until actual freezing occurs. The tissue freezing point would be several degrees below 0° C. (32° F.), and it might, in some species, be many degrees below.

So much for low temperature toleration. Returning to the Canada Jays, how can they stand on a stove top for several seconds? First, they did. Second, there need be no mystery about it.

Assume that the bird flies in, with feet at 0° C. (32° F.), and lands on a stove surface having a temperature of 120° C. (248° F.). There would be contact or near-contact, by nail tips and by callosities on the toes. Assume a callus is one millimeter thick. Adopt reasonable values of thermal properties for the callus material. Compute (by methods not included here) the temperature to which the living tissues would come, by virtue of heat conducted through the callus to interior toe tissue. The writer's figures show that, within the five to eight seconds cited, such tissue would just about reach the danger temperature of perhaps 44° C. (111° F.) in this time and for these circumstances.

Other parts of toes and tarsi not in contact with the stove would be heated by radiation and natural convection. Computation readily shows that these parts would take a still longer time for the living tissues to reach a lethal temperature. Thus, the time limit appears to be set by contact parts, rather than noncontact parts.

It should be understood that there is no magic by which these heat problems can be solved accurately. Some of the basic data needed have to be assumed, and the answers have a margin of error. However, the computations do show whether the phenomenon is reasonably possible.

Close observation might show that when the jay's foot is cold and stiff, it does not fully open. If only the nail tips touch the stove top, the surface could be well above 120° C., without injuring living tissue in five to eight seconds.

Some proper lines of investigation are easily indicated. How cold can a bird's foot become before tissue freezing occurs? Can the bird operate the foot, at least awkwardly, at any temperature short of tissue-freezing temperature? Is the foot richly or poorly equipped with heat-sense and cold-sense nerve endings? Is the heat-sense inoperative when the foot is very cold? If so, harmful scorching could ensue when a stand on a very hot stove is made. Is there a cold-sense mechanism present that does not result in feelings of discomfort, but does warn the bird that the feet are about to freeze; or is it simply that stiffness causes the bird to cease activity, whereupon the feet are drawn up and warmed enough to be saved? How does leg and foot circulation vary with the temperature of the parts (a job best done, perhaps, with tagged atoms)?

As far as I know, not even a start has been made to look into any of these questions.—A. D. MOORE, *University of Michigan.*