PLATE 2

Photomicrographs of kidney sections of ewes, stained with haematoxylin and Sudan IV, exposed with blue filter, peak transmission about 465 mμ.

		Assessment of fat*
1.	Pre-service control	−ve
2.	After 100 days on adequate diet	−ve
3.	High-plane, unstarved	−ve
4.	Low-plane, unstarved	+
5.	High-plane, starved for 6 days	+
6.	Low-plane, starved for 6 days	++

* For method of assessment see Table 1.

The Energy Expenditure and Food Intake of Individual Men

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Within the last 15 years an interest in the importance of calorie expenditure and its relationship to intake has begun to reassert itself after a long interval of time. Broadly speaking there have been two reasons for it: the first has been a desire to find out more about the mechanisms which relate intake to expenditure—what regulates appetite, in fact—and the second an interest in industrial and field physiology. The first detailed study of energy expenditure and dietary intake was made by Bedale (1922–3). Bedale measured the oxygen consumption of 100 schoolchildren at twenty-five different activities and the time they spent on these activities. Wiehl (1944) investigated by a diary and interview technique the activities of high-school boys and girls in the United States over a 2-day period. These activities were listed under the headings of sleeping, sitting, and light, moderate and severe exercise, and the mean expenditure agreed very well with the intake, but the individual intakes varied from 50 to 190% of the expenditures. Keys (1945) criticized these findings as showing the fallacy of computing requirements in this way, and pointed out that individuals who were not rapidly gaining or losing weight must be in calorie balance. This is true, but they need not be in daily balance. Fox (1953) estimated the calorie expenditure and the food intake of members of a village in the Gambia over a period of a year. He measured the oxygen consumption at various tasks and recorded the time spent on the different occupations. Owing to a period of food shortage which coincided with the heavy farming work in preparation for the forthcoming harvest, calorie balance was only achieved over a matter of months, with corresponding losses and gains of weight.

Lehmann (1953) described the expenditure of energy on a number of industrial occupations which had been subjected to close analysis, but unfortunately these studies took no account of the energy expenditure outside working hours. Passmore, Thomson & Warnock (1952) made a balance sheet of the energy intake and expenditure of a small group of students under laboratory conditions, and obtained virtually exact agreement between the two over a period of 1 week. Garry, Passmore, Warnock & Durnin (1955) made a study of coal miners by a combination of oxygen measurements, diary records and dietary observations, and obtained figures for the men's energy expenditure at their daily occupations and its relation to their calorie intakes in terms of food. Bransby (1954) collected records of the time spent by 152 industrial workers at their jobs and at various out-of-factory activities, and he also made a dietary survey on the individual men. Widdowson, Edholm & McCance (1954) made a group survey of seventy-seven cadets at a military establishment. The total food intake was measured at each meal for a week and the expenditure of energy computed by means of a diary technique supplemented by a few direct measurements of oxygen consumption. The intake was found to be 3705 Cal./cadet/day and the expenditure 3420 Cal./cadet/day. This agreement was considered to be reasonably good, but it was felt that if the diary technique could be improved and if the necessary measurements of oxygen consumption could be made on a small group of men, their individual outputs of energy could be measured with sufficient accuracy from day to day to make it profitable to compare them closely with their individual intakes and so find out more about this important biological relationship.

EXPERIMENTAL

General. The investigations were made at the same establishment as before (Widdowson *et al.* 1954); the life of the place had changed little in the meantime. Twelve cadets were studied for a period of 2 weeks—from 29 June to 12 July 1953. Six of them were intermediates in their second 6 months (nos 1–6), and six were juniors in their first 6 months (nos. 7–12). All belonged to the same unit and were selected after discussion with the unit commander as being similar in height, weight, athletic interests and training (Table 1).

Measurement of food and calorie intake. All the food eaten by each individual cadet was weighed every day for 2 weeks. The cadets sat at one table at the end of the large dining hall and three assistants were responsible for seeing that nothing was eaten that was not weighed. Most foods were provided in limited amounts, and these portions were weighed at a side table and their weights recorded before being handed to the cadet. Foods that were available in unlimited quantities, that is bread, potatoes and sometimes other vegetables, were weighed on spring balances which stood on the dining table; the cadets helped themselves to these foods and one of the assistants noted the weights and recorded them. All plate waste was weighed and subtracted from the weight of the portion served. The composition of cooked dishes was calculated as before from a knowledge of the raw ingredients and the method of cooking.

An assistant was present in the canteen whenever it was open and he recorded the amounts of all foods and drinks bought by each of the twelve cadets taking part in this investigation. The composition of these 'extras' was also calculated from a knowledge of their ingredients. The cadets themselves were responsible for keeping a record of any additional foods, e.g. chocolate and biscuits, which they ate during the fortnight of the investigation.

