STRESS IN POLAR EXPLORATION

By H. W. Simpson*

Abstract. A field investigation of human stress situations in polar regions was carried out, using the blood eosinophil level and the urinary 17-hydroxycorticosteroid (17-OHCS) output as indices of adrenal hyperactivity.

Men living in a British Antarctic Survey sledging station were found to have a fairly stable venous blood eosinophil count. Significant deviations from this level occurred when disturbing radio signals were received and when departure on a sledge journey was imminent. While in the field there was a profound eosinopenia in the evening after travelling, and this usually extended to the following morning; in one instance the chronic eosinopenia lasted 85 days. Similarly, in a party ski-ing 400 miles (640 km.) across the Greenland Ice Sheet there was a raised output of 17-OHCS in the urine for the full 40 days of the crossing. No adaptation to the stress took place.

The question of whether people in the higher socio-economic group have high 17-OHCS excretion rates is discussed.

Why do explorers explore? The polar epics are a series of desperate situations: crevasses, starvation, cold, crushed ships and so on. Are explorers under "stress," or are they comparatively unaffected because they are more resistant or adaptable than other people?

This study is an objective assessment of some stress situations in the Antarctic and Arctic, using two indices of adrenocortical function: the venous blood eosinophil count and the urinary output of 17-hydroxycorticosteroids (17-OHCS). Although a great deal is known of the adrenal response to adverse situations lasting up to a few days (Gabrilove, 1950; Frost and others, 1951; Thorn and others, 1953), little is known of the response pattern to stress lasting several months, and it was hoped to find out if adaptation occurs, i.e. if under prolonged stress the adrenal function rises and then returns to normal.

Expeditions are particularly well suited to studies of chronic stress; they are, of course, often of long duration and the close confinement seems to engender good co-operation of the subjects. Moreover, the results are comparatively easy to interpret because the base routine is so simple.

The field work was carried out while the author was serving as a Medical Officer with the British Antarctic Survey and, later, as a leader of a small expedition which skied 400 miles (640 km.) across the Greenland Ice Sheet.

Methods

Eosinophils were counted directly by the method of Thorn and others (1948). Antecubital venous blood was obtained by venipuncture. Mixing with acetone-eosin diluent was carried out in a small tube and the total count included the cells on both sides of two Fuchs-Rosenthal counting chambers. Retrospective analysis of eosinophil scatter in the chambers showed almost perfect Poisson distribution even when the numbers varied greatly in magnitude. Thus, the value for the standard deviation divided by the square root of the mean was between 0·943 and 1·086 (Berkson and others, 1940). This indicates that the technique was satisfactory in spite of it being carried out in the field. (For more details see Simpson (1959).)

Total 17-hydroxycorticosteroids were measured by a modification of Norymberski's technique (Appleby and others, 1955). Complete urine collections were made each day in polythene containers, the volume recorded and an 8 ml. aliquot taken. These small unpreserved specimens were then brought back to Glasgow for analysis. The storage qualities of these corticosteroid metabolites have already been investigated and found excellent (Simpson, 1965*a*, *b*).

Results

Since individuals have widely different normal eosinophil counts, it is essential to establish this value in each individual before coming to any conclusions about the significance of a particular level (Simpson, 1959). There is, of course, a marked diurnal variation in parallel with adrenal function but this difficulty may be circumvented by making observations at the same time of day (Bliss and others, 1953; Doe and others, 1954; Peterson, 1957).

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Accordingly, a "station-hut summer level" was obtained, as a control for any stress situations, for each subject who was serving at a British Antarctic Survey station on the Antarctic Peninsula. It consisted of at least eight different day counts during the comparatively warm period (average outside temperature at about freezing point) when there was no apparent stress, within the time limits of 09.00 to 11.00 hr. The individual levels were so clear cut (Table I) that, given an unknown blood from one of the five subjects investigated, it would nearly always have been possible to name the donor by making an eosinophil count. Moreover,

TABLE I. CONTROL DATA

Subject	*Age*	*Eosinophil count and standard deviation*	*n**	*Occupation*
Leader	32	129±22	10	Surveyor
A	26	402±73	11	Medical Officer
B	22	237±30	14	Meteorologist
C	25	54±18	17	Meteorologist
D	24	87±27	8	Meteorologist

* Number of readings.

this individual mean level was stable over long periods; in subject A, for example, the level 2 years later in the United Kingdom was 370±S.D. 36 ($n=6$), which is within one standard deviation of the Antarctic level given in Table I.

Stress situations

Stresses experienced while living in the station hut. One man (subject B) was studied over a period of 2 months at the station hut by making counts on alternate days. The object of this was to have a continuous series of eosinophil counts over a fairly long period and thus to obtain a complete record of any sudden unexpected stresses which are always a possibility at an Antarctic station. The results are given in Table II.

