PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

Nutrition

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Nutrition

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Nutrition appeared somewhat late on the scene in the I.B.P. projects in the U.K., but eventually it occupied an integral part of many of the H.A. (human adaptability) investigations. The nutritional data obtained in the studies of isolated and near-isolated communities in Tristan da Cunha and in New Guinea provided information of wide nutritional significance. There were also detailed and extensive studies in Israel which, similarly to those in New Guinea, attempted to relate nutritional factors to environment, working conditions, and physical fitness. Some extraordinarily low energy intakes found in Ethiopians have induced much speculation on the extent to which man can adequately adapt to restricted food supplies. Interesting nutritional observations, of general importance, have also arisen from results obtained on such disparate groups as Glasgow adolescents, Tanzanian and Sudanese students, children in Malawi and vegans in the U.K.

Introduction

The nutritional component of the U.K. I.B.P. projects on 'human adaptability' had, initially, a somewhat restricted ambit: it occupied a part, often an important part, of several H.A. investigations but it was not, by itself, the principal reason for a study on a population. Indeed, throughout the course of the I.B.P., the situation remained that only some relatively minor studies were concerned primarily with nutrition.

In the event, a great deal of interesting nutritional information has been obtained which has considerably influenced our attitude to the most important nutritional problem of the present day and of the immediate future, the energy and protein requirements of populations. The information has accrued from a small number of studies on apparently diverse groups of individuals living in Ethiopia, New Guinea and the U.K., but it has been augmented by results from other groups.

Perhaps we have tended too much to think of nutritional 'adaptability' in an esoteric fashion, and we may be unduly preoccupied with populations who exist in situations of reduced availability of food. In a contrasting situation, populations living in highly industrialized and commercially developed countries show many adaptations, including nutritional ones, and these may be operating over a much shorter time-scale than those in industrially undeveloped communities. These also should be studied in depth. For example, it is at least conceivable that in circumstances where food is plentiful we may adapt in ways which effectively waste the food in the body – perhaps by digesting or absorbing it less efficiently, by increasing our metabolic rate, or even by increasing our level of physical activity. There is not a great deal of evidence in support of some of these possible adaptations but the fact is that their existence has not been fully explored and we are often too much influenced by thinking of the impossibility of such adaptations at extreme levels: it seems ridiculous to envisage someone who has become extremely obese through eating large quantities of food as being impelled to exercise strenuously as a direct consequence of his high energy intake. On the other hand, at a more modest level, perhaps the preoccupation of peoples in industrialized countries with the playing of games and sports, with climbing mountains and skiing, with actively and purposefully expending energy with no other end in view than the expenditure of excess energy, who is to say at present that this might not in part be determined by the large energy-availability in the diet?

There are many investigations required, in our own populations, of 'human adaptability' in a nutritional sense, and these are *perhaps* more likely to be undertaken as an outcome of the I.B.P. studies.

Of the studies which are to be mentioned in this brief review, it is my most sincere hope that none of the investigators, whose labour had often to be undertaken in difficult field circumstances, will feel that my fleeting and perhaps superficial references to their results indicate my assessment of their value. I have had of necessity to concentrate on one or two points of specifically nutritional interest and have therefore been somewhat cursory in my treatment of studies where the nutritional results were useful in the general assessment of the population, but not, by themselves, extraordinary.

Nutritional studies outside the U.K.

Israel

In the study referred to already by Dr Harrison on the Yemenite and Kurdish Jews in Israel, the prime interest was to assess the role of genetic and environmental factors in determining physiological characteristics. Edholm, Samueloff, and their colleagues (1973) showed that although 'there were very considerable (genetic) differences between the Yemenite and Kurdish Jews, so much so that genetically they could be considered as utterly dissimilar', yet these 'two ethnic groups...living in virtually identical conditions, were physiologically indistinguishable. Environmental factors therefore play a large part in determining physiological characteristics but the role of genetic factors could not be definitely identified.' That statement, which I have quoted *verbatim* from the appropriate section of the *Philosophical Transactions of the Society* is likely to receive frequent quotation in the recurrent controversy on the respective roles of genetic factors and environment.

