Physiological Research in Northern Alaska

G. EDGAR FOLK, JR.[1]

Considering field physiology as a whole, long and continued search for information about the Arctic might be classified informally as: I. The Pemmican and Scurvy Period; II. The Birdskin and Plantpress Period, and III. The Experimental Period. In naming the third period I am trying to create a picture of a third wave of workers moving to and over the Arctic Slope with their slide rules and telethermometers.

One cannot separate the accomplishments of these three periods of work nor limit them in time (Table 1). For instance, the Pemmican and Scurvy Period is still with us today; at the time of writing, this can be illustrated by the British Trans-Arctic Expedition of 1968-69 which is in Class I., yet Wally Herbert and his team also belong in the Experimental Period because they are collecting physiological data.

Table 1. Key Dates in Arctic Physiological Research, Canada and U.S.A.

1881	International Polar Expedition 1881-1883 (Lieut. P. H. Ray).
1913	Canadian Arctic Expedition 1913-1918 (Vilhjalmur Stefansson).
1917	University of Alaska founded.
1921	First journey for physiological anthropology (Levine).
1947	Arctic Research Laboratory established at Barrow (U.S. Navy).
1947	Arctic Aeromedical Laboratory established at Fairbanks (U.S. Air Force).
1948	Arctic Health Research Center established by U.S. Public Health Service.
1952	Ice islands manned by NARL.
1958	Aircraft began to be used extensively by NARL for oceanographic, gravimetric, magnetic and biological research.
1963	Institute of Arctic Biology opened at University of Alaska.
1963	Inuvik Research Laboratory established.

One of the early explorers who had an interest in physiology was Lieutenant P. H. Ray: during his 1881 expedition he made nutritional observations on the Eskimos at Point Barrow. Nutting (1893) is an example of a naturalist of the Birdskin Period with physiological interests. His expeditions were motivated by the hope of discovering the physiological stimulus for the migration of birds to areas thousands of miles to the south; his hypothesis and data on wind direction were new and substantial.

Stefansson, who by 1918 had spent five and a half years on the arctic ice pack and tundra, has been called a nutritionist and physiologist; he had received his training at the University of Iowa. The next author to publish definitively on arctic physiology was Levine (1937) whose first expedition began shortly after

[1]Department of Physiology and Biophysics, The University of Iowa, Iowa City, U.S.A.

the founding of the University of Alaska (1917). Later he made ten more expeditions above the Arctic Circle, collecting samples for studies on the nutrition of native peoples; he introduced an important area of work which he named "Physiological Anthropology". His point of view has influenced every anthropology department in the country. Levine, called "Vitamin Vic" by his friends, had a sparkling personality; his genius resulted in 200 papers being published in his lifetime. His field studies were launched from Omaha, Nebraska.

Laboratory-based research work began at Barrow in the 1940's. What types of scientists were responsible for this invasion of a land formerly dominated by whalers, fur traders, oilmen and construction workers? Were they physiologists? The early publications in 1948 by M. C. Shelesnyalk included surveys of the work of all types of scientists including those who worked on such topics as polar ice and oceanography. Apparently (to add a competitive note) *physiological* work was undertaken earlier: Laurence Irving in 1942 published a paper on carbon monoxide in snow houses and tents. He also wrote a review in 1948 of the biological investigations at Point Barrow. Irving's research party was followed by others, resulting in a continuous stream of published physiological investigations from Point Barrow since the mid-1940's. Some of the types of information obtained are listed in Table 2. In each of these physiological areas substantial publications have been completed in separate projects by about four scientists. Their presence at the Naval Arctic Research Laboratory represented considerable bustle since most of them brought research assistants and graduate students for

Table 2. Physiological Studies on the Arctic Slope.*

Mammals	
Blood Analyses	Levine, Musacchia, Wilber and Musacchia (1948), Allison.
Nutrition	Stefansson, Levine, Rodahl, Drury, Milan.
Energy Metabolism	Levine, Irving, Hanson, Fisher.
Fat Metabolism	Stefansson, Levine and Wilber (1949), Irving, Pitts, Wilber, Rodahl.
Circulation	University of Iowa Team (Folk *et al.* 1966).
Temperature Regulation	Irving, Scholander, Hock, Strecker and Morrison (1952), Milan (1962), Henshaw.
Animal Navigation and Sounds	Griffin, Schmidt-Koenig, Poulter, Mellen.
Eye Physiology	Janes (1966), Scholander, Iowa Team.
Reproductive Physiology	Musacchia, Hart, Mayer.
Biological Clocks	Lobban, Iowa Team, Andrews *et al.* (1968), Boland.
Bird Physiology	
Nutrition	Irving, West, Cade.
Temperature Regulation	Irving, West, Gessaman.
Photoperiodism	Nutting (1893), Farner.
Soil Organisms	
Growth of Bacteria	Boyd.
Plant Physiology	
Photosynthesis in continuous light	Tieszen.

