TABLE I. METEOROLOGICAL DATA FOR HALLEY BAY
(The year has been divided into three seasons)

	Summer I			*Winter*					*Summer II*			
	February 1961	*March*	*April*	*May*	*June*	*July*	*August*	*September*	*October*	*November*	*December*	*January 1962*
Monthly mean temperature (°C)	−11·3	−17·6	−22·9	−19·7	−33·1	−32·7	−32·3	−28·8	−14·2	−12·4	−5·8	−4·9
Mean monthly maximum temperature of daily extremes (°C)	−7·1	−12·1	−18·0	−14·2	−27·1	−27·2	−25·5	−22·2	−10·3	−7·3	−3·3	−2·9
Mean monthly minimum temperature of daily extremes (°C)	−15·7	−22·0	−28·0	−24·6	−38·7	−38·4	−38·4	−34·8	−18·6	−16·2	−8·5	−8·5
Mean monthly wind speed (kt.)	10	14	12	18	11	8	10	9	21	10	12	8
Mean number of hours daylight	24	14	7	0	0	0	0	12	17	24	24	24

TABLE II. THE CHANGES IN BODY WEIGHT AND SKIN-FOLD THICKNESS (THE MEAN OF FOUR SITES: NAMELY, SCAPULAR, PECTORAL, BICIPITAL AND ABDOMINAL) AT MONTHLY INTERVALS, WITH THE SEASONAL CHANGES IN FOOD INTAKE

	February 1961	*March*	*April*	*May*	*June*	*July*	*August*	*September*	*October*	*November*	*December*	*January 1962*
Mean body weight (kg.)	74·3	75·2	76·8	76·6	76·9	77·1	77·4	77·4	76·9	77·1	77·0	77·0
Mean skin-fold thickness (mm.)	7·8	8·3	8·7	9·5	9·1	9·6	9·3	9·5	9·1	9·1	9·3	9·3
Seasons	Summer I			Winter					Summer II			
Food intake (kcal.)	3·850			3·360					3·660			
Protein (per cent)	13·9			11·4					11·1			
Fat (per cent)	38·9			39·6					41·6			
Carbohydrate (per cent)	47·2			49·1					47·3			

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ADIPOSE FAT COMPOSITION IN YOUNG MEN IN ANTARCTICA

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The influence of low ambient temperatures on the composition of the fat of animals has frequently been investigated, but the effect on man while resident in the cold has not been studied. It has been shown that in fungi and seeds grown at differing environmental temperatures, the degree of unsaturation of the component fatty acids is proportional to the surrounding temperature (Pearson and Raper, 1927; Hilditch, 1951). The lower the temperature, the more unsaturated is the fatty acid composition. There are similar findings in animals, both in the laboratory and in the field (Henriques and Hanson, 1901; Young and Cook, 1955; Irving, Schmidt-Nielsen and Abrahamsen, 1957; Kodama and Pace, 1963). Further, in man subsisting on the same diet but living in geographical regions characterized by marked differences in the ambient temperature, the same hypothesis has been evoked in explaining dissimilarities in the degree of unsaturation of the subcutaneous fat (Macdonald, 1961; McLaren and Read, 1962). It was considered that serial studies in the adipose fat of men living at an Antarctic station might provide data that would help to substantiate these theories.

A survey was carried out by one of us (D.L.E.) between February 1961 and January 1962 on 19 male adults manning the British Antarctic Survey station at Halley Bay, which is situated on the east coast of the Weddell Sea in lat. 75°36′S., long. 26°39′W.

Subjects. The average age of the group was 24·5 yr. (range 22–34 yr.), the average height was 179·6 cm. (range 165·9–194·0 cm.) and the mean body weight at the initiation of the experiment was 74·2 kg. (range 60·4–100·4 kg.). Though the personnel could be divided into four separate occupational groups: namely, scientists, technicians, manual workers and cooks, there is considerable overlap in both the type and the amount of work performed by these groups, and the cold exposure of the four groups was similar for the greater part of the year.

The environment. In Table I the average outside temperatures with the mean wind velocities are shown for each month of the year. The year could be divided into three seasons: summer I, winter and summer II, as shown in the table. It is relevant that, though the outside temperatures were decidedly low, the actual exposure climate of the subjects rarely varied from an average level of approximately 13° C, and the sub-clothing temperature, or microclimate, was usually in the range of 32° to 33° C (Norman, 1965).