The actual values for the energy intake and expenditure were much as would be expected in farming communities, where most of the men worked in the fields and the women, who were primarily housewives, were also responsible for looking after hens and cows and worked occasionally in the fields. However, one or two points need to be made specifically about these results and their general nutritional importance. Firstly, the energy value for the women, in spite of their apparently active life, was still only 9.41 mJ (2250 kcal)/day which is relatively low – and there were occasional very large discrepancies between the measured energy intake and expenditure of some of the groups, as much as 3.14 MJ (750 kcal)/day in some instances, presenting a methodological problem which is giving some of us concern at the present time.

Tristan da Cunha

The extensive and interesting genetic findings in the islanders of Tristan da Cunha have also been described by Dr Harrison. A small number of these islanders, 7 men and 10 women, were subjects in an investigation of their food intake and energy expenditure (Chambers & Lewis 1969). The men were mostly working in industrial jobs – bulldozer driver, carpenter, crane driver, mechanic – and the women were housewives, teacher, maid, typist, etc. The intakes and expenditures of energy would not excite comment now – 10.50 MJ (2510 kcal)/day of energy intake for the men (64 kg) and 7.41 MJ (1770 kcal)/day for the women (51 kg) – but one small point illustrates clearly the changing outlook towards 'believable' energy levels which has occurred during the past 5 or 6 years: the results for two of the subjects, a 16 year old boy weighing 52 kg whose energy intake was 7.11 MJ (1700 kcal)/day and a young woman of 64 kg who had an intake of 5.44 MJ (1300 kcal)/day, were omitted from the series for no other reason than that these results were thought to be too low to be acceptable. As I shall be illustrating later in regard to the Ethiopian and New Guinea data, values of that order in an individual would now be barely worthy of notice.

Malawi, Tanzania, the Sudan

A variety of discrete studies involving nutritional observations were carried out in Malawi, Tanzania and in the Sudan. Those in Malawi were concerned with an assessment of the nutritional status of children under 5 years of age and of their families from a combined clinical and biochemical examination, by anthropometric measurements, and a household dietary survey (Burgess, Burgess & Wheeler 1973). The aim of this study was to provide information which might result in an improvement of the local and national health services and therefore it had an immediate and practical purpose which is, perhaps unfortunately, not always obvious in many nutritional investigations.

In Tanzania, studies have been reported which have given extra much-needed information on the contribution to body mass changes of alterations in fluid and in energy balance (Dore, Weiner, Wheeler & el-Neil 1975), and to the amount of nitrogen, sodium, potassium and iron excreted by people who are physically active in a hot climate (Weiner, Wilson, el-Neil & Wheeler 1972; Wheeler, el-Neil, Wilson & Weiner 1973).

In relation to the requirements of protein in the diet, since nitrogen is lost in sweat, it is conceivable that people who have to undertake heavy work in a hot climate, and who therefore lose large quantities of sweat from the body, may also have comparatively large losses of nitrogen and need increased protein in the diet to compensate. Weiner *et al.* (1972) found results similar to most of the other published work on this problem and showing that these nitrogen losses were small and tended to become even smaller on a low-protein diet: there seemed no reason to suggest that extra protein might be required by manual workers in tropical climates.

Sweating, although apparently also of no significance for the Na and K balance, could be important in iron balance. Wheeler *et al.* (1973) found that when dietary iron was low the loss of iron in sweat could be a significant factor in iron depletion.

One of the most intriguing of all the investigations in the I.B.P. must surely have been that described by McCance and his colleagues (McCance *et al.* 1971) on the adaptive responses of Cambridge and Sudanese students to an acute change in their environment: the Sudanese men and women were flown to and deposited in Cambridge in mid-winter and 'conformed to the British way of life' – including their food – for an 8-day experiment and the Cambridge students were similarly transferred at a later date to Khartoum. Particular attention was paid to the measurement of the intake and losses of water, salt and energy.

One suspects that the transference must have been mildly traumatic, at least to the Sudanese, and variable reactions can be inferred from some of the descriptions. The routine was hard and the fully occupied day starting, presumably in the winter dark, at 8 a.m. ended after supper when 'the subjects returned to Sidney Sussex College where squash rackets, table tennis and refreshments of known mass and composition were available'. We are not actually told whether these adapting Sudanese ever played squash after supper – surely an indication of the ultimate in human adaptability to the English way of life.

