The participants were investigated with regard to physical fitness and cold tolerance before and after the expedition. The maximal oxygen uptake before the journey averaged 3.95 l./min, or 54 ml./min/kg. body weight. This places them above the average of the usual student population of Oslo, which is 3.2 l./min, or 44 ml./min/kg. body weight, but far below the average for champion cross-country skiers, which is 4.8 l./min, or 71 l./min/kg. body weight.[5] As far as physical fitness is concerned, this group of polar adventurers belongs to the upper part of the normal population of young adult Norwegian men, but they are not "supermen" like the extremely well-trained cross-country skiers of Scandinavia. The maximum oxygen uptake, however, was 5-10% lower in all subjects after the expedition. The reasons for this small but important decrease cannot be stated. In addition to the cold stress, nutrition was poor during the journey. Measurements after the expedition were taken two to three weeks after cessation of work, during a period when the subjects were rather sedentary and overfed. The decrease may thus be related to a detraining effect.

The conclusion which can be drawn from these studies is that the addition of cold acclimatization to physical training has little if any effect on the aerobic work power and related circulatory and respiratory functions.

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Commentaries

Commentary: J. S. HART, *Ottawa, Ontario*

I WOULD like to comment on some differences in the responses of small mammals and man to combined exercise and cold stress. It is generally believed that heat produced by exercise substitutes completely for shivering, and therefore replaces it in cold environment. This has been shown repeatedly in men exercising at different levels in the cold. I would like to point out that the replacement of heat production in the cold by exercise heat is not a general finding in small mammals, and to offer a hypothesis to account for the differences in thermogenic responses.

In Fig. 1 is shown the oxygen consumption at different work levels in young men in warm and cold environments[1] and in white mice[2] running at different speeds at two different temperatures. You will note that in the men oxygen consumption in the cold was increased only during rest, whereas the oxygen consumption of mice was increased by cold at all levels of activity. The increase was additive at all temperatures.

The addition of heat from exercise to the extra heat required in the cold has been shown to be associated with non-shivering thermogenesis in small mammals that are acclimatized

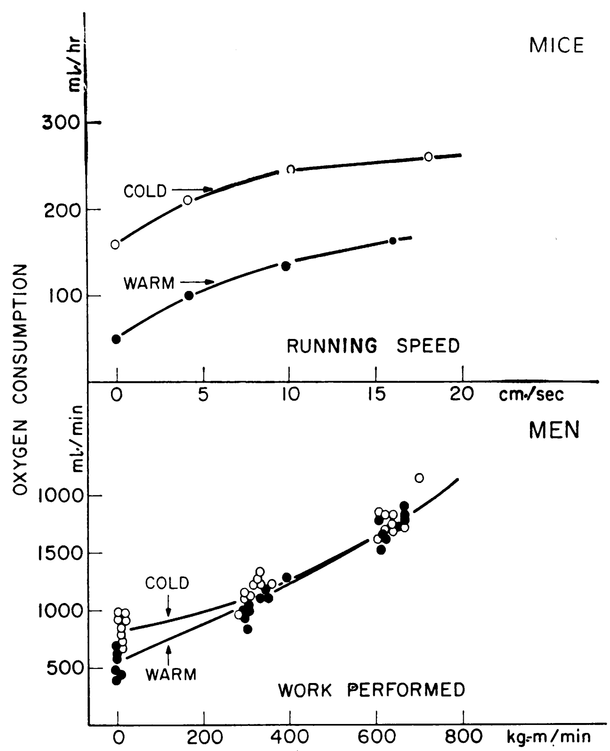

Fig. 1.—Addition of heat production from exercise and cold in white mice[2] and replacement of heat production due to cold by exercise heat in men.[1] In the latter, extra heat production in the cold does not appear during exercise.