The dietary intake. The food throughout the year, which was plentiful with no restriction or rationing at any time, was largely tinned or dehydrated. Apart from the lack of fresh fruit and vegetables, the diet was essentially similar to that eaten in the United Kingdom. Seal and penguin meat was occasionally consumed.

The food intake of each subject was accurately measured at regular intervals throughout the year. The mean total calorie intake was 3,600 kcal./man/day, 12·1 per cent being derived from protein, 39·8 per cent from fat and 48·1 per cent from carbohydrates. This percentage composition of the diet is similar to the average diet in the United Kingdom. The seasonal mean levels of food intake are given in Table II. The reduction in calorie intake in the winter months was significant ($p<0·001$).

Body weight and skin-fold thickness. The body weight and the skin-fold thickness were measured at monthly intervals. The body weight increased by 2·5 kg. during the first 2 months of the survey ($p<0·001$) and then remained comparatively constant, i.e. the subjects were in isocaloric balance for the whole of the year bar the first 2 months. The skin-fold thickness increased during the first 3 months ($p<0·001$) and then remained constant.

The adipose biopsies. Specimens of subcutaneous fat from the buttock were taken at regular intervals from 19 subjects using the punch-biopsy method of Hirsch and others (1960). The samples were stored at a temperature varying between −20° and −6° C in a 1 : 1 (volume) solution of isopropyl alcohol and petroleum ether (boiling point 30–60° C). To reduce the

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risk of oxidative changes, 1 ml. D.L. a-tocopherol (Roche) was added to the extracting solution. The specimens were placed in 30 ml. bottles, which were firmly sealed with tape.

At the end of the year, the samples were transported to the South African Institute for Medical Research in Johannesburg, where the laboratory analysis was carried out. The samples were transmethylated by a micro-technique (Stoffel, Chu and Ahrens, 1959), and their fatty acid composition was analysed by gas-liquid chromatography. A Pye argon gas chromatograph was utilized (Lovelock, 1958) at a temperature of 180–181° C with a 120 cm. glass column (4 mm. internal diameter) filled with 80–100 mesh chromosorb on which 20 per cent polydiethylene glycol succinate (LAC–2R–728) was coated. The percentage compositions of the component fatty acids of the adipose biopsies were calculated by triangulation of the differential record, and by direct measurement of the integral records. Results from the differential and integral records showed close agreement. Replicate analyses of the same sample were found to be accurate to ±3 per cent. A number of biopsies showed a poor yield of subcutaneous fat and they did not produce satisfactory peaks on the chromatographic record. A total of 139 samples was finally analysed.

A typical tracing taken from the chromatograph of adipose fat is demonstrated in Fig. 1. The numbering system of Dole and others (1959) was followed, indicating the chain length and number of double bonds, namely: 14 : 0, myristic; 16 : 0, palmitic; 16 : 1, palmitoleic; 18 : 0, stearic; 18 : 1, oleic; 18 : 2, linoleic; 18 : 3, linolenic. The qualitative nature of the fatty acids is based on the comparison of their retention times with those of a standard mixture. Although all the visible esters in the chart were computed as a percentage, only the major esters are discussed in the assessment of the results.