TABLE II. THE EFFECTS OF SUDDEN UNEXPECTED STRESSES

		Number of readings	*Eosinophil level and standard deviation*	*Percentage*
Non-stress controls	Living in comfortable station hut in summer. No stress apparent	14	237±30	100
Stress	1. Received radio news that first relief ship sinking	1	165–2·4	69
	2. Ship's arrival imminent	1	165–2·4	69
	3. Due to leave on sledging journey in 4 hr.	1	135–3·4	57
	4. Nearly killed in boating incident previous day	1	128–3·6	54
	5. Morning after man-hauling sledge 21 miles (34 km.)	1	110–4·0	46

In "stress 1" the relief ship was holed after hitting an ice floe, and as the forward hold filled with water an SOS was sent out and the boats lowered. Later the Master of the ship found that by going astern the leak was less serious and the pumps gained. This was the first ship for 8 months and all the station's replacement personnel, supplies and mail were on board.

In "stress 4" a member of an adjacent foreign station was seen being swept out to sea in a rowing boat by the prevailing current. His outboard motor had run out of petrol and he had lost the oars. Already one man had been killed in an identical manner the previous year and as the weather was deteriorating the situation was extremely dangerous. Subject B, with three companions, put out to sea in a disused and leaky rowing boat in a desperate attempt to reach the man, but after struggling for 4 hr. they had to give up the attempt and only just managed to return as, by then, there was a gale-force wind blowing offshore. Fortunately the man was eventually rescued as a helicopter from an ice-breaker spotted him 25 miles (40 km.) out and let down a rope ladder.

The weather as a possible stressor. At one period of the year my sledging party was marooned on a peninsula by lack of sea ice and by dry glaciers inland on which it was almost impossible to sledge with dogs. We were completely isolated but not apprehensive, as there were large quantities of food and fuel, and ample tents to live in. Days were spent feeding the 18 dogs, making weather observations and hunting seals. Since it was autumn the weather fluctuated violently. The temperature varied from −10° to +31°F (−23·3° to −0·6°C) and the wind from calm to 40 kt. (20·6 m./sec.). In winds over 30 kt. (15·5 m./sec.) one has to shout to one's companion in the tent because of the drumming canvas, and sleep is difficult. During the period, eosinophil counts were made each day at the same time on the four men for 4 weeks (Sundays excepted). Full field meteorological observations were made and the "wind-chill factor" of Siple (quoted by Pratt (1958)) was determined as an estimate of the combined effect of cold and wind.

In order to determine whether meteorological conditions had any effect on the level of circulating eosinophils, correlation coefficients were computed between (i) the eosinophil count and the minimum temperature recorded on the same day and also on the previous day, and (ii) the eosinophil count and the wind-chill factor recorded for the same day and also for the previous day. The coefficients (Table III) indicate that there is no significant correlation between weather variations and the circulating eosinophil count. None are significant even at the 5 per cent level ($r=0{\cdot}40$).

TABLE III. CORRELATIONS BETWEEN THE EOSINOPHIL COUNT AND THE PREVAILING WEATHER

Subject	*Minimum temperature (same day)*	*Minimum temperature (previous day)*	*"Wind-chill factor" (same day)*	*"Wind-chill factor" (previous day)*
Leader	−0·02	+0·21	+0·07	+0·07
A	−0·11	+0·07	−0·01	+0·13
C	−0·32	+0·13	+0·19	+0·11
D	+0·19	+0·33	0·00	−0·01

Readings made on the same day as sledging. It was difficult to obtain eosinophil readings the same day as dog-sledging, as physical fatigue in the evening made counting a great effort. There were, however, four occasions when sledging parties arrived at the station when I was already there, and these results are given in Table IV.

Since all the post-sledging readings are more than two standard deviations below the station-hut levels at the same time of day, they are considered significant. These journeys were all a particularly easy 1-day standard 17 mile (27 km.) run back from a satellite hut to the main station hut, and would have had a minimum effect as compared with dog-sledging journeys in general.

TABLE IV. IMMEDIATE EFFECT OF SLEDGING

	Control		*Stress*	
Subject	*Control eosinophil count* and standard deviation* (per mm.^{3})	*Number of readings*	*Immediate post-sledging level* (per mm.^{3})	(per cent)
E	144 ± 60	14	21	13
Leader	127 ± 28	8	49	38
			43	34
D	65 ± 14	5	25	38
			Mean	31

* For early evenings.