* If no date is given, the author's works may be found in *Arctic Bibliography*.

training. Many of these students have returned to work on their own projects, and some of the topics, which are listed in Table 2, deserve special comment: 1) Blood analyses for vitamin content or for blood group studies; much of the large body of data accumulated resulted from work initiated by that colourful researcher, Victor Levine; 2) Nutritional data were obtained from both native peoples and military personnel stationed in the Arctic so that the caloric cost of living in a hostile environment could be described; Stefansson made many contributions in the field of arctic nutrition, as did Rodahl; 3) Energy metabolism is typified by attempts to determine the difference between the basal metabolism of natives and non-natives, and by the present-day exciting and fundamental work on the metabolic turnover of cesium and strontium, by Hanson (see Palmer and Hanson *et al.* 1963); 4) Fat metabolism will always receive much research attention because of the high fat diet in the Arctic (Rodahl and Issekutz 1965); one intriguing question is whether the Eskimos can eat only fat without demonstrating ketosis; 5) Temperature regulation obviously represents the most important physiological topic in the Arctic (Irving 1948); 6) Studies on animal navigation were introduced by Griffin (1952), and exciting data have been contributed by Poulter and others more recently on the communication of sea mammals under the ice; 7) Studies on eye physiology, which lead to an understanding of snow blindness, were introduced by Janes *et al.* (1966) and by Scholander; 8) Very early studies on reproductive physiology were begun by Musacchia (1954) on arctic and temperate zone animals because of the obvious question as to whether continuous light and the extreme cold on the Arctic Slope would alter the reproductive cycles of a species of mammals also found much farther south; 9) Investigations on the measurement of time by animals are often referred to as studies of biological clocks; Mary Lobban (1958), at an early date, realized the possibility of a real alteration or confusion of man's biological clock by the action of continuous light; she introduced definitive and basic studies on natives at the Point Barrow laboratory in 1956 showing that their physiological clock was different from that of people in the temperate zone. Similar work was done on non-natives (Lewis and Masterton 1955) and white rats (Folk 1959). I have limited these remarks to work on mammals but comparable information has been obtained in the areas of bird physiology, microbiology and plant physiology.

Following are some examples of the types of physiological data obtained. Fig. 1 illustrates a very grumpy-looking grizzly bear that carries a radio-capsule in his body cavity to broadcast body temperature and heart rate during the long winter months when he is taking a vacation from life's problems by going into dormancy (Folk *et al.* 1966). From this animal and seven others (including black bears and polar bears) came proof that bears in winter dens show more of the characteristics of true hibernation than was formerly believed (Figs. 2, 3 and 4).

Several months after the polar bears in Fig. 2 were photographed, two new radio capsules were placed in them; these transmitted physiological data for one year and 1.5 years respectively. During the third summer and winter of carrying radio capsules, each of the bears weighed approximately 570 pounds.

The same order of results as those shown in Fig. 3 were obtained on three black bears and two other grizzly bears. During the winter of 1968-69, similar data

FIG. 1. Five-year-old grizzly bear, repeatedly studied with radio capsules. For three summers and winters this animal carried Iowa Implantable EKG and Body Temperature Capsules. During the winter of 1968-69 it also carried three blood flow transducers. In spite of the presence of this electronic gear, not to mention the surgical operations, the bear weighs 670 pounds.