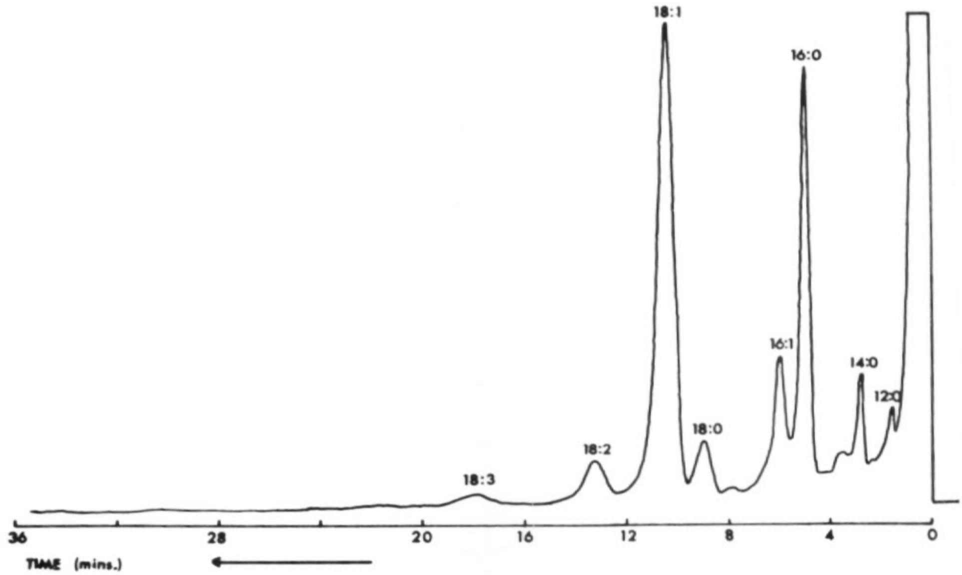

Fig. 1. A reproduction of a chromatograph of the adipose fat of subject P.N. The fatty acids are marked according to their short-term denomination.

RESULTS

The grand mean for 139 estimations of the adipose fat composition and the individual mean values with standard deviations are shown in Table III. It is seen that the individual mean levels demonstrate considerable variation and that there is also a similar though smaller intra-individual variation.

The seasonal changes in the percentage composition of the adipose fat are shown in Table IV. Examination of all the individual values of oleic acid by variance analysis indicates

Table III. The mean percentage compositions of adipose fat for each individual and for the entire group. The standard deviations are included. The food intake with the chemical composition is also given

Subject	*Number of biopsies analysed*		*Fatty acid: short-term denomination* (Mean percentage ± S.D.) 14 : 0	16 : 0	16 : 1	18 : 0	18 : 1	18 : 2	18 : 3	*Mean food intake* (kcal.)	*Protein* (per cent)	*Fat* (per cent)	*Carbohydrate* (per cent)
E.T.	8	Mean	3·1	21·9	9·3	4·1	51·3	5·8	2·2	2,854	10·3	39·4	50·3
		S.D.	1·1	1·4	1·5	1·3	4·1	1·4	0·3				
B.P.	7	Mean	3·6	23·6	8·9	5·0	48·2	6·8	2·3	3,496	12·1	36·0	52·0
		S.D.	0·4	2·3	1·5	0·8	3·7	1·1	0·7				
M.J.	7	Mean	3·7	22·1	11·2	3·7	48·7	6·2	2·2	3,634	12·7	38·1	49·2
		S.D.	0·8	1·8	1·4	0·9	4·9	0·4	0·4				
G.T.	6	Mean	2·1	24·4	5·2	5·4	56·6	4·7	tr	3,357	13·4	42·5	44·1
		S.D.	0·9	2·7	0·8	1·3	5·3	1·3	—				
A.P.	9	Mean	3·4	22·8	9·6	6·0	50·3	5·8	1·5	3,562	10·8	40·0	49·2
		S.D.	1·0	2·8	1·4	1·3	3·0	0·6	0·4				
J.S.	7	Mean	3·8	22·7	9·0	4·6	49·0	6·2	2·1	3,401	12·5	40·2	47·3
		S.D.	1·6	1·6	1·3	0·6	4·6	1·2	0·4				
C.D.	5	Mean	2·9	23·7	8·2	4·1	50·3	6·3	1·4	3,346	13·5	41·9	44·5
		S.D.	0·6	1·3	0·3	0·9	1·6	0·7	0·3				
K.S.	7	Mean	4·4	23·4	10·1	4·3	46·5	6·0	2·6	3,312	12·2	40·3	47·5
		S.D.	0·5	0·9	1·4	0·7	0·7	0·7	0·3				
C.M.	10	Mean	3·5	23·1	9·0	3·2	50·6	6·0	1·8	2,671	13·2	38·2	48·6
		S.D.	0·8	1·5	1·8	1·0	2·7	0·7	0·6				
M.T.H.	7	Mean	3·8	23·9	9·3	4·4	47·2	6·2	2·1	4,625	10·2	47·5	42·2
		S.D.	0·7	2·2	1·8	1·1	2·9	1·2	0·4				
E.D.	5	Mean	3·4	20·9	6·8	4·4	51·5	8·0	1·7	3,628	13·0	37·5	49·5
		S.D.	0·8	4·1	2·7	1·3	3·2	2·5	1·0				
M.B.R.	7	Mean	4·6	24·6	8·8	4·8	45·3	7·6	1·7	3,000	10·7	38·7	50·6
		S.D.	0·9	1·2	0·6	0·2	1·9	1·9	0·3				
D.J.	7	Mean	3·8	23·9	10·0	4·5	46·3	5·8	2·7	3,227	11·2	36·8	31·9
		S.D.	0·8	1·4	0·7	0·3	2·3	0·5	1·0				
P.N.	6	Mean	4·4	22·6	8·6	3·4	48·9	6·2	1·5	3,604	13·0	45·3	41·7
		S.D.	1·3	0·9	0·4	0·6	4·3	1·4	0·2				
S.M.	10	Mean	2·3	20·1	7·6	5·1	48·4	7·1	3·5	3,588	15·1	36·6	48·3
		S.D.	1·1	2·9	1·7	1·1	5·1	1·4	1·0				
G.B.	6	Mean	2·9	21·3	11·3	3·9	46·9	8·9	2·1	4,182	11·5	39·3	49·2
		S.D.	0·9	1·4	0·5	1·0	3·5	0·4	0·6				
R.L.	11	Mean	2·7	20·5	7·5	4·8	52·1	6·9	3·1	5,122	10·7	45·6	43·2
		S.D.	0·9	2·3	0·9	0·8	4·9	0·7	1·5				
D.A.	8	Mean	3·9	23·1	9·2	4·0	48·0	5·5	2·5	3,987	10·6	43·7	45·6
		S.D.	0·8	1·7	1·2	0·8	3·8	0·8	0·4				
D.E.	6	Mean	2·6	22·8	7·9	4·8	49·1	7·2	2·3	3,589	11·3	42·6	46·1
		S.D.	0·9	2·0	1·7	1·2	3·8	1·6	0·9				
Grand mean			3·39	22·59	8·83	4·47	49·26	5·89	2·25				
Standard deviation			1·16	2·44	1·93	1·19	4·52	2·25	0·93				