Results from a prolonged dog-sledging journey. On its final visit of the summer, the relief ship left four of us on the coast about 50 miles (80 km.) south-west of the main station. Our object was to find a route from the coast to the unmapped Detroit Plateau, which forms the backbone of the northern part of the Antarctic Peninsula. The plateau, which undulates between 6,000 and 8,000 ft. (1,850 and 2,460 m.) for several hundred miles, is bounded by abrupt escarpments. The steep gradients and accompanying crevasses (Fig. 1) and ice falls make it a difficult area for sledging, especially as the weather there is generally bad, and it took nearly 3 months to find a route and sledge back to the main station. There were two periods of severe danger. During the first of these there were several crevasse incidents when dogs had to be rescued; there were also two occasions when the leader's dogs charged down-hill out of control in heavily crevassed areas, as they could obtain no grip on the bare ice and became discouraged. In the second period, both tents were blown down simultaneously in the middle of the night by gusts of wind estimated by the meteorologist at 80 kt. (41·2 m./sec.); most of the 50 lb. (22·7 kg.) boxes of supplies were blown away.

During the field period, 192 eosinophil counts at the same time of day were made on the four sledgers (48 each). Counts were begun after breakfast and completed in the same order; the levels therefore reflected previous events or anticipation of the current day's programme.

As the data were collected, it became apparent that the leader of this party was in a state of sustained eosinopenia, whereas his companions (subjects A, C and D) were having only transient changes. In order to highlight this observation, their results have been converted to percentages of the individual control levels and pooled to form a contrast to the leader's results (Fig. 2). Note that Fig. 2a shows only transient depressions which correspond to times of obvious severe stress, while in Fig. 2b (the leader's results) there is a sustained eosinopenia for the full 85 days of the journey. Moreover, the subsequent period in the station hut shows counts very similar to the initial control period, thus confirming its validity. When the leader's data were analysed from the point of view of environments, different levels emerged for each (Table V). Although the "station-hut summer" and "station-hut winter" levels

TABLE V. VARIATION OF EOSINOPHIL LEVEL WITH ENVIRONMENT
(one subject)

Environment	*Eosinophil count* (per mm.^{3})	*Number of readings*
Station hut (summer)	129	10
Station hut (winter)	116	14
Living in tent (static)	80	21
Living in tent (sledging previous day)	54	10

Fig. 1. Manhaul sledge and crevasse. Note the sledge wheel which is used to measure distances travelled.

are not significantly different, the *latter* is significantly higher than levels while living in a tent but not sledging ($p = < 0 \cdot 01$); moreover, the level while living in a tent (static) is significantly higher than the level the day after sledging ($p = < 0 \cdot 001$). Isolated results from other journeys indicated that on those too he had a continuous eosinopenia, and it can therefore be inferred that he was in a "stress" state for more than 6 months of this year. Clinically, this reaction correlated well with the fact that he was overweight and mentally unsuited to polar travel. It was significant that for the second winter of his Antarctic tour he resigned his leadership, preferring the post of surveyor without responsibility for the station.

A 237-mile (381-km.) manhaul sledge journey. The previous journey described was hazardous and of long duration; it had an unusual amount of mental stress but relatively little physical stress. Only 200 miles (322 km.) were covered in 85 days and the sledges were pulled by huskies.

Later in the year, a special journey was made in order to investigate the effect of prolonged physical exertion on the eosinophil count. During this journey three men manhauled a 300–400 lb. (136–182 kg.) sledge 237 miles (381 km.), circumnavigating James Ross Island off the north-east coast of the Antarctic Peninsula. Alternate mornings were left free to determine the eosinophil level in the venous blood, and on each intervening day an average distance of 18 (15–22) miles (24–35 km.) was sledged. By good fortune the progress of the journey was never interrupted by bad weather.