Whatever the means by which energy was expended, it was greater, as also was the food intake, in Cambridge than in Khartoum and the Sudanese tended to gain mass. Subjectively, this is a common impression, that foreigners coming to live in England tend to increase their body mass. It would be interesting to know whether this is a widespread occurrence and whether or not it is temporary. Also, the higher level of energy intake and expenditure found in the cold climate of Cambridge is something about which one would very much like more generally valid information. The effect of climate is considered in the current FAO/WHO Report (1973) to be an insignificant factor in affecting energy requirements, and some people would believe that this is not necessarily correct.

Ethiopia and New Guinea

Some of the most interesting nutritional results have been obtained in the studies in Ethiopia and in New Guinea. These were both large scale and extensive studies on contrasting local populations, and nutrition was only one of several disciplines involved. It is perhaps slightly disappointing that, in spite of the laudable multi-disciplinary approach, there has not yet been an integrated analysis of the different sets of data. There are many reasons for this but it is still a disappointing deficiency to a satisfactory completion of the I.B.P.

In part the nutritional findings in Ethiopia and New Guinea are complementary and I shall deal with some of the results together. The Ethiopian data are not yet published in full, but my colleagues Miller, Mumford, Rivers, Evans and their co-workers have kindly supplied me with a summary of part of the nutritional findings.

With hindsight it is possible to see how the values quoted on the Ethiopians studied by Miller and his colleagues, and later those published on New Guinean adults by Norgan, Ferro-Luzzi & Durnin (1974), have had a radical effect on our concepts of physiologically possible energy intakes. The energy intake determinations by Miller & Rivers (1972), on apparently healthy people showing almost no signs of undernutrition, of 5.02–7.53 MJ (1200–1800 kcal)/day as an average for groups of men at different seasons of the year and 3.35–5.02 MJ (800–1200 kcal)/day for groups of women, still appear inconceivable (more recent data from the same workers are given in table 1). However, I feel that they had, indirectly, an important impact in that many of us started to examine such low results with somewhat less scepticism.

It is critical to stress that the nutritional results on the New Guineans, and possibly also on the Ethiopian subjects, were obtained on muscularly well-built and physically active peoples who did not appear to have, for most of the year, a restricted supply of food and who did not, in general, show any signs of nutritional deficiency. The investigations in both countries were continued during all the different seasons of the year.

Table 1 shows a summary of the results on the adult populations. Although the numbers of subjects studied in Ethiopia are small, yet the intakes of energy are only slightly lower than those of the New Guinean coastal people. The methodology in both studies was similar. These two populations have such low intakes that if they do represent an adaptation which has either occurred or is possible on a large scale, this represents a nutritional finding of the highest significance.

The energy intakes of the New Guinea highlanders may be interpreted in a comparable fashion, although the absolute values are much higher because of the very considerable amounts of physical activity required by their way of life on the steep hillsides.

Table 2 shows results on the children in both types of community, somewhat arbitrarily divided into three age-ranges. Here there are occasional very large differences between the Ethiopian and New Guinean groups, part of which may be because of the small numbers of some of the Ethiopian groups. In some cases I would be unable to explain such low intakes – for example, in the under 5s, although there might be a small extra unrecorded energy supply from breast milk, the total energy intake is less than half the calculated basal metabolic rate and only one quarter of the F.A.O./W.H.O. recommended intakes for children of that body mass. The New Guinean values in contrast correspond to the F.A.O./W.H.O. recommendation.

Table 1. Energy intakes in Ethiopia and New Guinea

	n	sex	body mass kg	kcal/day	MJ/day
Ethiopia					
adults	7	M	57	1830 ± 360	7.66 ± 1.51
	14	F	47	1220 ± 370	5.10 ± 1.55
New Guinea					
adults	51	M	56	1940 ± 480	8.12 ± 2.01
coastal	69	F	47	1420 ± 410	5.94 ± 1.72
highland	43	M	57	2520 ± 480	10.54 ± 2.01
	41	F	51	2100 ± 460	8.79 ± 1.93

