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1 *Introduction*

G. AINSWORTH HARRISON

Much has been written about the relationship between the quantity and quality of the food available to people and their health and disease susceptibility. Even for traditional and developing societies, which are the concern of this book and where nutritional problems are essentially ones of shortage, an enormous amount of work has been undertaken looking at the morbid effects of these shortages. What then has this book to offer that is new?

In the main, nutritionists have tackled the problems of malnutrition in physiological and medical terms, concentrating on the mechanisms by which nutritional diseases develop and the requirements to prevent or remedy them. This has rightly been a top academic as well as practical priority, but it deals only with the proximal situation of human nutritional requirements for physiological homeostasis. Were human beings domestic animals such a focus might be sufficient in itself, but because people live in variable and changing environments, and because they are called upon to participate in varying activities, skills and behaviours, and because, most importantly of all, they are parts of complex social structures with varying social demands and privileges, the full understanding of human morbidity from nutritional causes needs a wider approach than the exclusively physiological one. Food is as much a social resource as a collection of nutrients, and it can dominate social organisation as much as biological need. The way it is produced, and distributed, stored and preserved, prepared and cooked can as profoundly affect the nutritional health of a community as its total quantity. To understand, therefore, many features of human nutritional disease, requires an anthropological as well as a physiological insight. The aim of this book, and the symposium upon which it is based, is to encourage such a dual approach.

In the symposium (July 18th & 19th, 1988), a group of nutritionists with wide experience of nutritional problems in the Third World, and with a sympathy for holistic approaches, were brought together with some biological and social anthropologists who have an interest in nutrition from an evolutionary, ecological and social point of view, in the

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hope that a fruitful dialogue would develop. The book, we believe, demonstrates that this indeed happened, but also indicates that there remain useful opportunities from continuing it.

The first contribution, by Professor J.C. Waterlow, deals with the very important issue of human nutritional needs, and particularly with the question of possible variability in these needs. Surprisingly, nutritionists have only quite recently been concerned with whether or not there is nutritional adaptability, i.e. whether nutritional needs respond to nutritional environments in ways that safeguard health. Perhaps this is partly because they became isolated from evolutionary thinking, but it probably also reflects a deep assumption that nutrition was too fundamental to permit variation. It is gratifying that this assumption is being questioned but, as Waterlow's paper makes clear, resolving the issue is empirically very difficult.

The second and third chapters deal respectively with the effects of malnutrition on work capacity and mental development. Dr G.B. Spurr reviews his own extensive researches, mainly in Columbia, on the relationship between nutritional status, physical development and an individual's ability to perform physical work, and Dr S. Grantham-McGregor considers the ways in which poor nutrition can affect the mental activities of West Indian children, mainly by restricting their ability to play. Although neither of these contributions deal explicitly with the morbid state, they have profound relevance to it. In human beings, capacities to perform physical and mental work have ramifying consequences on economic and social status, and through this to nutritional health. The financially poor form the nutritionally and environmentally deprived; and ill-health can lead to a vicious spiral of increasing deprivation, through its reduction in ability to work and thus greater ill-health.

The two contributions by Professor A.A. Jackson and Dr B.S. Hetzel deal explicitly with important diseases of nutritional origin. Kwashiorkor, so common among children in many developing countries, has been known now for a number of years. Its aetiology, however, is still far from fully understood, as Professor Jackson clearly shows, and it is a much more complex entity than the simple protein deficiency disease it was once supposed to be. The situation with goitre and cretinism is much clearer, and treatment with iodine is one of the great successes in nutritional epidemiology. Such success, however, depends not only on having full scientific knowledge but also the logistic means, such as those provided by Dr Hetzel's International Council for Control of Iodine Deficiency Disorders, to ensure that treatment actually reaches those in need of it.

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It is almost axiomatic that malnutrition predisposes to infectious disease; if not to infection itself, certainly to severity. The proposition has, however, been little researched empirically, and there are at least some cases, e.g. malaria, where the well-nourished may suffer more than the malnourished. What is known is reviewed very systematically by Dr S.J. Ulijaszek.

It may seem odd to find in a book concerned with Third World countries a paper on the elderly in Britain. However, as Professor Hodkinson shows, there are a number of interesting parallels between the nutritional status in the two situations. The causes for inadequate food intake are, of course, not the same, but both have important financial and social elements. It is also salutary to see the problems of one's own elderly within the broader framework of world malnutrition.

On the world scale, however, it is the child who is most vulnerable to food shortage. This is for biological and social reasons, and both are no doubt involved in contributing to the enormous variability in child malnutrition within a single population and, indeed, within a single family. The situation is deserving of much more attention, particularly in post-weaning children who have been largely ignored. Here two contributions are devoted specifically to children (as well as the analysis of mental development by Grantham-McGregor). Drs J.D. Haas and J-P. Habicht deal with the difficult problem of assessing levels of malnutrition in children; a particularly pressing concern in intervention programmes with limited resources, and Dr P.S. Nestel provides a case study of child health and growth in the Sudan.