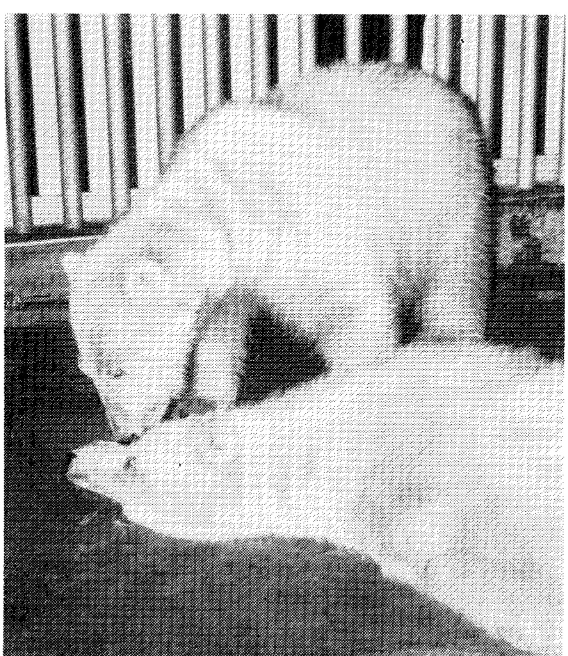


FIG. 2. Two polar bears carrying radio capsules at two years of age. One is unconscious from ether anesthesia, and the other bear is anxiously attempting to awaken it by licking its mouth.

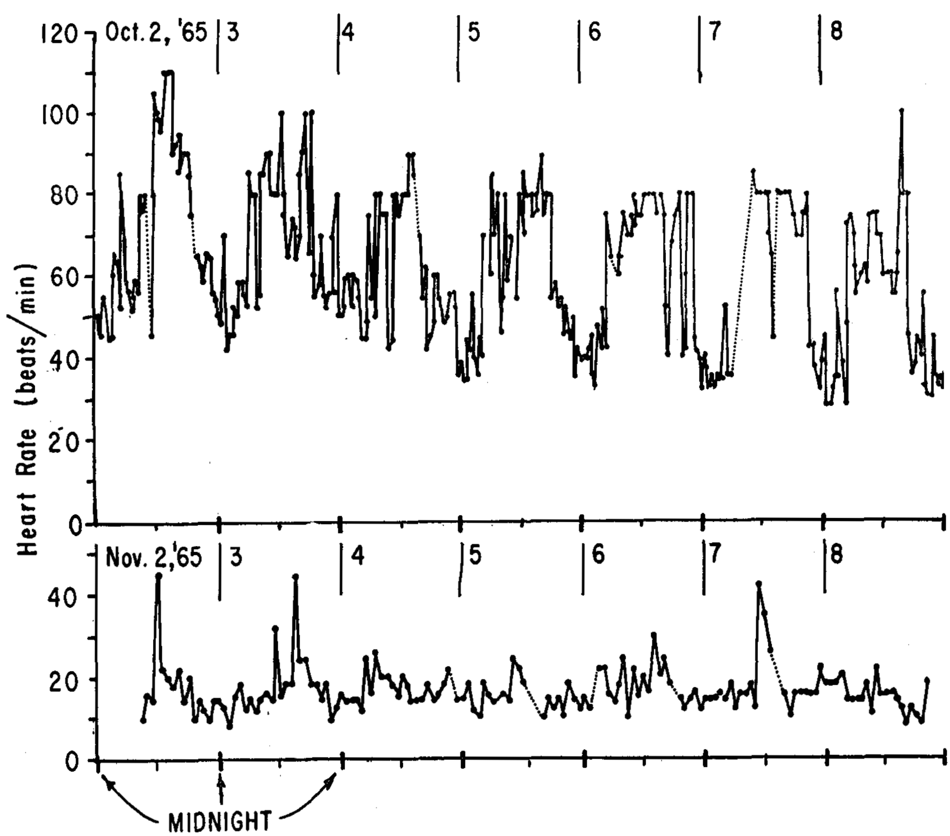


FIG. 3. Heart rates recorded daily every 30 minutes showing the dormancy stages as arctic grizzly bear ('Blondie') went into winter-den condition. Sleeping heart rates began at 40 b/m, became 30 b/m, and by November, 8-10 b/m.

were obtained from the polar bears. One polar bear showed minimum sleeping heart rates of 60 b/m in June, July, August and September. During the month of February the bears were in conditions appropriate for dormancy and the heart rate of the bear which had shown summer minimum rates of 60 b/m gradually dropped until 27 b/m was observed during sleep. On other nights a rate of 30 b/m was common. Undoubtedly the heart rate would have decreased further except that the radio capsule failed at that point.