Table 1. *Ages, weights and surface areas of the twelve subjects*

Subject no.		Age: Years	Age: Months	Weight (kg)	Surface area (m^2)	Height (cm)
1		19	1	68·4	1·87	180·3
2		20	0	69·4	1·90	184·2
3		19	10	67·0	1·87	182·9
4		19	5	78·8	2·08	189·9
5		20	0	71·5	1·89	179·1
6		20	9	83·8	2·14	189·9
7		18	9	67·1	1·84	177·8
8		19	4	68·5	1·86	179·1
9		19	4	62·4	1·74	172·7
10		19	8	76·7	2·00	184·2
11		18	6	69·3	1·71	172·1
12		18	11	65·9	1·85	181·6
	Mean	19	5½	70·0	1·89	181·1
First survey (mean of seventy-seven cadets)	Mean	19	9	68	1·84	178

The calorie, protein, fat, carbohydrate and alcohol intakes of the individual cadets were calculated from food tables (McCance & Widdowson, 1946*a*), each of the 14 days being calculated separately.

Time study. The diary method used was similar to that employed by Garry *et al.* (1955) in their investigation of the calorie expenditure of the East Fife coal miners. Each cadet was issued with a diary form which covered 18 h. It was collected at breakfast time, when a new form was issued. By a simple code it was possible for the subject to indicate, by one letter only in most instances, what he was doing at any particular minute. For certain activities it was not possible for the subject to do more than indicate the beginning and end of the time spent. Such activities included military parades, games and lectures, and for these the observers timed the various phases accurately with a stop-watch. A drill parade, for example, would be timed and shown to consist of so many minutes standing to attention, at ease, rifle drill and so on (Table 2). Since all the cadets in any one team would, in general, be attending the same parades, it was relatively easy to have a detailed observation of such activities. Metabolic determinations were made to cover as far as possible all phases of activity by the cadets. Many estimations were made on activities such as lying, sitting and standing, which covered the greater part of the day. From the diary sheets the time spent in the various activities each day was calculated, and the energy expenditure of a particular activity was entered on the form so that the energy expenditure involved for each activity could be calculated. Complex actions, e.g. a period of 2 h drill, were calculated on the basis of so many minutes of standing or other activities, and the calorie expenditure for standing, for rifle drill and so on was used to compute the total expenditure.

Metabolic measurements. Expired air was collected using Douglas bags and the Max Planck Institute (M.P.I.) calorimeter. A number of estimations were made serially on the same subjects with the M.P.I. calorimeter and Douglas bag. The M.P.I. calorimeter has already been fully described (Kofranyi & Michaelis, 1940; Lehmann, Müller & Spitzer, 1949–50; Orsini & Passmore, 1951; Müller & Franz, 1952). In order to overcome possible inaccuracies while learning the technique the first determinations made on the cadets were of energy expenditure during sitting, standing and lying, and the order of these was arranged in the form of a Latin square. The M.P.I. respirometers were calibrated at frequent intervals by passing air through a gasmeter at a constant rate and thence into the M.P.I. respirometer. Varying rates were used, and hence the constancy of the calibration factor was determined. When light activities were involved such as sitting, standing or lying, subjects used a conventional mouthpiece and a light Perspex valve holder. When heavier activities, such as cycling or games were involved, masks with inspiratory and expiratory valves were used instead. These masks were similar to the R.A.F. 'H' masks, with a dead space of about 250 ml. Masks were in general preferred by the subjects to mouthpieces when any active movement was involved.

Table 2. *Analysis of drill parade. Subject no.* 1

Activity	Time (A) Min	Sec.	Calorie cost Cal./min (B)	Total (Cal.) (A)×(B)
Standing: at ease	22	40	1·78	40·35
at attention	43	27	2·05	89·07
Arms drill	24	10	13·20	319·04
Dressing the ranks	10	29	3·08	32·28
Marching: quick	13	12	10·48	138·34
slow	6	45	7·86	53·06
Total	120	43	5·57	672·14

Gas analysis. Five members of the team carried out gas analyses, four using the Haldane gas analysis apparatus and one the Scholander apparatus. The gas samples were transferred from the small rubber bags attached to the M.P.I. respirometer into glass sampling tubes at the site of the metabolic investigations. If Douglas bags were used, the volumes of gas in them were measured in the laboratory or on the site, and samples transferred to sampling tubes. Analyses were carried out within 1–10 h after collection. On a number of occasions two samples of the same collection of expired air were obtained, and the analyses of these were carried out by different workers. The results of these analyses were used to check the accuracy of the individual analysts. All analyses were carried out in duplicate.

The duplicate analyses of one analyst gave results which indicated on the average 0·48 vol. % less oxygen than those of the others; her results were discarded. Calculation of the calorie value of the oxygen consumed was made using Weir's (1949) technique.