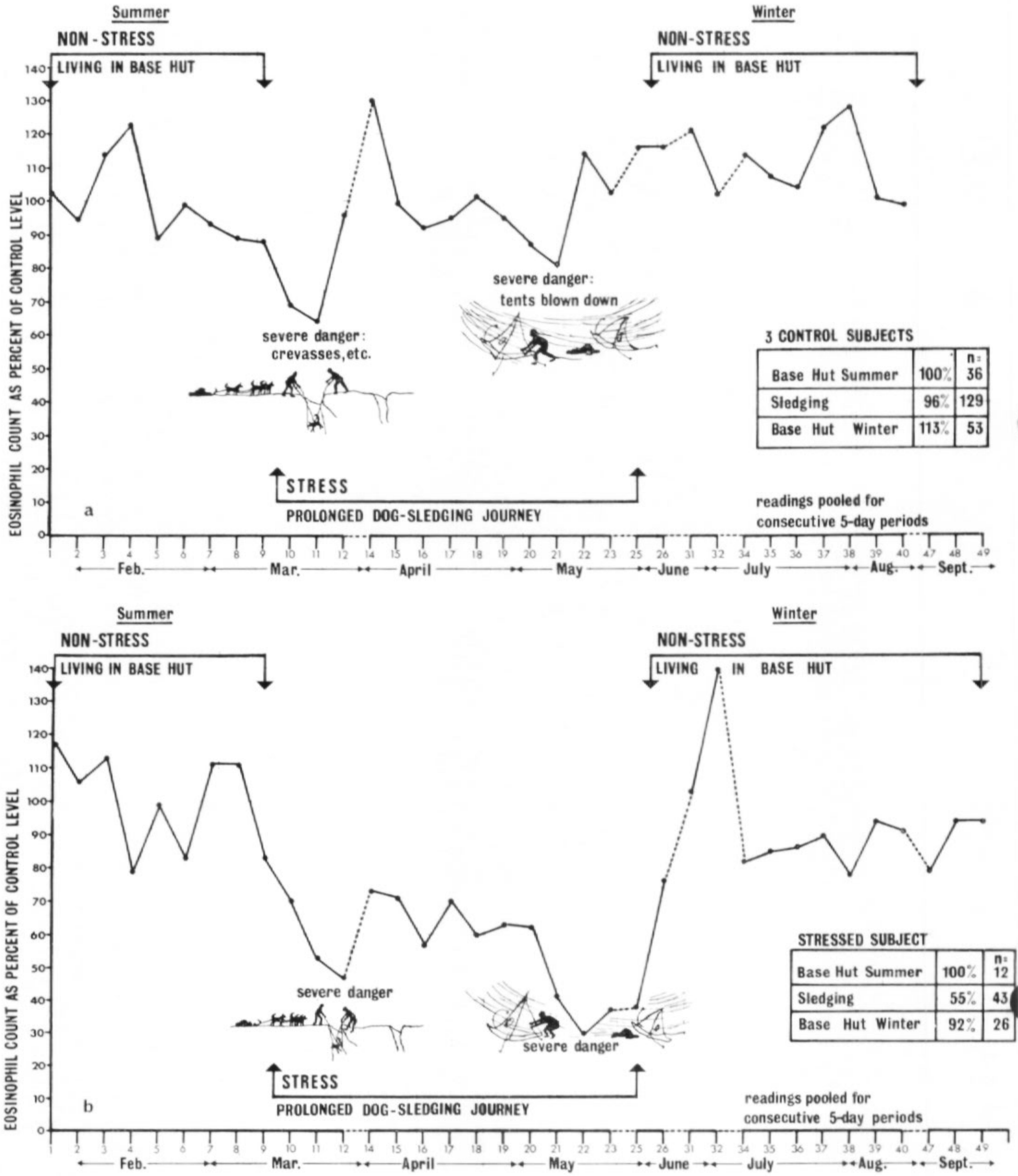

Fig. 2. Venous blood eosinophil counts made over a period of 9 months. Counts for consecutive 5-day periods have been pooled.

a. Pooled results of three subjects, showing only transient eosinopenias during the sledge journey when the dangers were particularly severe (cf. the continuous eosinopenias of manhauling).

b. One subject (base leader), showing prolonged eosinopenia during sledging period and subsequent return to control levels.

Subject C had a level of 28 eosinophils/mm.[3] (Fig. 3) on the day after manhauling, compared with a mean of 54/mm.[3] $\pm$S.D. 18 whilst living in the station hut in apparent non-stress conditions. This represents a mean eosinopenia of 52 per cent and is significant ($p = <0{\cdot}01$). After he arrived back at the station there was a rebound rise of circulating eosinophils with two readings over 90/mm.[3] which were his highest. (He had 104 different day counts made over a period of 9 months.)