Fig. 5 illustrates the radio-transmitter itself; Fig. 6 gives the record obtained. An arctic fox (Fig. 7), carrying an internal physiological transmitter which lasted for six months, contributed information on how he tolerates the extreme cold −55°F. (−49°C.) in midwinter; this information also explains how he manages his behaviour patterns when there is a change from the winter's total lack of sunlight to continuous daylight in the summer. (What does a *nocturnal* animal do when there is no period of darkness?) The next two illustrations (Figs. 8, 9) concern eye physiology studied at NARL; these are funduscopic pictures of the backs of the eyes of two red foxes, one lives at Point Barrow and the other lives in Iowa. This technique permits a search for a protective layer of pigment for the arctic

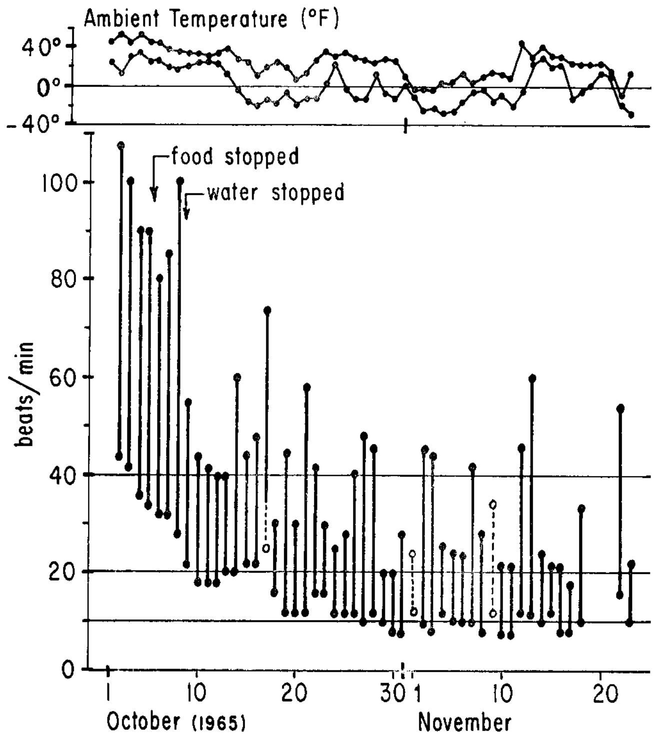


FIG. 4. Combined maximum and minimum daily heart rates during onset of dormancy in the grizzly bear described in Fig. 3. Most daily values were selected (maximum-minimum) from half-hourly readings (48 readings per day). Where vertical lines are dashed, some data were lost, but readings were selected from at least 30 observations per day.

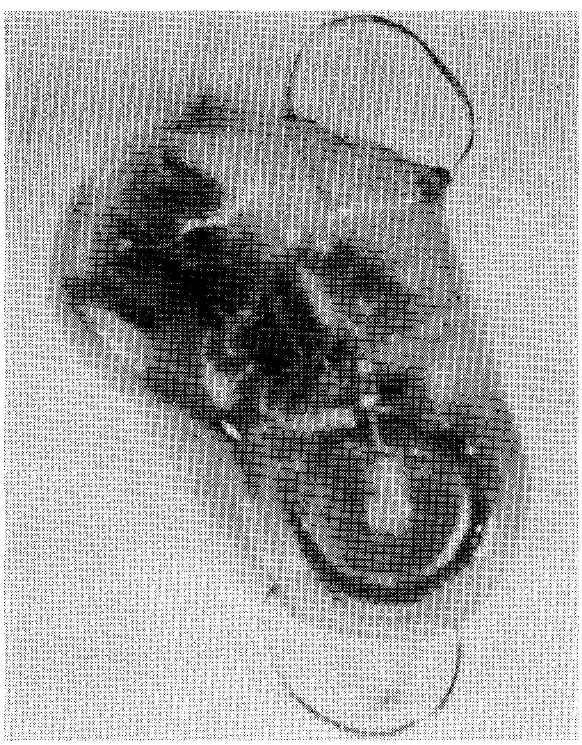


FIG. 5. Small EKG radio capsule with a battery life of six months weighing 16 grams. The two loops are stainless steel electrodes which touch the ventral body wall after the capsule is sewed in the peritoneal cavity. Note at bottom the mercury battery of the type used in electric wrist watches. There is no evidence that any of the animals with implanted radio capsules are aware of the presence of the instruments in their body cavities.