RESULTS

Intakes. Table 3 shows the mean intakes of calories, protein, fat, carbohydrate, alcohol, calcium and iron in this investigation and in the previous one (Widdowson *et al.* 1954). The proportions of the various dietary constituents were very similar to those found in the group investigation previously made at the same establishment,

Table 3. *Composition of the average diet of the cadets in the present investigation and in the earlier one* (*Widdowson* et al. 1954)

Item	Previous investigation (mean for seventy-seven cadets for 1 week)	Present investigation (mean for twelve cadets for 2 weeks)
Calories (Cal./day)	3705	3432
Protein (g/day)	104	99
Fat (g/day)	139	123
Carbohydrate (g/day)	509	488
Alcohol (g/day)	11	8
Calcium (g/day)	1·28	1·14
Iron (mg/day)	23·7	21·0

but all the amounts were a little less on the second occasion. This difference is entirely due to a reduction in the amount of food bought at the canteen and outside, for the average calorie intakes in the dining hall were almost identical in the two investigations (2527 and 2549 Cal. for the first and second surveys respectively). Seniors were included in the first investigation but not in the second; these had a special canteen of their own which served such foods as bacon and egg, baked beans on toast, sausages and chips, and when the results of the previous investigation were re-examined it was found that the seniors obtained on the average twice as many calories from the food they ate in their canteen as the intermediates and juniors obtained from theirs. The calories which the intermediates and juniors derived from food that they bought were very nearly the same in the two investigations (900 and 883 Cal. respectively), and their mean total calorie intakes were almost identical on the two occasions (3427 and 3432 Cal./day).

There is a suggestion that for some reason the metabolic observations slightly reduced the intake of food. Both groups ate a little less during the weeks when the expenditures were being measured. In the junior group the mean calorie intake was 3212 Cal. against 3469, and this difference was statistically significant; the difference for the intermediates was not significant and no reason can be assigned to either of them.

Expenditures. The time spent on various activities and the calorie expenditure involved in these activities are shown in Fig. 1. These results were in general similar to those obtained in the first survey, and the time and energy spent sitting and sleeping are again noteworthy. Since, however, the second survey was so much more complete it has been possible to dispense with a block for 'miscellaneous activities'. Much more time was spent 'standing' in the second survey and to a large extent accounted for the time previously assigned to 'miscellaneous activities'. Sitting did not take up quite so much of the total time as it did in the first survey; more time was spent in walking and less on cycling; in fact the cadets taking part did very little cycling in the second survey, for they lived in the main building which also housed the dining room, canteens and lecture theatres. In the first survey the sleeping quarters had been nearly half a mile away from lecture theatres and dining hall, and the cadets had had to cycle this distance repeatedly during the day.

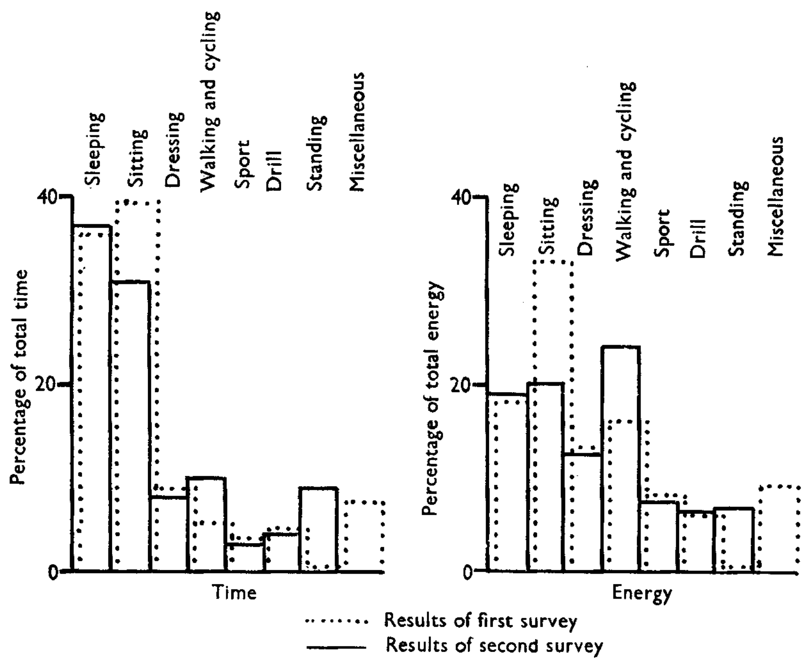

Fig. 1. Percentage of time and energy spent by the cadets in various activities. The percentage of the total time (2 weeks) spent in any particular activity is shown on the left-hand side of the figure. On the right is shown the percentage of the total energy expenditure used in these activities. The results of the first survey (Widdowson *et al.* 1954) are given for comparison. The results of the two surveys are similar, but the column headed 'Miscellaneous' is absent from the second survey, as much more detailed information was obtained.