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the "between men" effect to be significant at the 0·5 per cent level, and that the overall change over the entire year is just significant at the 5 per cent level. The remaining fatty acids show small variation.

TABLE IV. THE MEAN PERCENTAGE COMPOSITIONS OF ADIPOSE BIOPSIES TAKEN DURING THE THREE SEASONS. STANDARD DEVIATIONS ARE INCLUDED

Season	*Fatty acid: short-term denomination*						
	14 : 0	16 : 0	16 : 1	18 : 0	18 : 1	18 : 2	18 : 3
February–April (Summer I)	3·5 ±1·1	23·2 ±2·2	8·9 ±2·0	4·8 ±0·8	47·6 ±4·1	6·7 ±2·0	2·1 ±0·7
May-September (Winter)	3·4 ±0·8	22·6 ±1·7	9·3 ±1·5	4·2 ±0·9	49·2 ±2·9	6·7 ±0·9	2·1 ±0·6
October–January (Summer II)	3·2 ±0·9	22·1 ±2·6	8·1 ±2·0	4·5 ±2·7	50·4 ±4·2	6·5 ±1·6	2·4 ±0·8

DISCUSSION

The mean composition of the subcutaneous fat of the Halley Bay group agrees with observations made on subjects in Boston, Massachusetts (Hegsted, Jack and Stare, 1962) and those made by Hirsch and others (1960) on 12 normal males and females resident in New York (Table V). However, in the latter group linoleic acid was considerably higher than in the Antarctic group, whereas in the Bostonians it was lower. It has previously been shown that the composition of the adipose fat taken from several widely differing geographical groups: namely, Japanese, Colombians, Nigerians and Jamaicans, could not be shown to be significantly different from each other, though this was suggested from the mean levels (Hegsted, Jack and Stare, 1962) (Table V). The results of the present survey do not really differ from other assessments (Kingsbury and others, 1961; Scott and others, 1962) and they fall within the range of the latter. It is evident that, in the Halley Bay subjects, linoleic acid existed in a greater proportion than in any other of the tabulated geographical groups, and it seems possible that this difference might represent a positive reaction to cold stress.

The significance of the "between men" effect for oleic acid in the variance analysis indicates that the amount of this acid in the adipose fat varied significantly for different individuals. No reason is evident for this finding, since the composition of the adipose fat does not appear to be related to differing amounts and type of calories consumed by each individual as shown in Table III. However, the range of variation is small, as shown by the deviation of the grand mean, 49·3±4·5 per cent.

The overall changes found over the year were small in magnitude and they were on the borderline of statistical significance. They are not considered to be an indication of compositional change due to exposure to low temperature, but they may rather be due either to the significant changes in the amount of calories consumed by the individuals during the different seasons, as shown in Table II, or to the different degrees of physical activity at different times of the year, as reported in a previous study of these subjects (Antonis and others, 1965).