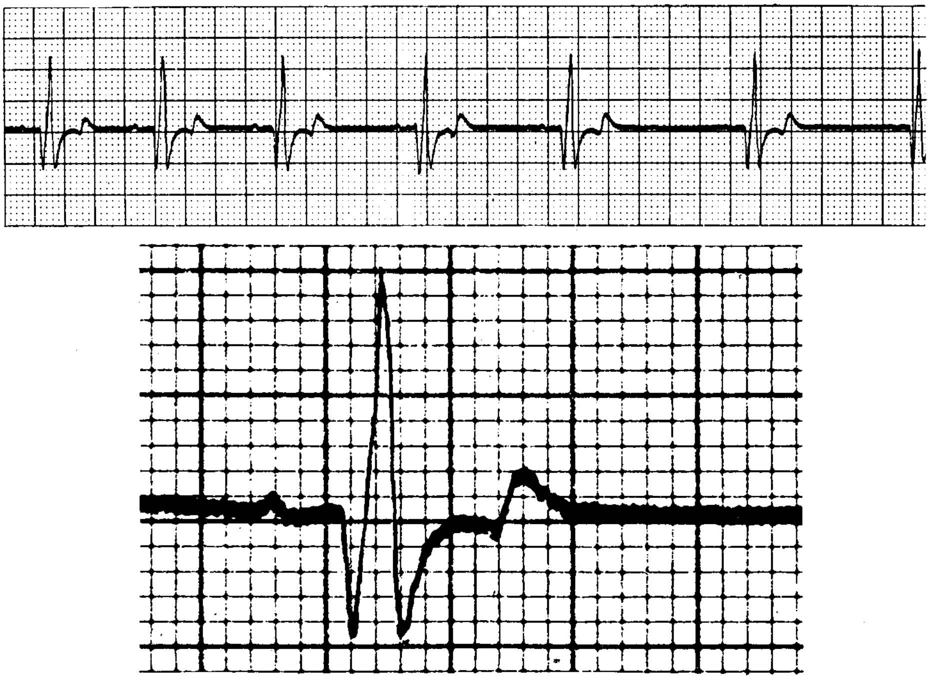


FIG. 6. Heart rate record (electrocardiogram) transmitted by the Iowa Radio-Capsule. The upper line is a record of seven heart-beats. The lower record is an enlargement of one beat, showing that the radio presents the same bioelectrical spikes of each heart-beat as found in records made in a medical clinic.

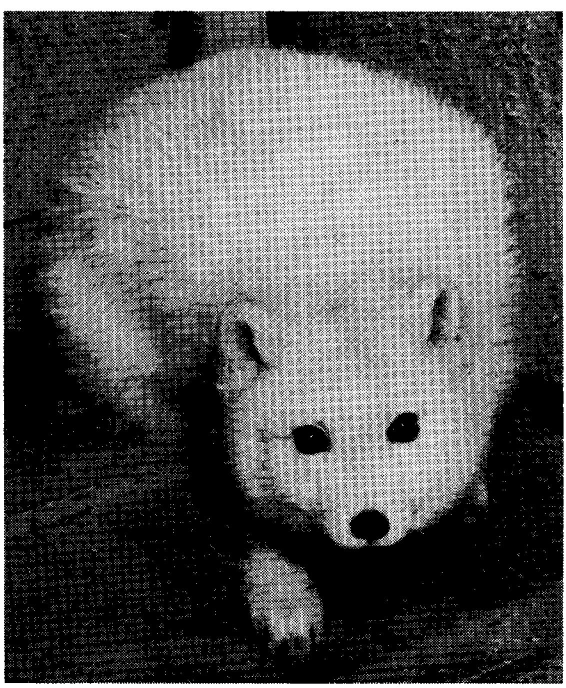
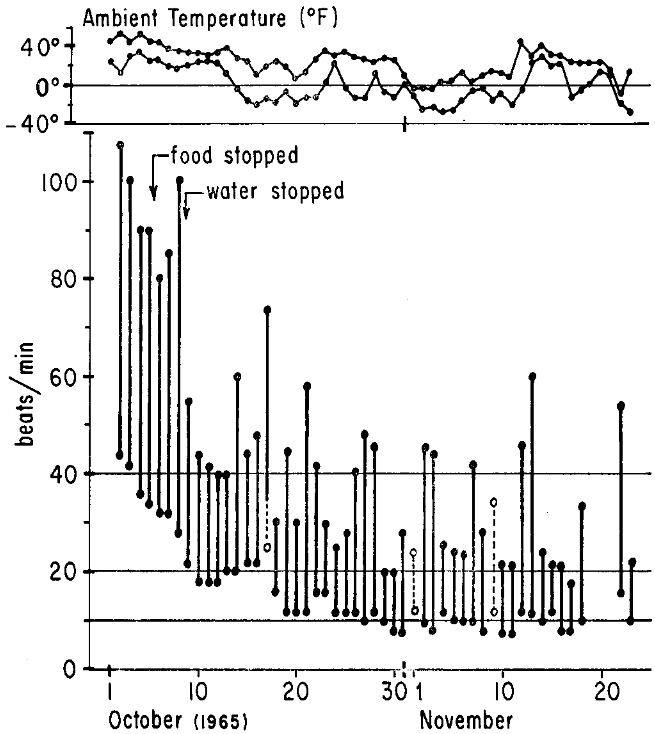