It is easy to forget, particularly in modern industrial societies, that food is not only a starting point for human biological needs, but also an end point of human economic activities. These activities are themselves determined by innumerable factors of environment, technological development and social custom, and are endlessly variable. We may therefore expect that nutritional disease will be closely related to economy, but this is a matter little considered by human biologists. The valuable potential of this relationship is clearly demonstrated in the review of Dr S.S. Strickland.

It has been argued that widespread malnutrition is rare in fully traditional societies; that such societies have acquired systems that regulate population size to the resources and technology available. Whether this be so or not many such societies experience severe seasonal hunger, and food shortage can then be so great as to dominate social processes as well as biological ones. Because of their regularity seasonal shortages can, however, be prepared for, and the way this is done is not only intrinsically interesting but may well be of wider practical value. The

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topic is discussed here by Drs I. de Garine and S. Koppert, mainly from their extensive experience of the 'hungry season' among West African cultivators.

De Garine and Koppert bring us firmly into the social domain, and the two final chapters are concerned exclusively with this. Dr Barbara Harriss considers the extremely important issue of food distribution within the household and its relation to disease in South Asia. She amply demonstrates the marked sex bias there against women in the ways food is usually shared, and she traces the consequences of this in varying gender morbidity and mortality. She also, however, sees other important cultural factors contributing to this variation.

Dr R. Burghart pursues such cultural factors even further; specifically in relation to varying conceptions that different people have of their body images and self-hood. He stresses how important these are to a person's sense of well-being. He is also concerned with the way the 'social body' is identified and conceptualised in different societies, and the consequences of this in food distribution priorities. Much of what he writes is of vital relevance for intervention programmes, since he well demonstrates that 'the nutritional knowledge of the health educator does not replace the ignorance of local people'.

And so from fundamentals of physiology to fundamentals of social anthropology; all brought together most meaningfully in a proper discussion of diet and disease. It surely demonstrates that no field of human biology demands a more interdisciplinary approach than that of human nutrition.

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2 *Mechanisms of adaptation to low energy intakes*

J.C. WATERLOW

Summary

No attempt is made in this paper to define adaptation in any precise way. The aim is simply to describe actual and possible responses of man to life-long intakes of energy that by Western standards often seem inadequate. The responses are discussed under three headings:

(i) Maintenance of a low body weight, which can be achieved by one or both of two ways: to be small in height as a consequence of retarded growth in childhood, and to have a low body weight in relation to height. An attempt is made to define the acceptable limits of low body weight.
(ii) Economy in the cost of physical activity. It is probable that there are ergonomic adaptations acquired by tradition and practice, of which perhaps the most important is that given tasks should be performed slowly rather than fast. This is an area where more research is clearly needed.
(iii) Biochemical and metabolic changes that promote economy. Here we can do little more than speculate. Possible mechanisms are reductions in the rates of energy-dissipating reactions such as protein turnover and ion-pumping. Since slow muscle fibres are more economical of energy than fast fibres, a preponderance of slow fibres would in theory confer an advantage, provided that, as indicated in (ii) above, a pattern of moving slowly is acceptable. Many of the biochemical mechanisms are controlled, or at least influenced, by the activity of the thyroid gland.

At all levels it is necessary to consider costs or trade-offs that balance possible advantages.

Introduction

I shall not try to define adaptation in any precise way or to distinguish it from concepts such as accommodation, homeostasis, regulation, etc. (for discussions see Waterlow, 1985a, b, 1986). Many years ago some of us wasted a great deal of time in sterile arguments about the exact distinction between the clinical forms of malnutrition known as

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kwashiorkor and marasmus, and I do not want to fall into that trap again. However, there is one aspect of adaptation that does need to be stressed in the present context: the fact that the word as ordinarily used carries a value judgement. In any given environment, such as a hot climate or a high altitude, it is by definition 'better' to be adapted than not adapted. But what if two people, A and N, are living in different environments? How can we compare them? N is tempted to say 'I am normal and you are adapted'. This tendency is shown by the way in which we apply universally our Western standards of growth, body size, basal metabolic rate (BMR), etc.

It is probably a reasonable generalization to suppose that every adapted state carries both gains and losses, and it is difficult, if not impossible, to avoid subjective value-judgements in comparing the end-results. For this reason, after 25 years of thinking and writing about adaptation, I am almost inclined to give up using the word and to confine myself to objective questions of the form: 'how does this particular function respond to this particular stress or change?'.