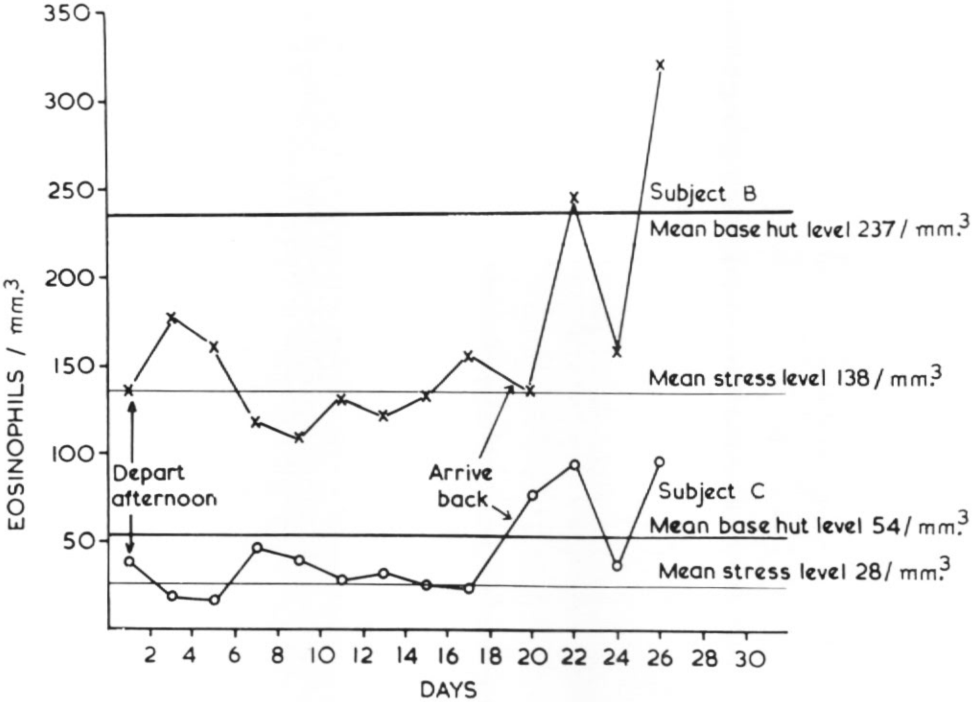

Fig. 3. Direct venous eosinophil cell amounts made on two subjects during a 237 mile (381 km.) manhaul sledge journey, compared with their mean station-hut levels (non-stress). In both instances the means are significantly different ("t" test).

Subject B, who was a less experienced sledger than subject C and also younger and persistently hungry, showed a continuous eosinopenia of 138/mm.[3] (58 per cent) compared with his normal of 237/mm.[3] at the station. None of the stress readings came within one standard deviation of the controls and the difference between the means is highly significant ($p = < 0{\cdot}001$). 8 days after the stress had finished he too had the highest reading of his entire series (320/mm.[3]).

It is interesting that subject C (Fig. 3) showed a very high eosinophil count on the *first* day after returning, which is really a normal post-sledging day and, if physical stress was solely responsible for these day-after-sledging eosinopenias, it is difficult to see why this day should be an exception. However, there was some mental stress on the journey: we were unable to find paraffin at a depot (shortage of fuel and therefore of water is more serious than shortage of food); then treacherous rifts were encountered on the ice shelf; and finally, on the last day the weather changed and it was only with tremendous effort that we reached the station before a hurricane broke. (Another party only 15 min. behind us was delayed for 4 days.)

As a rough guide to energy consumption and physical stress, body weights were measured before and after the journey. The initial weights were as follows: subject B, 189 lb. (85·7 kg.); subject C, 162 lb. (73·5 kg.); and subject A, 142 lb. (64·4 kg.). Immediately on returning, the weight deficits were 5 lb. (2·3 kg.), 6·75 lb. (3 kg.) and 6·5 lb. (2·9 kg.), respectively. After 24 hr. these had fallen to 0·75 lb. (0·34 kg.); 3·5 lb. (1·58 kg.) and 3·25 lb. (1·47 kg.). If this initial 1-day weight deficit can be attributed to water loss, then the arrival dehydration was of the order 1·5–2·0 l. This compares with 2·8–4·0 l. of fluid drunk daily by members of the successful Everest Expedition who would, of course, have been subjected to greater ventilation because of altitude (Pugh, 1954).

The actual body substance losses of 0·75 lb. (0·34 kg.), 3·50 lb. (1·58 kg.) and 3·25 lb. (1·47 kg.) appear small and indicate that the sledging rations, which contain 4,200 cal., are just about adequate in spite of severe physical stress. The intake of Captain Scott's fatal polar party was 3,975 cal./day. (See Kinloch (1959) for discussion of expedition rations.)

The stress of ski-ing across the Greenland Ice Sheet. Bearing in mind the results of the preceding section, I thought it would be of interest to study the adrenal response of a longer, more ambitious, ski-manhauling journey using a more direct index of adrenocortical function—the 24-hr. output of total 17-hydroxycorticosteroids. The intention was to see if there was a comparable stress response or, alternatively, adaptation (i.e. a high initial response falling to control levels even though the stress was sustained).

Geographically, the aim of the expedition was to cross Greenland from Angmagssalik on the east coast to Søndre Strømfjord on the west, ski-ing 400 miles (640 km.) across the ice sheet and walking over 30 miles (48 km.) of tundra. The main difficulty of such a journey is the ascent and descent of the steep, fast-moving, crevassed glaciers at either end. The three other subjects were keen to attempt the journey because it presented a challenge, and they therefore consented to being guinea pigs for the physiological work. It was the first time that a woman had traversed the ice sheet, and only the second time that it had been crossed by a party in this manner (i.e. unaided by dogs or tractors); the first party was that led by Nansen. A full description of the journey, has been published previously (Simpson, 1965*c*). The results obtained are given in Table VI. Normal hormone levels were established while the party rested for a week in comparative comfort at Angmagssalik, after completing preparations for the crossing. These control values were known to be authentic for three of the subjects, since they were closely comparable to readings obtained previously during a Scandinavian holiday ("holiday levels" in Table VI).