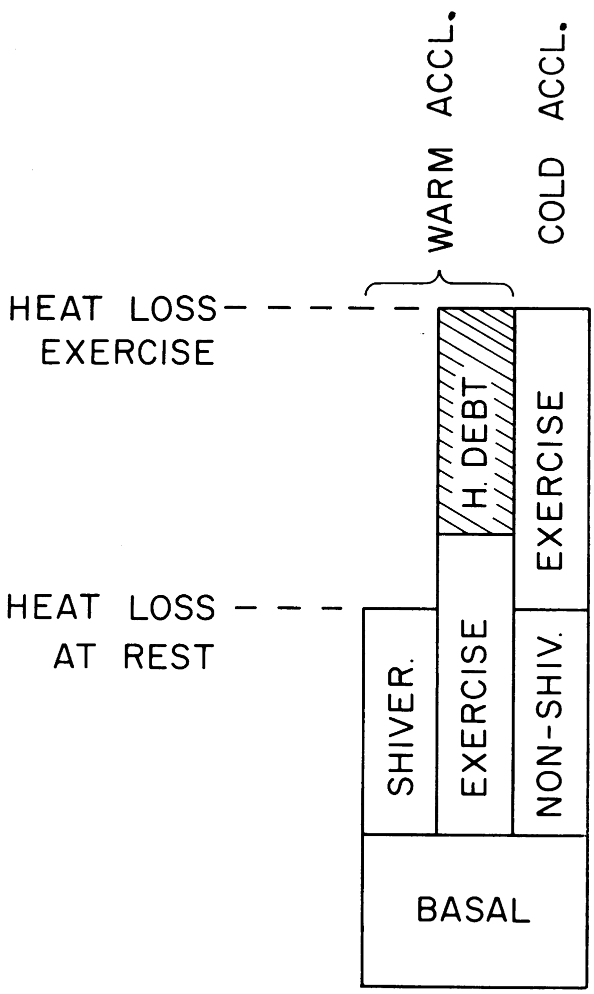

Fig. 2.—Diagram showing heat loss during exercise and rest in a cold environment (left), substitution of exercise heat for shivering in warm acclimated rats (middle) and addition of exercise heat and non-shivering thermogenesis in cold-acclimated rate (right). In the warmth-acclimated rats there is a heat debt, because the exercise eliminates shivering but is insufficient to compensate for the extra heat loss.

to cold.[3] It is not present in animals acclimated to heat; such animals produce heat in the cold only by shivering. Fig. 2 is a diagram showing substitution of exercise heat for shivering in warmth-acclimated rats,[3] and in addition to exercise heat to non-shivering thermogenesis in cold-acclimated rats. The failure to demonstrate addition of heat production from exercise and from cold exposure in man may be associated with the fact that the men were not acclimated to cold and possessed no significant degree of non-shivering thermogenesis.

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Commentary A. C. BRYAN, *Downsview, Ontario*

EVEN from a cardiovascular point of view, it is difficult to see any real advantage in living in a cold climate. In a hot environment, the very large skin blood flow and depletion of blood volume put a considerable load on the cardiovascular system, even at rest. As a result, the process of heat acclimatization leads to cardiovascular changes very similar to those of physical fitness.

In comparison, the cardiovascular effects of cold are quite trivial. While there are marked changes in peripheral blood flow with temperature, considering the whole body, vasomotor thermoregulation is only important over a very narrow temperature range—from about 28 to 31° C. Above this temperature range, cooling is largely evaporative. Below this range, the conductance of the whole body shell is constant; that is, the maximum vasomotor insulation has been achieved. Therefore, below this, body temperature can only be maintained by increased heat production—shivering or non-shivering thermogenesis or by muscular exercise. Neither shivering nor muscular exercise are particularly efficient in maintaining body temperature, the increased muscle flow increases the conductance of the shell, and motion increases the convective losses. But whereas shivering can only increase metabolism four- or fivefold, exercise can increase it 10- or 20-fold, depending on the degree of physical fitness. Therefore, as Andersen has demonstrated, the maximum oxygen uptake is an important measure of man's ability to withstand cold stress. The corollary is that to keep comfortable in a cold climate you have to do more work than in a temperate zone and, in consequence, you should become fitter. However, this has not been demonstrated under the rather specialized conditions of Andersen's experiments.

In many respects not only is work good for the cold, but cold is good for work. One of the limiting factors in exhausting work is probably venous return. Cold reduces the compliance and the volume of the capacitance vessels and therefore facilitates venous return. Heat dissipation might also be optimal, but it is a modern paradox that it isn't. Modern arctic clothing provides an almost tropical microclimate, and heat dissipation during heavy work is a major problem, because sweat ruins the insulative properties of the clothing. Indeed in civilized countries true cold exposure is becoming rare, because of all the environmental extremes, cold is the easiest to "engineer out". The average Canadian male, in his hot car, his hot house, and his thermal underwear, is rarely exposed to the cold.