Tables 4–7 give the detailed results of the measured expenditure at various 'tasks'. Most of the figures are means of a number of tests made on the same subject. Since the establishment was a military one, a good deal of attention was devoted to drill. The way in which each figure is derived will be made clearer by reference to Table 2, which shows the calorie expenditure on various aspects of drill by one of the subjects and the times spent on them during the whole parade. Apart from their absolute values for future reference the figures shown in these tables have two main interests according to whether they are compared vertically or horizontally, Some points to be noted are perhaps: (1) The figure for lying was of the order of 1·5 Cal./min, so that these men would have required about 2200 Cal./day to prevent them from losing weight had they been kept in bed. This seems a reasonable estimate, but it may be a little high, for it has been shown (Courtice & Douglas, 1935–6) that previous activity can maintain a higher output of energy at rest for several hours. (2) The vertical comparisons require little comment. The 'indoor' activities grouped themselves round about 2 Cal./min, but dressing was a more active pursuit than this for most of these young men; it may be so for many other people for it is a task very often performed 'in a hurry'. Climbing

Table 4. *Cost (Cal./min) of activities for individual subjects*

Subject no.	Activity: Lying*	Sitting†	Standing‡	Marching§	Running‖	Stair-climbing¶	Dressing**
1	1·55 (2)	1·49 (3)	1·78 (2)	6·44 (1)	11·15 (1) 8 m.p.h.	—	—
2	1·31 (3)	1·62 (2)	1·78 (3)	6·02 (2)	12·33 (2) 7·5 m.p.h.	—	3·26 (2)
3	1·70 (3)	1·74 (3)	1·85 (5)	5·75 (3)	10·58 (2) 7·5 m.p.h.	—	—
4	1·44 (4)	1·61 (2)	2·19 (3)	7·34 (2)	10·56 (3) 7·5 m.p.h.	—	4·98 (1)
5	1·86 (3)	2·06 (3)	2·20 (3)	4·42 (2)	—	—	4·88 (1)
6	1·30 (4)	1·34 (3)	1·43 (3)	6·33 (2)	13·32 (2) 7·8 m.p.h.	—	—
7	1·39 (5)	1·59 (5)	1·65 (3)	6·33 (2)	15·0 (3) 10–11 m.p.h.	14·79 (2)	3·95 (2)
8	1·33 (1)	1·47 (3)	1·85 (4)	4·53 (4)	10·52 (2) 6·5–7 m.p.h.	6·12 (1)	3·56 (2)
9	1·18 (7)	1·46 (4)	1·61 (8)	5·29 (6)	10·9 (2) 7·5 m.p.h.	10·1 (1)	3·18 (2)
10	1·62 (3)	1·65 (2)	1·90 (4)	7·21 (1)	13·14 (2) 8–9 m.p.h.	—	3·63 (2)
11	1·47 (1)	1·46 (2)	1·64 (1)	5·48 (2)	11·8 (2) 7·5 m.p.h.	—	3·84 (2)
12	1·60 (4)	1·74 (4)	1·99 (3)	5·64 (2)	13·66 (2) 7·5 m.p.h.	—	4·85 (2)
Mean	1·48	1·60	1·82	6·03 (excluding no. 5)	11·67 (excluding nos. 7 and 10).	10·30	4·00

Figures in parentheses give number of determinations.
* Not in basal state. Subjects lay for 10 min before determination made.
† Note small difference between lying and sitting.
‡ Standing at ease.
§ Army pace, i.e. 3·4 m.p.h. Level surface. Subject no. 5 had an injured knee, walked at 2·8 m.p.h.
‖ At the double in uniform, level ground. Subjects nos. 7 and 10 ran at higher speeds.
¶ Steps 7 in. high. Time up and down forty-six steps: subject no. 7, 48 sec., subject no. 8, 67 sec., subject no. 9, 45 sec.
** Trousers, tie, collar, shirt, anklets, boots, socks, belt removed and put on, and cycle repeated.

stairs and the outdoor sports demanded the expenditure of considerable energy and had they occupied more of the subjects' time would have made a great difference to their overall requirements. (3) Some of the tasks, e.g. drill, were more strenuous for all the men on some days than on others, but (4) there was a great difference in the efficiency with which any two men might perform the same task. Subject no. 4, for example, expended more energy on nearly all his activities than no. 11, but this prodigality was not apparent when he lay down. Subject no. 9 lay, sat and stood with very little expenditure of energy, whereas no. 5 did just the reverse. These differences

Table 5. *Calorie cost (Cal./min) of kit cleaning*

Subject no.	Kit cleaning: Ironing*	Polishing†	Rifle cleaning‡
1	—	2·16 (2)	3·16 (1)
2	3·92 (1)	2·66 (1)	—
3	—	2·24 (1)	2·42 (2)
4	—	2·38 (2)	—
5	3·95 (2)	2·45 (3)	2·86 (2)
6	—	—	—
7	3·70 (2)	2·38 (2)	—
8	—	—	2·68 (2)
9	—	—	2·30 (4)
10	—	2·49 (2)	—
11	4·24 (2)	—	2·71 (1)
12	5·16 (2)	—	—
Mean	4·20	2·40	2·70

Figures in parentheses give number of determinations.
* 5½ lb. electric iron. Standing and moving between table and board.
† Sitting, polishing leather, buttons and other parts of kit.
‡ Sitting two-thirds of the time, standing one-third.