During the first 5 days of the journey across the ice sheet, when we skied over hazardous thawing sea ice (Fig. 4) and then up a steep crevassed glacier, there was a dramatic rise of output in the 17-hydroxycorticosteroids (pooled mean = 161 per cent), and these high levels were sustained over the next 5 days when we were still climbing towards the 8,150 ft. (2,508 m.) ice-sheet summit (pooled mean = 167 per cent). During the subsequent 15 days the party

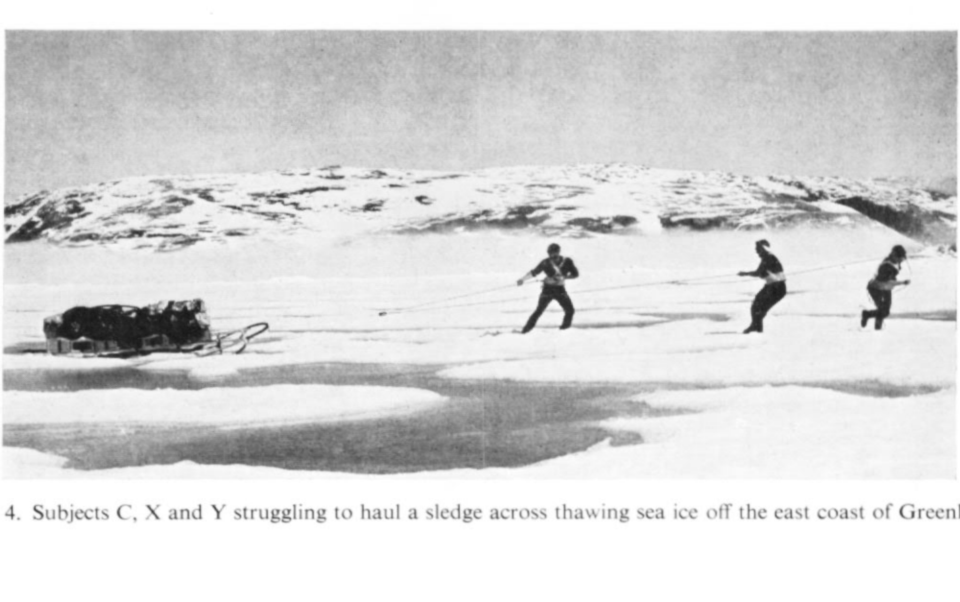

Fig. 4. Subjects C, X and Y struggling to haul a sledge across thawing sea ice off the east coast of Greenland.

Table VI. Daily outputs of 17-hydroxycorticosteroids before, during and after 400 mile (640 km.) crossing of Greenland on skis

Subject	*X*♀			*Y*♂			*A*♂			*C*♂			*Pooled mean*
	17-OHCS (mg./day ± S.D.)	*n*	per cent †	17-OHCS (mg./day ± S.D.)	*n*	per cent †	17-OHCS (mg./day ± S.D.)	*n*	per cent †	17-OHCS (mg./day ± S.D.)	*n*	per cent †	
Control													
Holiday levels	9·6±1·8	9	104	No data			10·9±1·7	8	102	16·4±0·9	4	109	105
Pre-journey levels	9·2±0·7	7	100	17·2±1·8	6	100	10·7±2·9	6	100	15·0±2·3	7	100	100
During crossing													
First 5 days	16·6±3·8	5	180	22·2±3·6	5	129	18·4±3·6	5	172	24·2±3·1	5	161	161
Second 5 days	22·9±5·2	5	249	21·5±2·0	5	125	15·1±1·6	5	141	23·2±1·5	5	155	167
Third 5 days	21·0±2·1	5	228	19·8±2·3	5	115	15·7±1·8	5	147	21·1±2·6	5	141	158
Fourth 5 days	16·4±1·8	5	178	18·5±1·1	5	108	14·8±1·8	5	138	21·0±2·5	5	140	141
Fifth 5 days	14·2±0·9	5	154	17·7±1·6	5	103	14·4±1·4	5	135	21·1±2·3	5	141	133
Sixth 5 days	16·6±3·1	5	180	22·3±2·9	4	130	16·2±3·2	5	151	23·3±4·1	5	155	154
Seventh 5 days	16·7±2·6	4	182	28·4±7·9	5	165	14·6±1·6	5	136	18·2±1·6	5	121	151
Eighth 5 days*	19·5±2·7	5	212	24·0±1·8	5	140	11·5±1·3	5	107	14·8±1·8	5	132	148
Immediate post-stress period	15·9±2·4	7	173	20·1±4·0	7	117	12·7±2·1	5	119	15·7±2·5	5	105	128
After return Normal routine in United Kingdom	14·0±2·2	12	152	21·4±2·9	12	124	19·0±3·8	12	178	24·1±4·2	12	161	154

