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Rome, 22 March – 2 April 1971

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ENERGY AND PROTEIN REQUIREMENTS

Report of a

Joint FAO/WHO *Ad Hoc* Expert Committee

1. INTRODUCTION

The Joint FAO/WHO *Ad Hoc* Expert Committee on Energy and Protein Requirements met in Rome from 22 March to 2 April 1971. The meeting was opened by Mr E. M. Ojala, Assistant Director-General, Economic and Social Department, FAO, who welcomed the participants on behalf of the Directors-General of FAO and WHO. In his opening statement, Mr Ojala emphasized the need to define protein and energy requirements with greater precision and accuracy. Recent developments in the race between population and food supplies, rapid urbanization, and continuing maldistribution of income in many countries were cited as some of the factors indicating that serious problems of food and nutrition were bound to persist and intensify.

Nutritional standards are used to assess the adequacy of diets and of national food supplies. They provide basic information for the establishment of national production and consumption policies and the planning of programmes aiming at an adequate and equitable distribution of food supplies. On a different level, they are used widely in the planning of diets for population groups. They also provide important reference information for the epidemiological study of nutritional deficiencies.

The importance of such knowledge led FAO to convene expert groups on energy requirements in 1949 [1] and 1956 [2], and protein requirements in 1955 [3]; FAO and WHO convened another expert group on protein requirements in 1963 [4], and other joint FAO/WHO expert groups have dealt with calcium, iron, and vitamin requirements.[5, 6, 7] The task of such meetings was to define general principles and make recommendations that can be applied, with appropriate adjustments, in different parts of the world and to different people.

The reports on energy and protein requirements [1-4] all emphasized that the recommendations were provisional, tentative, and open to testing and further research. The present Committee was therefore convened to re-examine the question of energy and protein requirements in the light of new data.

The general method of approach used by the 1949 and 1956 meetings on energy requirements was to set the requirements for a reference man or woman under well defined conditions and then to consider the variations introduced by such factors as physical activity, body weight, age, climate, pregnancy, and lactation. Requirements of infants, children, and adolescents were considered separately. This approach has been widely accepted.

The first report of the FAO Committee on Protein Requirements [3] was a pioneer attempt to establish requirements in terms of a "reference protein" of high nutritive value, taking into account knowledge available at that time on amino acid requirements and amino acid content of foods. The report stimulated research and was revised in 1963 by an FAO/WHO Expert Group [4] which gave particular attention to the requirements of adults. It adopted a factorial approach — this is a summation of the obligatory losses of nitrogen from the body and the requirements for growth, plus an additional allowance to cover the normal stresses of life and individual variability. There is now evidence that the estimates used for obligatory urinary, faecal, and cutaneous nitrogen losses were high, so that protein requirements may have been incorrectly assessed, at least in the case of adults. There are also indications that the biological variation in nitrogen requirements is greater than 20%, a figure considered by the 1963 Expert Group [4] to include most of the population.

Another innovation made by the 1963 group was the proposal that chemical scores for protein value should be based on the ratio of each essential amino acid to total essential amino acids (A/E ratio). However, FAO obtained experience in the application of the 1963 recommendations in the course of its Indicative World Plan, Regional and World Studies [8] and met practical difficulties in using the A/E ratio as a basis for scoring the protein of foods and diets. There was a need to re-examine this approach and to place chemical scoring of the nutritive value of proteins on a more convenient basis.

The present Expert Committee was convened to consider energy and protein requirements together and to examine fully this interrelationship so that a diet or a food supply might be assessed simultaneously in terms of its energy and protein content.

Thus, while the present Expert Committee was convened with the same general terms of reference as the previous expert groups, i.e., "to define energy and protein requirements as accurately as possible on the basis of existing scientific knowledge", its specific tasks were to :

(*a*) examine the characteristics and criteria of the reference man and reference woman ;

(*b*) review new data as a basis for revising estimates of requirements and recommended intakes for energy, protein, and essential amino acids ; and

(*c*) review the method of chemical scoring and other methods used in the evaluation of the nutritive value of proteins.

The Committee was asked to examine the interrelationships between requirements for energy and proteins and to recommend means for the integration of requirement scales for energy and proteins, if that were feasible.

2. BASIC CONCEPTS

2.1 General considerations

In approaching the definitions of human requirements for protein and for energy, the Committee recognized the need to consider separate aspects. If food is freely available, people tend to eat enough food to meet or exceed their individual requirement for energy. If food consumption is consistently above or below the physiological needs for energy, body weight and/or body composition will change. Both excess and inadequate intakes are potentially harmful. Hence it is appropriate to estimate the average energy requirement for various age/sex groups, but obviously the average requirement cannot be applied to an individual whose needs may be above or below the average. The average is applicable to large groups or to populations.