Table 6. *Calorie cost (Cal./min) of games and sports*

Subject no.	Archery	Cricket: Batting*	Cricket: Bowling*	Squash	Tennis	Cycling†	Motor cycling‡	Driving§
1	4·77 (1)	—	—	—	6·43 (1)	7·41 (2) 12–13 m.p.h.	—	—
2	5·71 (2)	—	—	—	6·87 (2)	6·17 (2) 11–12 m.p.h.	—	—
3	—	6·02 (2)	6·70 (2)	—	—	7·55 (2) 12 mp.h.	—	—
4	—	9·86 (2)	7·02 (2)	—	—	—	—	—
5	—	—	—	—	—	8·42 (2) 10 m.p.h.	—	—
6	—	9·22 (2)	9·13 (2)	—	5·69 (2)	7·91 (2) 12 m.p.h.	—	—
7	—	—	—	11·85 (3)	7·24 (2)	15·77 (1) 18 m.p.h. 8·14 (1) 12–13 m.p.h.	—	—
8	—	6·89 (2)	9·15 (2)	9·05 (4)	—	—	2·14 (2)	2·45 (2)
9	—	—	—	8·51 (2)	—	6·29 (2) 12 m.p.h.	2·87 (2)	3·67 (2)
10	—	—	—	11·46 (2)	8·48 (2)	8·61 (2) 12–13 m.p.h.	—	—
11	—	—	—	11·20 (2)	7·78 (2)	8·16 (2) 12 m.p.h.	3·46 (2)	4·06 (2)
12	—	—	—	9·02 (1)	7·43 (2)	9·28 (2) 13 m.p.h.	—	—
Mean	5·24	8·0	8·0	10·18	7·13	7·72 12–13 m.p.h.	2·82	3·38

Figures in parentheses give number of determinations.
* Batting and bowling at the nets. Batsmen ran between wickets twice every six balls.
† Subject no. 5 injured knee, first value on subject no. 7 at much faster speed. Both omitted from mean. Runs made on nearly level road.
‡ Heavy army motor cycle on level ground.
§ 15 cwt. army truck. Driving on level ground.

Table 7. *Complex activities; metabolic cost (Cal./min) estimated from time study and experimental values*

Subject no.	Drill* Parade 1	Drill* Competition practice	Drill* Competition practice	Drill* Competition 1	Drill* Competition 2	Drill* Parade 2	Drill* Church parade	Weapon training	Potted sports† A In gym	Potted sports† B Outdoors	Obstacle course‡
1	6·50	4·89	5·56	4·68	6·60	5·58	4·31	2·09	—	3·76	5·94
2	—	4·98	5·62	4·58	6·10	5·59	4·12	2·03	—	4·0	6·35
3	5·62	3·99	4·52	3·94	5·64	4·58	3·74	2·11	—	3·32	5·69
4	7·07	4·55	5·29	4·86	7·05	5·48	4·86	2·47	—	3·86	6·03
5	5·16	—	—	—	—	—	—	2·35	—	3·64	6·38
6	6·21	4·00	4·76	4·18	6·15	4·91	—	1·81	—	4·0	6·55
7	—	4·82	5·41	4·29	5·99	5·33	3·74	2·26	2·86	—	—
8	—	4·60	5·43	4·83	6·96	5·54	4·68	2·19	2·56	—	—
9	—	4·50	5·12	4·22	6·0	5·10	3·82	2·08	2·46	—	—
10	—	4·77	5·29	4·38	6·0	5·27	3·98	2·58	2·90	—	—
11	—	4·15	4·76	4·02	5·67	4·77	3·77	2·13	2·58	—	—
12	—	4·36	4·94	4·29	5·90	4·98	3·48	2·46	3·06	—	—
Mean	6·11	4·51	5·15	4·39	6·10	5·20	4·05	2·21	2·74	3·77	6·16

* Entries all refer to drill parades. Juniors did not take part in parade 1.
† A series of exercises, some competitive, including relay race, sprint, rope climbing, vaulting, medicine ball, with rests between events.
‡ Practice over different obstacles, including water jump and scaling wall, with rest pauses.

were consistent from day to day, for the men's expenditure of energy on the quantitatively important tasks was often measured a number of times although the separate figures have not been given in Table 4. There was therefore a real spread in the amounts of energy expended on some of these tasks even by men who appeared very similar in all outward respects.