* Back-packing over tundra.
† Average reading as percentage of individual's own control data.
n Number of observations.

travelled fast over easy, almost level surfaces (Fig. 5) and the 5-day means fell successively to 158, 141 and 133 per cent. Stress during this stage was largely physical—250 miles (400 km.) were skied in 12 days. Then followed the three 5-day periods during which we descended to lower levels of the ice sheet and the hormone levels rose again to 154, 151 and 148 per cent. These increases corresponded closely to the stress of traversing the thaw zone where rivers, slush, morasses, crevasses and finally giant ice hummocks made progress desperately slow.

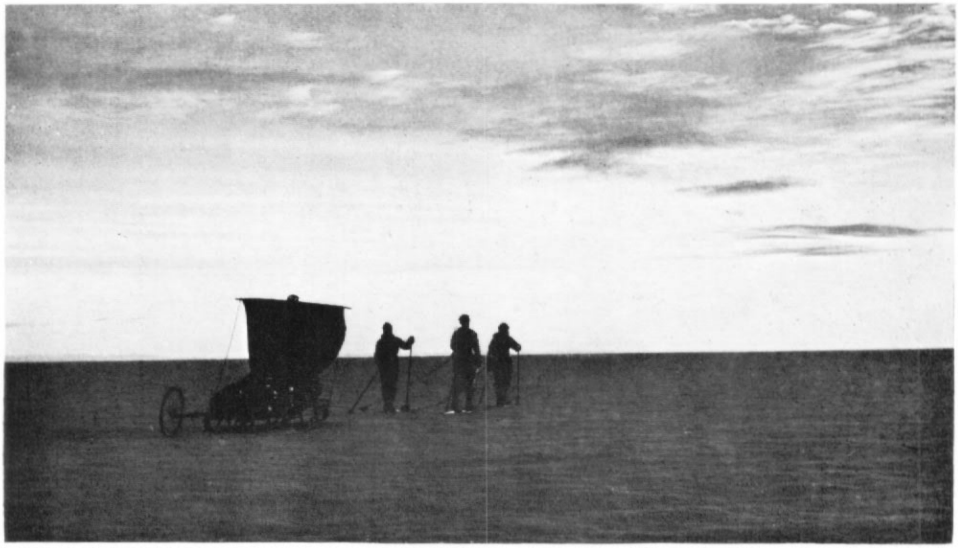

Fig. 5. Subjects X, Y and C ski-ing westwards over the Greenland Ice Sheet.

Throughout the week after we had reached the security of the United States base at Søndre Strømfjord, the levels were lower but still above normal, the pooled mean value being 128 per cent. It should be noted, however, that the three men had a pooled mean of only 113 per cent, the 128 per cent being heavily weighted by the woman's results. The woman's readings were relatively very high during the crossing and afterwards, a finding which correlates with the clinical observation that she was more physically exhausted than the men by the journey, and by the final effort of reaching safety. She commented that she did not feel "normal" for at least a fortnight after reaching security. Subject Y's highest readings were recorded after he had made a navigational error which resulted in a detour. Physically, he was the strongest member of the party and his relatively small rise for the middle part of the journey is in agreement with this. Subjects A and C, the joint leaders, recorded their highest levels during the first 5-day period when they were faced with making a critical decision, which could have proved disastrous, concerning the glacier route to be taken to the ice sheet.

The results indicate that no adaptation took place, since throughout the journey the changes in steroid excretion paralleled the changing degrees of stress encountered.

An attempt to obtain a second set of control readings in the United Kingdom resulted in unexpectedly high levels—in some instances as high as those obtained on the ice sheet. This observation is discussed later.

Discussion

There is some criticism about the use of eosinophils as a measure of adrenocortical function, since adrenalin from the medulla is also capable of causing some eosinopenia. This question has been reviewed (Simpson, 1959) and the conclusion reached that, if there is no fall of eosinophil level in a supposed stress, then both adrenocortical or medullary stimulation are unlikely; on the other hand, if there is a fall—especially if it is profound and sustained—

then it is more likely to be due to cortical hormones, though some direct effect and also potentiation is likely from adrenalin. Noradrenalin has no effect on eosinophils (Humphreys and Raab, 1950). Of course, adrenalin itself does not stimulate the adrenal cortex in man (Hunter and others, 1955), though it does in some mammals (Vogt, 1944). Thus, eosinophils are still a useful index of stress, especially where corticoid analysis is impracticable; moreover, an eosinopenia does appear to reflect the actual biological activity of corticoids and so, as an index of adrenocortical function, it avoids the sweeping assumptions necessary with body fluid corticoid analyses (i.e. constant protein binding, hepatic inactivation and renal excretion).