Detailed studies in Antarctica have shown that the proportion of the elapsed day spent out-of-doors by men on static stations, i.e. those that do not carry out survey work, is small and amounted to 9 per cent (Norman, 1965). Further, it was shown that the micro-climate of the individual, i.e. the temperature underneath the clothing next to the skin, seldom varied from 32° C. These facts would explain the small and indefinite changes produced in the adipose fat of the Halley Bay subjects. To produce unequivocal evidence of cold adaptation would clearly require a more prolonged and severe cold exposure. The lack of convincing changes in the subcutaneous fat composition adds support to the protagonists of the hypothesis, that mankind does not require to adapt to cold environments, in that he is thermally isolated from the environment (MacPherson, 1958; Edholm, 1960). Man is in control of his own micro-climate and the cold exposure is not great enough to produce physiological changes of any magnitude.

TABLE V. THE MEAN PERCENTAGE COMPOSITION OF THE ADIPOSE FAT OF THE HALLEY BAY GROUP, COMPARED WITH THAT TAKEN FROM SUBJECTS IN OTHER GEOGRAPHICAL REGIONS

Geographical groups	*Fatty acid: short-term denomination*						
	14 : 0	16 : 0	16 : 1	18 : 0	18 : 1	18 : 2	18 : 3
Halley Bay males	3·4 ±1·1	22·6 ±2·4	8·8 ±1·9	4·5 ±1·2	49·3 ±4·5	5·9 ±2·3	2·2 ±0·9
American males and females from New York (Hirsch and others, 1960)	3·3 ±0·1	19·5 ±2·1	6·9 ±0·1	4·2 ±1·1	46·3 ±4·4	11·4 ±1·4	0·4 ±0·1
Bostonians (Hegsted, Jack and Stare, 1962)	3·6 ±1·0	24·6 ±3·0	6·1 ±2·0	6·7 ±1·8	50·3 ±3·4	7·9 ±3·5	tr —
Southern England males and females (Kingsbury and others, 1961)	— —	21–30	5–8·5	5·85	42–51	5·8	—
New Yorkers (Scott and others, 1962)	4·1	25·0	6·3	4·3	50·2	9·5	—
Japanese (Hegsted, Jack and Stare, 1962)	3·4 ±1·6	24·9 ±4·9	10·5 ±2·8	4·8 ±2·2	40·6 ±4·2	9·4 ±3·5	
Colombians (Hegsted, Jack and Stare, 1962)	4·3 ±0·9	25·1 ±1·1	8·5 ±2·1	6·9 ±1·5	45·7 ±4·1	5·5 ±1·1	
Jamaicans (Hegsted, Jack and Stare, 1962)	8·4 ±2·0	26·6 ±2·9	10·1 ±2·6	5·8 ±1·8	37·7 ±3·2	5·8 ±2·0	
Nigerians (Hegsted Jack and Stare, 1962)							
Group A	—	26·2 ±3·7	6·7 ±2·5	9·6 ±2·6	42·3 ±3·4	8·7 ±3·7	
Group B	—	18·5 ±2·9	5·9 ±1·8	7·1 ±1·3	46·2 ±3·7	7·9 ±1·8	
Group C	—	28·7 ±2·5	5·4 ±2·1	8·0 ±1·7	46·1 ±2·5	8·0 ±2·2	

SUMMARY

A survey was made in order to define the influence of environmental temperature on the composition of adipose fat in young men taking part in an Antarctic expedition. Specimens of fat were taken at regular intervals, and at the same time a parallel estimate was made of the food intake, and body weight and skin-fold thickness changes. It was found that the grand mean values of the fatty acids, when expressed as a percentage of the total, were: myristic, 3·4 per cent; palmitic, 22·6 per cent; palmitoleic, 8·8 per cent; stearic, 4·5 per cent; oleic, 49·3 per cent; linoleic, 5·9 per cent; linolenic, 2·2 per cent. The mean values for each individual were scattered over a fairly wide range, which was of interest in view of the common diet consumed by the subjects. The overall variations in the proportions of the different fatty acids in the adipose fat were insignificant except for that of oleic acid which were just significant. However, due to the fact that the changes were small, positive conclusions in favour of the adipose organ being a useful index of cold acclimatization in man could not be made.

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