Requirements for protein also vary between individuals. There is little or no reason to believe that intake of protein is correlated with requirements, at least within a particular age/sex group. Insufficient intakes of protein are detrimental, but there are no demonstrated harmful or beneficial effects of intakes well above the probable requirement. For these reasons, the expression of protein needs must be approached differently from that of energy requirements. In the case of protein, it is appropriate to identify the level of intake at which there is minimal risk of the actual requirement of the individual not being met. Therefore, suggested levels of protein intake should cover the physiological needs of nearly all healthy persons, rather than being directed to the average need.

Terminology has been extensively discussed by previous FAO/WHO Expert Groups.[4, 6, 7] The term "recommended intake" has been defined as "... amounts considered sufficient for the maintenance of health in nearly all people".[7] The present Committee accepts this concept as applicable to protein. However, the Committee does not accept the previously used term but prefers to use the expression "safe level of intake" in this particular instance.

Protein intake may, and usually does, exceed the amounts suggested as physiological requirements in this report. These figures are estimates of the intakes required to maintain nitrogen balance and normal growth — the physiological requirements. In the opinion of the Committee these estimates provide an indication of how far the protein intake of an individual may fall before there is a significant risk that he may not meet his physiological requirement. In particular, the Committee emphasized that its proposals should not be taken to imply that existing protein intakes should be lowered to the suggested levels. The Committee recognized that the preferred diets of most populations provide 11–13% of the energy as protein (see section 4.3). In most instances, and provided that food is freely available to all, such preferences would ensure that nearly all individuals achieve intakes above those suggested in this report. The Committee recognized that according to the data provided by traditional epidemiological methods, the observed protein intakes in healthy populations would generally be higher than those suggested in the report. It was also recognized that the proposed levels might not represent optimal intakes, which remain undefinable in the absence of criteria of optimal health.

The Committee's concern was not only with populations as a whole but also with those groups of individuals within the population who may have lower intakes than the average for the population. For this reason, the Committee felt obliged to define as clearly as possible the limits to which protein intake might fall before an increase would be predictable in the risk of inadequacy in terms of known physiological need.

While recognizing that this concept applies to the recommendations of many previous FAO and WHO expert groups, the present Committee chose to adopt the term "safe level of intake", in order to avoid confusion about the intent or interpretation of its recommendations.

2.2 Definitions

The *energy requirement* of persons is the energy intake that is considered adequate to meet the energy needs of the average healthy person in a specified category.

Note : some individuals are expected to need less and others more than the average energy requirement, but in a group these surpluses and deficits cancel each other, and the suggested requirement represents the average of the group.

The *safe level of protein intake* is the amount of protein considered necessary to meet the physiological needs and maintain the health of nearly all persons in a specified group.

Note : This level is thus higher than the average requirement for protein.

These differences in concept have important implications, which are discussed in section 7.

Interpretation

The stipulated *energy requirement* and the *safe level of protein intake* may be used to evaluate the gross adequacy of the energy and protein supplies of populations, for planning diets and food supplies for populations, and for planning and evaluating food programmes and public health nutrition programmes. The safe level of protein intake can also be used to obtain preliminary information on the adequacy of the protein intake of individuals as well as groups of persons, but should never be used as the sole basis for the evaluation of nutritional status. For the latter purpose other criteria, such as clinical and biochemical examinations, are also needed.[9] The energy requirement, being an average value, is of limited use in the appraisal of dietary intakes of small groups; appraisal of the adequacy of energy intake is based primarily on clinical and anthropometric examinations.

As in previous recommendations of FAO/WHO groups,[4, 6, 7] the suggested intakes are intended to meet the needs of ordinary life situations but they do not apply to persons under severe stress of environmental origin, nor do they cover any additional requirements that may result from pathological conditions, such as severe infections and other disease states. Furthermore, the stipulated amounts of protein and energy are valid only when the requirements for all other nutrients are met and the person is not recovering from malnutrition. In this context it should be emphasized that the recommendations for protein are valid only when energy needs are also met.

Previous reports on energy requirements [1, 2] have used a "reference man" for purposes of calculation. The present Committee considers the concept to have been useful for calculating the needs of populations and continues the use of this model, although with a re-definition of the energy requirements of the reference man and woman. This report includes several categories of occupations suitable for the description of different populations.