Table 2. Energy intakes of children in Ethiopia and New Guinea

		n	sex	body mass kg	kcal/day	MJ/day
under	Ethiopia	4		10.4	250 ± 150	1.05 ± 0.63
5 years	New Guinea					
	coastal	63		12.1	1180 ± 350	4.94 ± 1.46
	highland	57		12.4	1100 ± 380	4.60 ± 1.59
5–9	Ethiopia	9	M	18	870 ± 190	3.64 ± 0.80
years		6	F	19	970 ± 320	4.06 ± 1.34
	New Guinea					
	coastal	32	M	18	1450 ± 450	6.07 ± 1.88
		37	F	17	1350 ± 420	5.65 ± 1.76
	highland	35	M	19	1600 ± 340	6.69 ± 1.42
		31	F	19	1480 ± 360	6.19 ± 1.51
10–14	Ethiopia	7	M	30	1510 ± 190	6.32 ± 0.80
years		3	F	31	850 ± 210	3.56 ± 0.88
	New Guinea					
	coastal	26	M	27	1640 ± 460	6.86 ± 1.93
		30	F	30	1600 ± 420	6.69 ± 1.76
	highland	25	M	30	1710 ± 410	7.16 ± 1.72
		28	F	33	1890 ± 330	7.91 ± 1.38

The 5–9 year olds show the same general pattern although the differences are less marked: the Ethiopian children were obtaining about half the F.A.O./W.H.O. levels and only about two-thirds the quantities of the New Guinean children even though their body masses were about the same.

This age group also shows the first indication of the diverging intakes of the coastal and highland populations.

The 10–14 year olds again provide some interesting comparisons. The boys in all 3 groups have roughly similar energy intakes, the Ethiopians being slightly lower than the others. Again because of the very small number of Ethiopian girls in the series, it is difficult to make reliable deductions but the intake of energy is radically different from either of the New Guinea groups in spite of these girls having approximately the same body masses.

It is also interesting to see that the intake of energy of the New Guinean coastal girls is higher than that of adult women, and that the highland girls had a higher intake than the boys. This will be referred to again later but it may well represent an adaptation where adolescent girls are allowed a relatively easy way of life to provide them with a satisfactory physique to withstand their hard adult existence.

Several other findings from the New Guinea study have wide-ranging nutritional importance. First, there was a slight decrease in total body mass with ageing, in all groups. Also, the amount of adipose tissue in the body did not increase with ageing. Both of these would be the opposite of the usual in the U.K. or similar populations where both body mass and body fat increase with ageing.

Secondly, in spite of low protein intakes from a diet which was largely vegetarian and contained only very small amounts of animal foods, there were almost no signs of protein deficiency, even in the children (Ferro-Luzzi, Norgan & Durnin 1975).

Energy adaptations in New Guinean women

Thirdly, there were some surprising findings in relation to the energy intakes of the non-pregnant, the pregnant and the lactating women. Pregnancy and lactation are considered by the F.A.O./W.H.O. Expert Committee on Energy and Protein Requirements, and by all similar National Committees, to be physiological states which necessitate a large increase in energy in the diet: pregnancy, as an average over the last 6 months, is supposed to need an extra 1.46 MJ (350 kcal)/day and lactation an extra 2.30 MJ (550 kcal)/day.

Table 3. Energy intakes of New Guinean women

	coastal			highland		
	n	kcal/day	MJ/day	*n*	kcal/day	MJ/day
*N.p.n.l.	34	1400	5.86	14	2070	8.66
lactating (0–1 years)	13	1410	5.90	14	2130	8.91
lactating (1+ years)	19	1490	6.23	6	2250	9.41
pregnant	9	1410	5.90	7	2000	8.37

* N.p.n.l., Non-pregnant and non-lactating.

Table 3 gives the very surprising results I mentioned on the effects of pregnancy and lactation on energy intake. These effects are almost negligible. What is the explanation? It could, of course, be that the New Guinean women were living on their body stores (as Dr Harrison, I think, suggested) and gradually losing mass with each pregnancy. This is not the case to any sufficient extent. Analysis of the anthropometric data collected in the demographic survey by Harvey (1973), shows no sign of a decreasing body mass related to child-bearing. As a consequence of the I.B.P. findings, an investigation was specifically mounted to examine this situation in highland women and this has again demonstrated no loss of body mass with repeated cycles of pregnancy and lactation (Greenfield, Clark & Serjeantson 1973).

How then does the pregnant and lactating woman maintain a physiological state without a large increase in her energy intake? In their recent study on highland women Greenfield & Clark (1975) have shown that their energy expenditure is reduced in pregnancy, particularly in the last 3 months, and that physical activity is also reduced in lactation, more so in the first 6 months (lactation often continues for 2 years or more) and more so also with the first child than with subsequent children. The women walked less, spent longer periods sitting – partly enforced because of the breast-feeding – and worked shorter periods in the garden. These findings fit well with our own data in table 3.