There is one other point worth making at this stage. Physiological characteristics seem to be of three general kinds: first, those that are rather closely fixed, as defined by Claude Bernard's concept of the constancy of the internal environment. Secondly, there are characteristics that seem to have an upper limit, from which they can only vary downwards. In this category come, for example, the plasma albumin concentration or the amount of protein per unit DNA in any particular type of cell. However much protein one eats, it does not seem to be possible to pass these upper limits, and the argument then is whether they should be regarded as 'preferred' points (see Payne, 1987). Thirdly, there are characteristics which in any population vary about a mean, so that a statistical definition can be made of a 'normal' range. For many of the characteristics in which we are interested the coefficient of variation seems to be of the order of 10–15 per cent, so that the range may cover a span of almost two-fold, from 70 to 130 per cent of the mean.* The BMR would fall into this category. I suggest that without physiological variability of this kind there would be little or no capacity for adaptation. Obviously, a characteristic that is fixed cannot adapt, though other things may adapt to keep it fixed.

* Since this paper was written Dr L. Garby of the Institute of Physiology, University of Odense, informs me that when conditions are rigidly standardized and results related to body composition, the between subject variation in energy expenditure may be as low as five per cent.

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Table 2.1. *Effect of body weight on energy expenditure*

	Subject	
	A	B
Weight, kg	50	65
Height, m	1.6	1.6
Body mass index, wt/ht^2	19.5	25.4
Basal metabolic rate kcal/d (MJ/d)	1445 (6.04)	1670 (6.98)
Maintenance expenditure (1.4 × BMR)	2020 (8.44)	2340 (9.78)
Expenditure of a moderately active man (1.8 × BMR)	2600 (10.87)	3010 (12.28)

Basal metabolic rates calculated from Schofield *et al.* (1985) for male subjects aged 18–30. A's expenditure is 14 per cent less than that of B.

There are three general strategies for economizing energy expenditure:

(i) a low body weight;
(ii) reduction in the amount or cost of physical activity;
(iii) increased biochemical efficiency, i.e. 'metabolic' adaptation.

The word efficiency is used here as a general term; it is essential to define it precisely in each particular context. Much of what I have to say about metabolic adaptation is little more than speculation – a discussion of possibilities. In most cases it is likely that only small savings can be made, but together they could add up to a significant economy. As Barcroft (1934) has said: 'Every adaptation is an integration'.

The relationship of body size to energy expenditure

This subject has been well discussed by Ferro-Luzzi (1988) in a previous symposium of this series. It is obvious that a smaller person will have a lower energy expenditure (EE), but there are some interesting implications. BMR, which accounts for more than 50 per cent of an average person's total EE, is related to body weight, and so also is the cost of physical activities that involve moving the body. Table 2.1 shows estimates of EE based on the prediction equations for BMR in relation to body weight produced by Schofield, Schofield & James (1985) and used in the most recent UN report on energy requirements (FAO/WHO/UNU, 1985). These equations were derived mainly from measurements in Western countries and cover a rather narrow range of body weights. At lower weights, as found in Third World countries, they may overestimate the BMR (McNeill *et al.*, 1987).

In Table 2.1 total daily EE is expressed as a multiple of BMR. The

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expenditure of a sedentary person with very little physical activity would be 1.4 BMR; that of a moderately active man, such as a peasant farmer in the Third World, would be 1.8 BMR. Subject A saves 14 per cent of B's expenditure, and if, as mentioned above, A's BMR is overestimated, the saving will be even greater. Quantitatively this is probably the largest single contribution to the adaptation that we are considering.

Suppose that B's intake becomes the same as A's, so that he is short of 300–400 kcal per day: if the energy equivalent of body tissue is taken as 6000 kcal per kg, in about nine months, B will have come down to the same weight as A and will again be in energy balance. If, as is conventional, the acceptable limits of body mass index (BMI) are taken as 20–25, B, who was a little too fat has now become a little too thin (Table 2.1). FAO (1987) calls this process of adapting to a low energy intake by losing body weight a *costless biological adaptation*. Is it really costless? Although the hibernating bear can apparently lose some 20 kg of weight without loss of lean tissue (Nelson *et al.*, 1975), this is not so for man. From the data collected by Forbes (1985), a weight loss of 15 kg, which is admittedly rather extreme, would involve a loss of some 3 kg of lean tissue, of which about half or more would be muscle. This is not a very great loss – about six per cent of the initial muscle mass; whether it should be regarded as a negligible cost will depend on the extent to which muscular work is important for the individual's way of life.

One may ask: what is the limit of this process of adaptation? Much is known about the upper limit of 'acceptable' BMI, above which the risks attached to being overweight become significant. The upper limit is usually set at 25. At the present time the average BMI of young adults in the UK is about 24 (Knight, 1984) so that a high proportion are overweight. By contrast, in Third World countries the average BMI of apparently healthy groups is usually in the range 21–19 (Eveleth & Tanner, 1976). Not very much is known about the lower limits of BMI compatible with health and normal function. A recent review suggests that people with BMI between 18.5 and 17 may be regarded as borderline; between 17 and 16 as probably having a deficient energy intake; and below 16 as frankly malnourished (James, Ferro-Luzzi & Waterlow, 1988).