Body size is affected by a number of factors, including genetic characteristics and nutritional history. Wherever possible, energy and protein requirements have been related to units of body weight to facilitate application of the recommendations to populations of variable body sizes. Tables of heights and weights are appended (Annex 1) for a group of well nourished children and adolescents used in sample calculations. These are given only as examples, and they are not intended to be interpreted as a standard or as desirable norms.

3. GLOSSARY OF TERMS AND UNITS

3.1 Energy requirement

The energy intake that is considered adequate to meet the energy needs of the average healthy person in a specified age/sex category.

3.2 Safe level of protein intake

The amount of protein considered necessary to meet the physiological needs and maintain the health of nearly all individuals in a specified age/sex group.

3.3 Reference man and reference woman

Hypothetical persons of defined age, body size, and physical activity, used for the purpose of calculating the energy needs of populations by means of appropriate corrections based on observed body weights, patterns of activity, and age structure.

(*a*) *Reference man.* He is between 20 and 39 years of age and weighs 65 kg. He is healthy, that is, free from disease and physically fit for active work. On each working day he is employed for 8 hours in an occupation that usually involves moderate activity. When not at work he spends 8 hours in bed, 4–6 hours sitting or moving around in only very light activity, and 2 hours in walking, in active recreation, or in household duties.

(*b*) *Reference woman.* She is between 20 and 39 years of age, similarly healthy, and weighs 55 kg. She may be engaged for 8 hours in general household work, in light industry, or in other moderately active work. Apart from 8 hours in bed, she spends 4–6 hours sitting or moving around in only very light activity, and 2 hours in walking, in active recreation, or in household duties.

3.4 Sample children and adolescents

The present report includes a table (Annex 1) of heights and weights of a sample population of seemingly well nourished children and adolescents.[10] These are not meant to be taken as reference or ideal standards but have been selected for use in the calculations of recommendations relating to these age groups in this report. Adjustments for the expected body size of well nourished children in a population under consideration may be appropriate where such data are available.

3.5 Units of energy

In the International System of Units, the unit of force is the newton, which accelerates 1 kg by 1 m per sec^2. The unit of energy is the joule (J), which is the energy expended when 1 kg is moved 1 m by 1 newton. Many international and national organizations have recommended that all forms of energy should be expressed quantitatively in terms of joules, and the

Committee decided to follow this recommendation but to express values in both joules and calories, the traditional unit of nutritionists. The usual unit of energy in nutrition studies is the kilocalorie (10^3 calories), and hence 1 kilocalorie (1 kcal) = 4.184 kilojoules (kJ).

The energy content of diets usually exceeds 1000 kJ and is generally expressed in terms of the megajoule (MJ), which is 10^6 J. Thus:

1 kcal = 4.184 kJ	1 kJ = 0.239 kcal
1000 kcal = 4184 kJ	1000 kJ = 239 kcal
1000 kcal = 4.184 MJ	1 MJ = 239 kcal

3.6 Energy value of foods

(1) *Energy sources*

Carbohydrate, fat, protein, and ethanol can all act as sources of energy for the body and are interchangeable in terms of energy within wide limits, i.e., in different weights according to their specific chemical compositions.

(2) *Composition of foods*

Tables of the composition of foods give the energy content of individual foodstuffs (Annex 2). Food composition is determined chemically, usually by direct analysis of moisture, ash, fat, and nitrogen (N). N is multiplied by a factor to obtain the protein content. The weight remaining after subtraction of moisture, ash, fat, and protein is usually ascribed to "carbohydrate by difference". Carbohydrate should be measured directly and expressed as available monosaccharides, but this is not commonly done.

(3) *Physiologically available energy*

The energy available to the body is the gross energy of the diet minus the losses in urine and faeces. The losses are usually allowed for by applying the Atwater factors [11] of 4 kcal (17 kJ) per g for protein, 9 kcal (38 kJ) per g for fat, and either 4.2 kcal (18 kJ) or 3.75 kcal (16 kJ) per g for carbohydrate, depending upon whether the carbohydrate is expressed as polysaccharides or as monosaccharides. 7.1 kcal (30 kJ) per g is the equivalent value for ethanol.