FIG. 7. Arctic fox carrying radio capsule which provided an EKG record for 9 months



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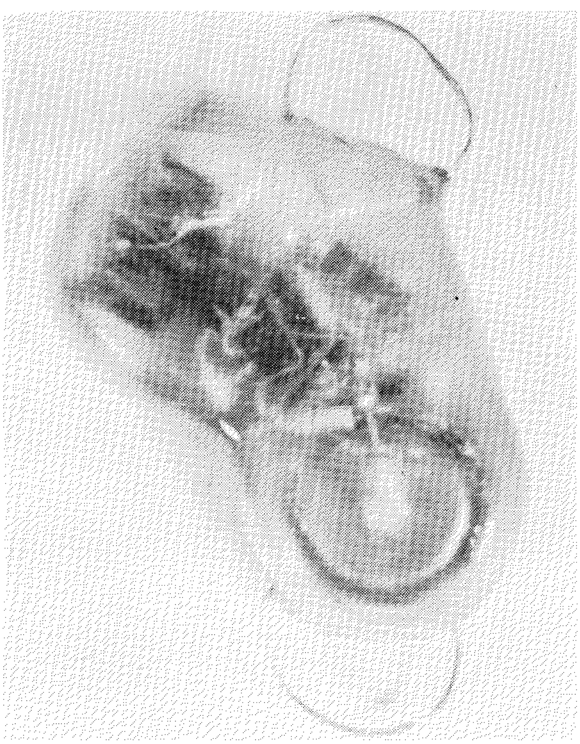

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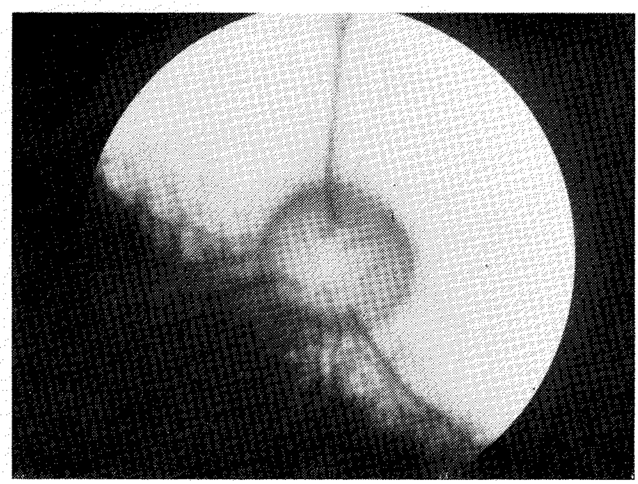

FIG. 8. Photograph of the back of the eye (funduscopic picture) of a red fox captured at Point Barrow. The central disc from which blood vessels radiate is the optic nerve. The pigment mass on the bottom left consists of melanin granules which are considered useful to protect the eye from excessive light.

animal compared with the temperate zone animal; the conspicuous layer which looks like a black tide creeping in to cover the rest of the eye is the pigment layer. The pigment of the foxes in the Midwest appeared to be no different from that of the arctic animals.