It seems to me that it is at least possible that these adaptations are entirely physiological. It may even be advantageous for the pregnant and lactating woman to spend more time sitting and to be physically less active: their requirements for extra energy may therefore at present be considerably overestimated and be occasionally a prescription for the development of obesity.

Nutritional studies within U.K.

The last two 'Human Adaptability' projects, which were entirely nutritional in origin and carried out on U.K. populations, will be referred to briefly. The first was a study on vegans, who eat a diet containing no animal foods whatever – not even milk, eggs, cheese – and the second a study on adolescents in Glasgow. These studies seem far away in impact from those in Ethiopia and New Guinea but there are some points of common interest.

Vegans and vegetarians in U.K.

The vegan study by Ellis & Mumford (1967) could find no evidence of any nutritional deficiency, other than perhaps a marginal deficiency of vitamin B_{12}. This conclusion has nutritional importance in demonstrating again that our concepts of the essential nature of animal foods for a satisfactory diet are not well-based.

Adolescents in U.K.

The final project produced some illuminating evidence of nutritional trends in adolescent populations in the U.K. Surveys carried out over a period of about 40 years (Widdowson 1947; Durnin, Lonergan, Good & Ewan 1974) indicate that the energy intake of 14 year old boys and girls has been steadily decreasing, in spite of the fact that some of the groups appear to be becoming fatter.

Table 4. Energy intakes of 14-year old adolescents

	boys		girls	
	kcal/day	MJ/day	kcal/day	MJ/day
Widdowson (1930s)	3070	12.85	2640	11.05
Durnin *et al.* (1964)	2800	11.72	2270	9.50
Durnin *et al.* (1971)	2610	10.92	2020	8.45

Conclusion

The general importance of these nutritional studies, in spite of the very limited nature of the investigations, may be considerable. One of the great causes of concern at the present day is whether or not the world is likely to be able to feed its population adequately, and what sorts of foods will this require. From these I.B.P. studies some evidence has been produced to suggest that our estimates of requirements for both energy and protein may be markedly too high, and that the necessity for sources of animal protein may also be much exaggerated. If this were generally valid on a wide scale, it would have enormous repercussions on much of the agricultural and economic policy of many countries of the world. If also the so-called protein-gap becomes of less significance than an energy gap, the industrial consequences are also of some moment – concentration on production of protein foods and high-protein yield crops and the necessity of many countries to import expensive protein foods, might change dramatically.

The implications are so exceptionally important that one of the benefits which should have arisen from our I.B.P. findings ought to be a strong impetus to investigate these problems in much greater depth, both here and in other countries. There are no signs that I am aware of that such an impetus exists in the only appropriate form – that is, by the provision of money for such investigations. Money for nutritional research in this country is not forthcoming and the Research Councils show little interest in supporting such studies. At the international level, where it is infinitely more important, I see no indication that the situation is any different.

Therefore, in some ways I am not sanguine about the long-term success of the I.B.P. While it lasted it was excellent but we perhaps did not assess adequately the implications of what we were doing. Now that those implications are clearer, we ought to have developed in the U.K. a better integrated inter-disciplinary approach to problems of human adaptability. I do not see it, unfortunately, and it is disappointing. It appears to be present in the U.S.A. where there are some quite exciting studies on energy flow in society with a combined approach between ecologists, economists, social scientists, anthropologists and physiologists.

The problems we urgently need to tackle in this country require such an inter-disciplinary approach. Our chairman mentioned in his introductory address that the I.B.P. was instigated, $11\frac{1}{2}$ years ago, because it was felt that not enough sense of urgency was evident among biologists in studying the problems of productivity and human adaptability. In Britain *now* we are faced with such stark and overwhelming problems that we cannot afford even the mildest degree of complacency. We need *now* to be critically examining – to restrict it to no more than the field of biology I know about – the energy flow and the availability of energy in our society for the foreseeable near future. We need an urgent inter-disciplinary attempt to advise on what energy we can spend in the near future, how many houses, office-blocks, factories, roads, airports we can build, how much and what kind of transport we can afford, whether we can afford to have many people living at long distances from their work, how we can feed ourselves, what adaptability is likely from changes which may occur in working situations, living situations, availability and alteration in diet, and so on.

I am generalizing, but I feel with a vague sense of unease that we are not fulfilling the role that the I.B.P. pointed out to us; and I think we should refrain from congratulating ourselves excessively on our present achievements as biologists who have been imbued with the principles of the I.B.P.

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