The Atwater factors have been misused; they were meant to apply to specific diets and not to single foods, nor to diets that differed from the mixed diets from which they were derived.[11, 12] With many types of diet, this misuse introduces no serious error, but if diets contain large amounts of roughage or unavailable carbohydrates, the energy from carbohydrates is overestimated. Because indigestible carbohydrates increase the intestinal loss of nutrients, the energy factors of protein and fat are also reduced.[13]

If the available monosaccharide content of food is known, the factor of 3.75 kcal (16 kJ) per g should be used. Otherwise the specific energy values [11] given in Annex 2 should be used to apply an appropriate correction factor for diets containing large amounts of unavailable carbohydrate. If some correction is not made, there may be errors of 5–10% in the calculated energy available from the diets eaten in many countries.

3.7 Crude protein

In this report, "protein" refers to crude protein, derived by multiplying the analysed nitrogen content by the factor 6.25. Foods contain nonprotein nitrogen, and the nitrogen content of food proteins commonly differs from the assumed average of 16%, so the figure for protein calculated by this method is imprecise. However, conclusions regarding protein needs are based largely on data from biological experiments in which the substance measured was nitrogen, not protein. Most tables of food composition give only protein content, and data on composition will have to be reconverted to N and crude protein according to the factor specified in the publication (e.g., table gives 17.1% protein in cereal product, 17.1 g of protein $\div$ cereal N factor 5.70 $=$ 3 g of N per 100 g product, $3 \times 6.25 =$ 18.75 g of crude protein per 100 g). A list of N : protein conversion factors [14] for different foods is given in Annex 3.

3.8 Net protein utilization

Utilization of dietary protein is determined by the digestibility and amino acid composition of the protein, other nutritive characteristics of the diet, and the age, sex, physiological state, and genetic make-up of the animal to which it is fed. When used as a precise term in this report, net protein utilization (NPU) refers to a value derived from feeding a diet in which protein was the single limiting nutritional factor and then measuring the percentage of ingested nitrogen that was retained for growth, repletion, or maintenance, i.e., the product of biological value and digestibility.

3.9 Relative nitrogen utilization

In this report, it is suggested that the safe level of protein intake be adjusted in accordance with the relative nitrogen utilization of the dietary protein. By this term is meant the comparative net protein value of the dietary protein relative to that of egg or milk when assayed under identical conditions.

3.10 Protein efficiency ratio (PER)

Gain in body weight divided by weight of protein consumed. Values are usually measured using rats. Some standardized procedures are available, for example, using diets containing 9.09% protein.

4. BACKGROUND

4.1 Historical

The history of the science of nutrition is a record of the use of two complementary approaches: epidemiology and physiology. Epidemiology draws maps of populations and of their behaviour; physiology analyses the responses to controlled situations in the laboratory or field. Many different standards of dietary requirements have been proposed in the past, either by individuals or by committees using information gathered in these ways.

Scales based solely on observations of actual food consumption have obvious disadvantages. When food is available in abundance and there is nothing to restrict consumption, more protein or, to some extent, more energy than is required may be consumed; on the other hand, when supplies are insufficient and purchasing power is low, consumption is likely to be less than requirements. In such circumstances "what is" will not be "what should be".

The two "fathers" of nutritional standards, Voit and Atwater, used figures obtained by observing the food eaten by groups or populations considered to be healthy and active. Their choice of consumption data as guides was based on recognition of the need to supplement balance methods with other evidence, as the following quotation [15] illustrates:

> One principle which thus far has not received adequate recognition in dietary standards may perhaps be expressed by saying that the standards must vary not only with the conditions of activity and environment, but also with the nutritive plane at which the body is to be maintained. A man may live and work and maintain bodily equilibrium on either a higher or lower nitrogen level or energy level. One essential question is, what level is most advantageous? The answer to this must be sought not simply in metabolism experiments and dietary studies, but also in broader observations regarding bodily and mental efficiency and general health, strength and welfare.

Later Chittenden, Sherman, Terroine, and others have attempted to use a physiological approach instead of the more empirical method for determining the minimum intake needed to maintain equilibrium. Information obtained in both ways has been considered in subsequent deliberations with different weighting of the evidence by different experts.

Energy requirements

In devising scales of energy requirements, attempts have been made to calculate factorially the actual daily energy expenditure of typical individuals by adding estimates of expenditure during so many hours of sleep, work, and recreation. More frequently, observations of actual food consumption have formed the main basis of energy scales, it being assumed that the quantity of food eaten by healthy people living a normal life represents their requirements. Sometimes both estimates of energy expenditure and observations of intake have been considered in drawing up standards.