Energy balances. Each person's daily intake and expenditure of calories is shown in Tables 8 and 9, together with the weekly means for the individuals, the daily and weekly means for the intermediate and junior groups and the daily and weekly means for both groups together. The mean expenditure for the twelve cadets over the whole fortnight was very close to that of the intake, and the same is true of the means for the groups of intermediates and juniors. In spite of the homogeneous nature of the groups and of their activities, the individual intakes differed by over 1000 Cal./day, even when averaged over 14 days. Greater variability than this has usually been found by those who have investigated less homogeneous groups of men, women or children (Widdowson, 1936, 1947; Widdowson & McCance, 1936), and their reality becomes more and more certain as the methods of measurement have been improved. The individual intakes were also highly variable from day to day, and this again was confirmation of previous findings. As often as not these intakes were far from being in daily or even in weekly or fortnightly balances with the expenditures. Subject no. 6, for example, had an intake of 4469 Cal. on 6 July and an expenditure of only 2605, and no. 4's expenditure exceeded his intake by 645 Cal./day over the whole fortnight. There is a particularly marked discrepancy between intake and expenditure on Thursday, 9 July, when there was a drill competition. The energy expenditure of the cadets was individually higher than on any other day or equal to the highest level, but the intake on this day was much lower than the average for the whole fortnight. There is a mean difference of 1027 Cal. between expenditure and intake. The food eaten in the mess was slightly above average, but only one-third of the normal amount was bought in the canteen. This may have been due, in part, to fatigue, and to less time being available to visit the canteen.

The daily intakes have been plotted against the expenditure in Fig. 2, and these differences seem much too large to be accounted for by experimental errors, which can hardly have been consistently in one direction or the other since the means for the intakes and expenditures agree so well. They must be accepted as real, and the men's changes in weight substantiate this, for although the subjects were not weighed at the beginning and end of the investigations owing to the difficulty of interpreting changes in weight over short periods of time, the routine determinations made every 4 months indicated that the weights of eleven out of the twelve men moved in the direction to be expected from their energy balances.

DISCUSSION

Since individual food studies were first made, it has always been a problem why two people of the same age and appearance and with similar occupations were so often found to have widely different calorie intakes. Widdowson (1947), for example, found that at every age between 1 and 18 years it was possible to find one child in a group

Table 8. *Daily calorie intake (Cal.) of the cadets*

Subject no.	Mon. 29 June	Tues. 30 June	Wed. 1 July	Thurs. 2 July	Fri. 3 July	Sat. 4 July	Sun. 5 July	Mean for week	Mon. 6 July	Tues. 7 July	Wed. 8 July	Thurs. 9 July	Fri. 10 July	Sat. 11 July	Sun. 12 July	Mean for week	Mean for fortnight
1	3024	2795	2418	3296	3528	2015	3477	2936	3373	3649	3464	2629	3893	3308	3089	3344	3140
2	3279	2749	3112	3464	2857	2143	2815	2917	3280	2868	3835	3899	3491	2750	2447	3225	3071
3	4553	3876	3650	3906	3566	2695	2747	3570	4700	4359	4006	4244	3930	3651	3143	4005	3788
4	4364	3190	3352	4065	3412	2705	3089	3454	3415	2923	4463	3076	2891	3652	3737	3451	3452
5	4128	4309	3151	3547	4524	3398	2939	3714	3761	3097	3419	2419	2924	4373	4261	3465	3589
6	4033	3596	4420	3774	4154	4625	3343	3992	4469	4298	3984	4090	4038	4523	4153	4222	4107
Mean for intermediates	3897	3419	3351	3675	3673	2930	3069	3432	3831	3532	3862	3393	3528	3709	3472	3617	3524
7	3316	2875	4066	4271	2380	3439	2506	3265	3563	2651	3092	2602	3426	3056	4265	3236	3250
8	3688	2642	3474	2708	2363	3391	2973	3034	3330	2697	2463	2866	2111	4934	2257	2951	2993
9	3611	3731	3904	3347	2261	4737	3164	3536	3703	2854	3347	2674	3203	4110	2105	3142	3339
10	4364	3968	4335	4463	4408	3107	3952	4085	3396	3073	3544	3466	4276	4115	4365	3748	3917
11	3685	3384	3399	3523	3242	3116	2705	3293	2866	2461	2960	2860	3013	2931	2730	2832	3063
12	3708	3808	4087	3215	3236	3632	3523	3601	3510	3195	3607	3164	4018	3385	2658	3362	3482
Mean for juniors	3729	3401	3877	3588	2982	3570	3137	3469	3395	2821	3169	2939	3341	3755	3063	3212	3340
Mean for all twelve cadets	3813	3410	3614	3632	3328	3250	3103	3450	3613	3177	3516	3166	3434	3732	3267	3414	3432