Another way of achieving a low body weight is to be short rather than tall, but with the same body proportions and the same BMI. If C and D both have a BMI of 22, C, at 1.72 m tall will weigh 65 kg and D, at 1.5 m, will weigh 50 kg. D has many advantages in being small: he or she not only needs less food but also needs less material for clothing and less living space. Therefore it might be argued that it is smart to be small. However, I would prefer to apply this argument only to adults. The

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suppression of linear growth in children (stunting) by nutritional and environmental handicaps is another matter altogether (see Waterlow, 1988). Here I want to consider only the effects of differences in height in adults, regardless of the way in which those differences may result from the interplay of genetic and environmental factors during growth.

There are disadvantages in being small, to set against the benefits. To the extent that people have to do external work, such as carrying loads or cutting sugar cane, it will be a disadvantage to have a smaller muscle mass. A small person has a smaller absolute working capacity ($\dot{V}_{O_2}$ max); at a given load our subject D, weighing 50 kg, has to operate at a higher proportion of his $\dot{V}_{O_2}$ max than C, weighing 65 kg, and therefore needs to have a higher level of cardio-respiratory fitness. This disadvantage is less at low work loads and disappears when people are mainly sedentary.

Stature also influences the energetics of movement. Leg length is related to stature, and in walking on the level in a free and natural way, common observation shows that a taller person takes longer strides. Alexander (1984) has introduced the concept of isodynamic patterns of movement. Walkers of different sizes will walk in an isodynamic fashion if their relative velocities are proportional to the square roots of their heights. If the body weights are the same, the activities will not only be isodynamic but also isoenergetic. It follows that at equal body weights a tall person will walk faster than a short one for the same energy expenditure, and will cover a fixed distance at a lower total cost. A man 1.7 m tall would be expected to save about seven per cent of the energy expended by a man of 1.5 m. In reality tall people tend to be heavier than short people, so the greater weight cancels out the advantage of greater height. The advantage will only be significant for people who are tall but very thin, such as the Dinka of the Sudan, whose average height is 1.82 m and weight 58 kg (Eveleth & Tanner, 1976). These people are nomads who presumably have to walk great distances, and one might speculate that their great height represents a biological/genetic adaptation.

I do not know how these relationships with stature would apply under other conditions, such as walking with loads or on a gradient. Mountain people are generally small, and it would be interesting to know whether gradient reverses the advantage of tall stature for walking on the level. It is likely that body weight is the dominant consideration, since the effect of weight on absolute energy expenditure increases with walking up hill.

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Reduction in the amount or cost of physical activity

The level of activity

The most obvious way of economizing energy is to reduce one's level of physical activity. In the last UN report (FAO/WHO/UNU, 1985) two categories of voluntary physical activity were defined, economic and discretionary. Economic activity is that on which a person's livelihood depends, and for many of us in the Western world is virtually nil. Discretionary activities are those which are not immediately essential, but which improve the quality of life or perhaps help to prolong it. In our society we could put sports, gardening, jogging, etc. in this category. In the Third World an example often cited is the energy cost for a mother to walk several miles to take her child to a health centre.

We know little about the extent to which people actually do reduce their activity in response to a shortage of energy supply. Such an adaptation would normally be undesirable if valuable activities were curtailed, but in extreme cases it may be necessary to preserve life. Levi (1987) has given examples from his experience in a concentration camp of extraordinary ingenuity in cutting down work without appearing to do so. In the wartime experiment on volunteers on a low energy intake, by 24 weeks the subjects had become lethargic, with a greatly reduced level of spontaneous physical activity (Keys *et al.*, 1950). Under more ordinary conditions Nature has done the experiment by subjecting people to a 'hungry season', when food from the previous harvest is exhausted and at the same time a great deal of work is needed for cultivating the new crop. For example, in the hungry season farmers in Upper Volta increased their energy expenditure at the expense of a loss of 3–4 kg in body weight. This seems to be a fairly general pattern in Africa (Ferro-Luzzi, Pastore & Sette, 1988). In the light of the previous discussion such a loss can probably be regarded as functionally costless.

Children seem to respond in a different way to a low energy intake, maintaining body weight and even growth at the expense of a reduction in physical activity (Rutishauser & Whitehead, 1972; Torun & Viteri, 1981). We do not know very much about this, because of the extreme difficulty of measuring free-living activity in children. A reduction in physical and exploratory activity in early life may be expected to impair psychological and social development and is therefore not an acceptable adaptation.

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