While living in the Antarctic station hut there was a fairly stable circulating eosinophil count. Significant depression from this level, however, occurred when exciting radio messages were received; in this isolated community all messages had an exaggerated effect—nearly everyone exhibited mild manic behaviour and little work was done. Most men hated the summer shipping season because of the frequent signals and disruption of the station routine; the arrival of mail seemed small compensation. The majority were, in fact, atuned to the isolated environment and preferred to have as little contact with the outside world as possible. Aircraft are only used at a few of the British Antarctic Survey's stations in the summer, and the area is only accessible to shipping during the summer.

Counts made in the evening after a day's dog-sledging showed an invariable and profound eosinopenia as compared with control counts (mean=31 per cent). These were the lowest readings of the whole study. When counts were made in the morning after a day's dog-sledging and a night's sleep (but with the party still in the field), the result depended on the individual and the type of sledging. With most men there was only an eosinopenia if the journey was especially hazardous, but in one individual there was a progressive profound eosinopenia for the full duration of the field period. Clinical confirmation of his stress state came when he resigned his leadership.

In contrast, the manhauling results invariably showed continuous stress response, both when eosinophils and when urinary corticoids were used as an index. This is of possible interest in any discussion of why Amundsen was so much more successful than Scott on the South Pole journey. All the eosinophil counts were made in the morning after a night's rest and therefore probably represent a chronic effect—possibly adrenal hyperplasia. It is interesting that subject C, who was on both the 237 mile (381 km.) Antarctic journey and the 430 mile (688 km.) Greenland journey, had an average eosinopenia of 52 per cent ($p = <0{\cdot}01$) during the Antarctic journey, whereas on the Arctic journey his 17-OHCS outputs averaged +143 per cent of the control (i.e. 21·5 mg./day compared with 15·0 mg. in the control period). This difference is again statistically significant.

The results of both journeys indicate that adaptation does not occur in the prolonged physical and mental stress of manhaul sledging. It is therefore reasonable to infer that, whatever physiological action the corticoids have in these situations, it is sustained throughout the stress. During the Greenland journey this lasted for more than a month.

After the Greenland expedition an attempt was made to obtain a second set of control readings in the United Kingdom but unexpectedly high levels were obtained—in some instances as high as those from the ice sheet. Twelve observations were made on random days while the subjects were at their normal occupations: subject X is an author and housewife, subject Y a company secretary, subject A a clinical lecturer and subject C a school-teacher. Thus, all of the subjects held responsible and, to a certain extent, competitive jobs, and it is apparent that such occupations may result in more stress and adrenal cortical stimulation than has been hitherto recognized. It is of considerable interest that a university lecturer has a higher output of 17-OHCS during 12 random days of the busy autumn term period than at any time during a ski traverse of a 400 mile (640 km.) ice sheet, the average levels being 170 and 140 per cent, respectively, above holiday controls. These observations accord with the fact that people in higher socio-economic groups tend to have raised steroid outputs (Barnicot and Wolffson, 1952; Politzer and Tucker, 1958; Edozien, 1960), and with my own observations that food-gathering Amerindians in the Surinam rain forest have much lower 17-OHCS outputs than medical students in Glasgow, even when their smaller body mass is considered (Simpson, 1965*a*). However, it is probably too early to conclude that there is adrenal hyper-function in affluent westerners; the results might merely indicate alteration in thyroid function and faster steroid turnover. More work is required especially since the question is highly relevant in the aetiology of stress diseases. Leonard's (1965) observation that East Africans have "normal" plasma cortisol levels is slightly clouded by the fact that he used convalescing patients and out-patients who might not be stress-free.

It has often been presumed that stress is a threat of some sort to the organism and therefore something to be avoided. Is this so? Some years ago, Pugh (1959) showed that skiers at a resort were stressed in the evening and he pointed out the obviously beneficial effects of these holidays. After a month of stress on our Greenland crossing we went straight on to complete a 250 mile (400 km.) canoe journey up the coast of Greenland, a journey in every way more dangerous than sledging. Obviously, the journey had not caused any marked deterioration in our physical condition. Equally, however, the leader of the long Antarctic sledge journey who was stressed merely by camping in the field, undoubtedly had mental changes which made continuation impossible. It would seem, therefore, that the difference between beneficial stress and that causing mental changes is a matter of degree and duration.

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