Table 9. *Daily energy expenditure (Cal.) of the cadets*

Subject no.	Mon. 29 June	Tues. 30 June	Wed. 1 July	Thur. 2 July	Fri. 3 July	Sat. 4 July	Sun. 5 July	Mean for week	Mon. 6 July	Tues. 7 July	Wed. 8 July	Thurs. 9 July	Fri. 10 July	Sat. 11 July	Sun. 12 July	Mean for week	Mean for fortnight
1	3558	3688	3718	3577	3252	3938	3633	3623	3699	3092	3096	4268	2949	4032	3142	3468	3546
2	3442	2921	3101	3708	3605	3992	3246	3431	3389	3062	3257	3895	3220	3579	2866	3324	3377
3	3476	3130	3917	3370	3634	3777	3375	3526	3197	3096	3824	4069	3189	3582	3100	3437	3482
4	3959	3380	4572	4081	3512	5527	3660	4099	4079	3397	3689	5341	3996	4537	3621	4094	4097
5	3549	3434	3205	3138	3125	3234	3032	3245	2856	3253	3219	3564	3331	3145	3215	3226	3236
6	3405	3328	3702	3260	3220	3860	2967	3392	2605	2853	2993	4203	3085	2840	2358	2991	3191
Mean for intermediates	3565	3314	3703	3522	3391	4055	3319	3553	3304	3126	3346	4223	3295	3619	3050	3423	3488
7	3798	3913	4648	3387	3546	3394	2878	3652	3223	3540	3735	4466	3264	4051	2837	3588	3620
8	3006	3247	3195	3036	3031	3417	2636	3081	2790	2645	3101	4025	2915	3715	2317	3072	3077
9	3005	3125	3941	2804	2771	2832	2413	2984	2578	2940	2861	3684	2634	3259	2848	2972	2978
10	3454	3935	3704	3762	3243	3623	2898	3517	3017	3102	3826	4468	3668	3634	3336	3579	3548
11	3127	3865	2809	3023	3006	3801	3480	3302	2750	3132	3593	4156	2773	3588	2338	3190	3246
12	3600	4025	3659	3201	3811	3927	3244	3638	3882	3378	3677	4178	3348	3278	3026	3538	3588
Mean for juniors	3332	3685	3659	3202	3235	3499	2925	3362	3040	3123	3466	4163	3100	3587	2784	3323	3343
Mean for all twelve cadets	3448	3500	3681	3362	3313	3777	3122	3458	3172	3125	3406	4193	3198	3603	2917	3373	3416

of twenty of the same sex who was eating nearly, if not quite, twice as much as another, and that these differences persisted if the two children were compared a second time. Differential changes in weight have not been found to be a complete solution, and it has been felt by most people that the differences between the intakes of food must originate in differences in the expenditure of energy. This study has shown that this is very probably so, for it has demonstrated that men may expend remarkably different

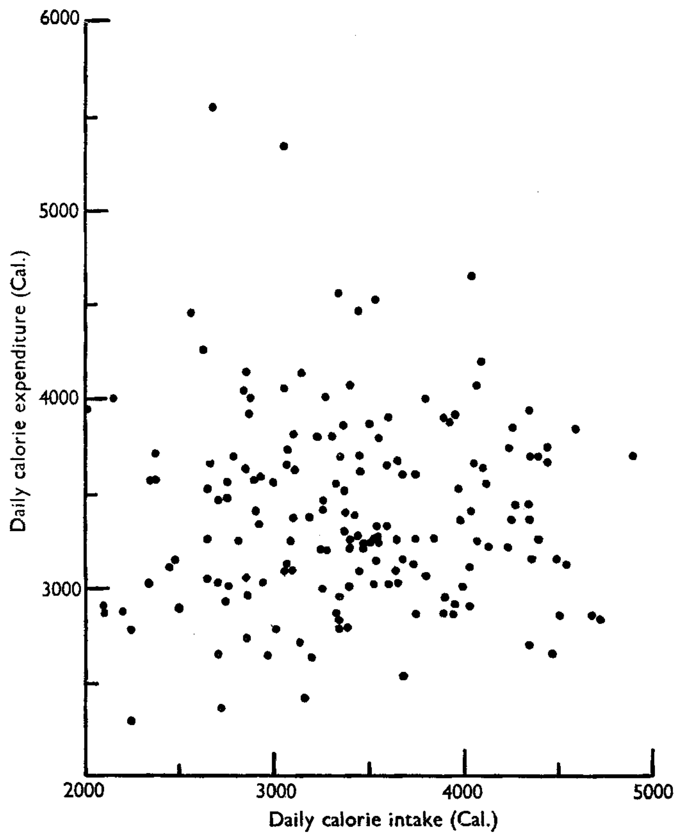

Fig. 2. Individual daily calorie intake and expenditure of the cadets. Daily individual food intake plotted against daily individual expenditure. Note the complete scatter of the results and the absence of any correlation.

amounts of energy in performing the same task. If one man can walk, sit and lie with half to two-thirds the energy expenditure of another, he will clearly require to eat much less food unless his occupation is a very different one and his hobbies equally so.

The expenditure of energy as dictated by circumstances and personal efficiency must create the demand for food, but how quickly and closely need the supply conform to the demand? In some animals, e.g rats and mice, the correlation is rapid and exact (Adolph, 1947; Kennedy, 1950; McCance, 1953*a*, *b*). Little is known quantitatively, however, about it in man, but here again the present experiments have been a help. There was no correlation between the expenditures and intakes of individuals (Fig. 2) on the same day or between the means for the expenditures and intakes on the same day, but there was a significant correlation between the mean daily expenditure and the mean daily intake 2 days later ($P = 0{\cdot}02$). These findings are illustrated in Fig. 3. Thus the intake of food tended to be low on days when the expenditure was very high and the deficit was made good some 2 days later. A much wider but equally spontaneous departure in the opposite direction from a person's customary plane of nutrition and a very belated correction was described by McCance & Widdowson (1946*b*). What controls this apparently simple banking and credit system is really quite unknown, but the mechanism is clearly the same one which made the African farmers recoup their nutritional debts when the new harvest came in (Fox, 1953), and German men whose