Now the question arises as to direction of physiological research: Who will be coming to the Arctic, what will they do, and with what tools will they do it? The present pool of physiologists with arctic experience indicated in Table 2 will and should increase. We must encourage that scientist who is naturally willing to be uncomfortable in the outdoor environment to join those workers who like to obtain data at NARL in the winter. That group of researchers must be ready and willing to live in, to understand, and be unafraid of the rigorous environment of the North. They must be conversant with the problems of airplane accidents on mountaintops or in the Arctic, when the thin wall of protection around man is torn off by the hostile environment that is always ready to bite into his tender skin. If the academic cold-weather physiologists are made welcome, they will

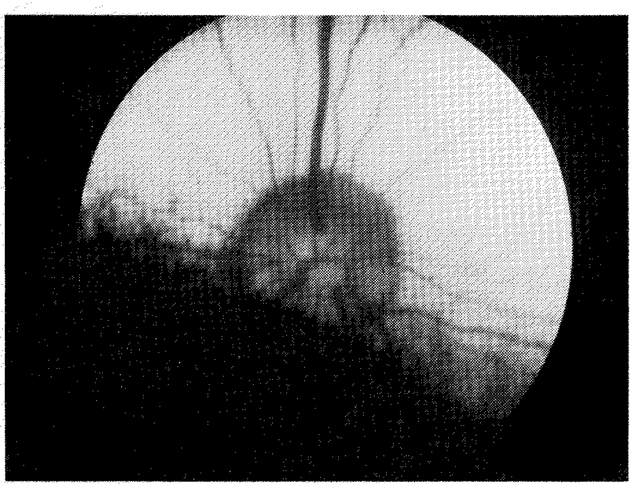

FIG. 9. A photograph obtained by the same technique at the back of the eye of a temperate zone red fox born and maintained in Iowa. In this case the pigment appears to crowd in more closely to the optic disc (optic nerve).

continue to arrive at Barrow winter and summer bristling with enthusiasm and eager for work.

What work will they do? There are new concepts today; the typical academic scientist has been striding energetically forward but has been temporarily stopped in his tracks because of a new demand: he must now not only take time to explain the details of his type of work, his methods, and his objectives but must relate them to the *social* objectives of his area of work. He must now look at his information as a resource: yes, physiological information is a resource. Now that our investigator has his philosophical-motor retuned, the emphasis of his research may go in two directions: that of encyclopedic knowledge (pure science), or that of applied science; or the individual scientist may wish to take part in both.

ENCYCLOPEDIC PHYSIOLOGY

The list of physiological topics in Table 2 itemizes the work to be done. Only a small fraction of the information needed on arctic cold weather physiology has been obtained. Part of the reason for this lack is that the "whole animal" research effort in this country as in other countries has been directed towards "molecular biology". This is an important area which has provided a better understanding of matters such as how membrane transport through the intestinal wall is accomplished. The pendulum is now swinging back and there is renewed interest in supporting research which involves the whole animal, especially in relation to his physical environment. The new information must first be organized as encyclopedic or pure knowledge. There are two ways in which this will be used. One is to satisfy the curiosity of alert, well-educated people; the other is to be used by scientists as a stepping stone for further research. The first point was amplified recently by Dr. Van Allen whose name is associated with the radiation belts around the earth. He made the comment that one should not have to justify assembling scientific encyclopedic knowledge as a part of the cultural drive any more than one should have to justify the support of literature, music, or art. Is the American public as a whole interested in encyclopedic knowledge, and does this apply to information concerned with the Arctic Slope? Yes, the eagerness with which semi-popular publications (such as the journal *Scientific American*) "reach-for" information on temperature regulation in the Arctic, indicates a curiosity about the physiological means of survival of animals in extreme environments. Are there more people interested in attending baseball games than there are in attending zoological parks? This is a question which applies to the present paper because at zoological parks today one is apt to find one or several exhibits where the animal is broadcasting its heart rate by radio to the public watching him. The answer is that there were 85 million visits to American zoos in 1968 which is more than the total attendance at all national football and baseball games (Conway 1969). Yes, there is a conspicuous increase in public interest in biological adaptations and thus more interest in the biology of the Arctic Slope than ever before.