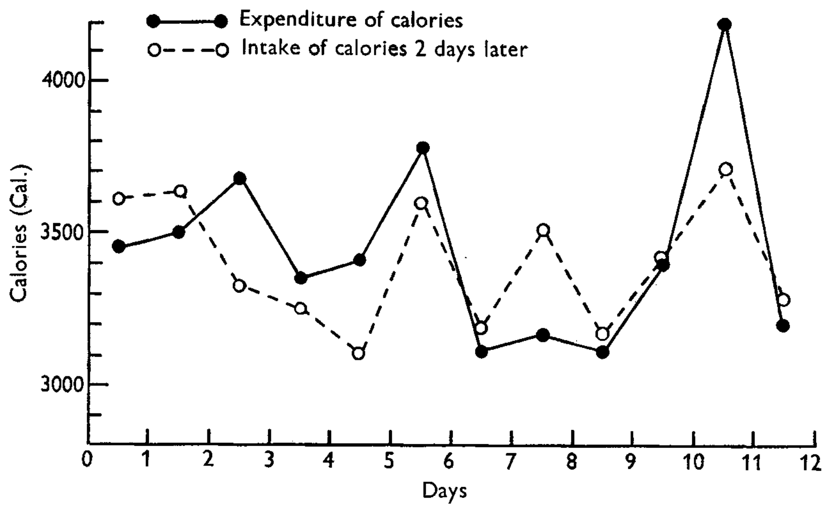

Fig. 3. Relationship between calorie expenditure and intake of the cadets. There is close agreement between the two plots indicating that daily intake of food is affected by the degree of activity 2 days previously.

intakes had been forcibly restricted in 1945–6, eat enough food to provide themselves with 6000 Cal./day for weeks on end when they were given the chance (Widdowson, 1951).

It is difficult to see how this belated adjustment of the intake of food to correct for an expenditure of energy incurred days, weeks or months before can be adequately explained by any theory which relates the sensations of appetite and hunger solely to the level of some metabolite such as glucose in the plasma or even in some specialized cellular sense organ (Mayer, Vitale & Bates, 1951).

To the world at large the amount of energy expended by military cadets in batting at the nets or ironing may not seem very important, but when a sufficient number of the activities to which men and women devote themselves has been investigated it will be possible to compile them into a complete set of tables, just as the composition of foods has been tabulated. A careful time and diary record will then enable the energy expenditure of a homogeneous group to be investigated with a degree of accuracy which will be quite sufficient for many purposes. Owing to the differences that may exist between any two people in the energy they expend on the same basal 'activities', individual records will always have to be treated with reserve. The diary technique, however, if conscientiously carried out, will nevertheless provide valuable information about details of the average calorie expenditure, show how time is spent and what are the major activities of mankind. In the surveys so far carried out the time spent sitting has varied from $8\frac{3}{4}$ to $10\frac{3}{4}$ h/day and the time lying down has been of the same order (Table 10). It looks as though man should be regarded now, if not in the past, as predominantly a sedentary rather than an upright animal.

Table 10. *Comparison of times spent per 24 h lying, sitting and standing by persons in different occupations*

	Time spent							
	Lying		Sitting		Standing		Total	
Subjects and reference	h	min	h	min	h	min	h	min
Mine workers (Garry *et al.* 1955)	7	45	8	9	2	34	18	28
Clerks (Garry *et al.* 1955)	7	42	8	22	4	3	20	7
Cadets—first survey (Widdowson *et al.* 1954)	8	26	9	13	—	$18\frac{1}{2}$	17	57
Cadets—present survey	8	37	7	6	1	58	17	41
Schoolboys (Wiehl, 1944)	9	28	10	28	—	—	19	56
Factory workers* (Bransby, 1954)	8	34	5	11	—	21	14	6

* Excluding working hours, which totalled 6 h 42 min/day.

SUMMARY

1. The individual expenditures of energy in a homogeneous group of twelve young men, cadets in a training establishment of the armed forces, were investigated daily for a fortnight by direct measurement coupled with an exact diary and timing technique. The expenditure varied widely from day to day.

2. The individual food intakes were also measured daily and varied equally widely.

3. The weekly and fortnightly balances between the two agreed when they were averaged, but there was no correlation between the mean expenditure on any one day and the intake on that day.

4. There was a correlation between the mean expenditure on one day and the intake 2 days later.

5. The energy expended on any one task, particularly a basal one such as sitting, lying or standing, often varied very much from one man to the next.

6. The energy expended by a number of men on tasks has been given in detail for future reference.

The dietary survey was carried out by Mrs L. A. Strangeways, Mr J. W. T. Dickerson and Mr L. A. R. Luff, and we thank them for all their help.

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