APPLIED PHYSIOLOGY

Let us consider the applications of encyclopedic knowledge related to the Arctic Slope and polar area. The instrumented arctic fox in the NARL outdoor cage experiences continuous lack of sunlight in winter and continuous light in summer. Possibly he responds to geomagnetic changes. The scientist who travels to Barrow to study the behaviour of foxes has probably turned *his* biological clock by five hours in one direction or the other. The scientist has a vested interest in finding out whether arctic foxes still have a regular crisp behaviour pattern which remains unchanged in spite of the great changes in solar stimulation. The scientist says: "If the fox can keep his physiological equilibrium and make adjustments in the face of chaotic changes in signals from the environment, so can I." The same scientist may fly from Barrow to Europe where he will now have to change his physiological clock by ten hours. The fox has to adjust to drastic changes in day-night cycles, but man's adjustment may have to be even greater. This has been emphasized by the satellite experiments where primates showed profound physiological upsets due to the accelerated day-night light cycle.

The earlier pictures of the bears symbolize biological studies which help us to understand man's responses when he experiences an accidental reduction in body temperature or a purposeful one for surgery of the heart or the brain. All eyes in this area will be turned in the future to the possibility of finding biological material which will give man a physiological vacation by suppressing his metabolism. Think how helpful such a material would be in time of famine; large groups of human populations could, perhaps, live comfortably on half rations.

In the area of temperature regulation, careful research data have established the temperature characteristics in extreme cold of reindeer, caribou, seals, and of man. Some of these measurements have agricultural applications. Those visionaries who brought 500 domestic reindeer from Norway in 1898 would probably have welcomed some encyclopedic information on the temperature regulation of the caribou before they took their European-type animals across the Arctic Slope. A second agricultural application is the fundamental work of one scientist on the domestic pig; he has explained the mechanism of how these animals as well as seals can tolerate extremely cold weather without a heavy coat of fur.

Now for a medical example: more information about the temperature regulation of arctic mammals will result in the further understanding of frostbite and trench-foot in man. This is of obvious interest to our military services; we are told for example that the cold-weather parachutist may meet a blast equivalent to $-175°$F. ($-115°$C.). Apparently newborn caribou, moose, and seals are rarely affected by frostbite; a great deal more information must be obtained in the next few years on this topic which could be called "comparative physiology of frostbite". At any rate, the animals just listed appear to have extremities which are cold-resistant whereas those of man are not. If this resistance proves to be due to the animals' circulation, then we might be able to increase the resistance of man by the use of drugs which affect circulation.

Some age-old problems still remain. What can we do for the infantryman who must live and work in waist-deep snow? In the future the *reason* he is there may be the failure of his personal jet-propulsion equipment. How shall we get 5,000 to 6,000 food calories into him each day when he exercises (or flounders), how shall we keep the insulation dry for this "tropical man in arctic clothing?"

A final illustration of applied physiology, in this case obtained at NARL, is drawn from the work of W. L. Boyd. He demonstrated and published 18 papers on the remarkable cold resistance in soil organisms which he cultures from the Point Barrow region. If we let our minds soar a bit, we can realize that we might be transporting on our feet or equipment organisms that are very cold-resistant or even insects down to the temperate zone. From the standpoint of practical economics, we depend on Boyd to tell us what might happen if these organisms were released in a climate which might encourage their proliferation.

The final question is: "What tools will the physiologist of the future use?" I have given one illustration of radio-telemetry from arctic mammals; when radio-obtained results are presented, this area of work always seems exciting and attractive. In actual fact the technique is in its infancy (Adams 1969). For instance, battery life is a problem in implanted capsules; it is unusual if a radio in the body cavity of an animal will transmit physiological information for several seasons. Considerable funds and a great deal of time will be required to make this technique more versatile. The usefulness of modern tools in the Arctic was illustrated during the recent journey on the ice pack by David Humphreys and his group. They spent 109 days on the ice and depended on sled dogs for much of their transportation. At one time they travelled to the coast of Greenland for surveying measurements. The sled dogs can be pictured bending low in the harnesses to pull the sleds just as the Eskimo dogs did in the same area 1,000 years ago. Then Humphreys stopped and spent 30 minutes warming up a radio to transmit his surveying readings directly to Minneapolis. There they treated his readings by computer and within minutes radioed back to him a message like this "You have proven that Greenland is 15 miles wider than it has been described before and thus you have added 3,000 square miles to the size of Greenland". I won't vouch for the accuracy of the details of this description, but surely this fascinating combination of the physiology of the sled dog, and the computer in Minneapolis, will symbolize the way that the scientist of the future will obtain much of his information about the challenges which remain to be overcome on the Arctic Slope and the arctic coast of Alaska.

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