Well-known scales of energy requirements include those put forward by Voit (1881), Atwater (1895), Lusk (adopted by the Inter-Allied Scientific Commission in 1918), the League of Nations Health Organisation (1935), and the National Research Council, USA (first published in 1943). Apart from these, tables of requirements have been drawn up by technical groups in various countries for national use. According to Voit, a labourer engaged in ordinary work in Germany required 3055 kcal daily from food as consumed. In Atwater's standard 3500 kcal were assigned to the average adult male, who was assumed to do 10 hours of "moderate" work per day. In Lusk's scale the requirements of an average adult male doing "moderate" work for 8 hours were assessed at 3300 gross kcal, with the understanding that this corresponded to 3000 net kcal, that is, energy from food as consumed, after the deduction of losses in the excreta. The League of Nations' scale centred on an allowance of 2400 net kcal per day, representing the requirements of an adult, male or female, living an ordinary everyday life in a temperate climate and not engaged in manual work. Supplements for manual work, on the basis of so much energy for so many hours of work, were added to the figure of 2400 kcal. For an adult male performing 8 hours of "moderate" work, the requirement was set at 3000 net kcal. The energy requirements of children were stated in terms of a scale of coefficients representing fractions of adult requirements.

In the scale of the US National Research Council as put forward in 1943, the recommended energy allowance for a physically active man of 154 pounds (70 kg) was 3000 kcal. Recommended allowances were also given for other degrees of activity, for example, sedentary (2400 kcal) and heavy work (4500 kcal). The scale also included recommended allowances for women and for children in the different age and sex groups.

These various scales were based on data obtained in the study of individuals and populations in North America and Europe and were primarily intended for use among such western populations. Scales that are to a greater or lesser extent modifications of such widely known scales have been drawn up in many countries for local application. Relatively few of these have been based on local investigations and observations. Among such scales may be mentioned those suggested by the League of Nations Intergovernmental Conference of Far-Eastern Countries on Rural Hygiene.[16] The requirement of an average man was estimated at 2600 kcal for India and 2400 kcal for Japan.

The previous FAO Committees on Calorie Requirements [1, 2] came back to Atwater's point of view and adopted a reference man and a reference woman with a way of life corresponding to a selected energy level, and a factorial approach was applied to adjust the allowances for various factors. It was a task for epidemiological research to determine if or how the reference man is related to real populations. The system then established has now been used for 20 years and has proved generally acceptable, although it is open to criticism in some details.

Protein requirements

The first estimates of protein needs were based on observations of intakes made in the second half of the last century. Thus, Playfair published surveys of British diets in 1853 and 1865 which demonstrated that protein intakes varied from 57 g on a subsistence hospital diet to 184 g in the case of a hard-wording labourer, observations that coincided with Liebig's view that protein was the fuel of muscle work. These and similar surveys led Voit in 1881 to conclude that the diet of the average working man should provide 118 g of protein, the remainder being made up of 56 g of fat and 500 g of carbohydrate. This view advocating ample protein, especially for heavy workers, was challenged in the early years of this century by several investigators, notably Chittenden (1905), who studied the physique of soldiers and athletes who had subsisted for months on diets providing no more than 50–55 g of protein daily. Chittenden concluded that such low intakes were not only compatible with health and physical performace, but were even beneficial.

Estimates of protein requirements based on such personal views have since yielded to the opinions of national and international committees. In 1936 the Technical Commission of the Health Committee of the League of Nations[17] advocated a level of 1 g of protein per kg of body weight, and this was also the daily allowance recommended by the United States Food and Nutrition Board in 1945. Both groups assumed that a considerable proportion of the allowance would come from animal sources. This distinction recognized evidence, gathered from 1900 onwards, showing that there are differences in protein quality for nutritional purposes.

In 1909, Thomas measured the biological value of individual dietary proteins by their effects on N balance, and in 1914 Osborne and Mendel measured the growth rate of rats to demonstrate differences in the efficiency of dietary proteins. In the 1930s, Rose and associates identified the essential amino acids, and it was then possible to show that differences in protein quality could to some extent be correlated with their content of essential amino acids. In 1946 Block and Mitchell proposed a "chemical score" for evaluating the nutritional quality of protein by means of the proportions of essential amino acids that it contained.

As a result of these studies of protein quality, more recent estimates of protein requirements have tried to provide guidelines for intakes of protein of different nutritive qualities. In 1957, an FAO Committee on Protein

Requirements [3] took account of N balance studies in man to arrive at an average minimum requirement for adults of 0.35 g of protein per kg of body weight, when the protein consisted of a reference protein of high nutritive value, such as whole egg protein. For optimal growth of infants, a level of 2 g of reference protein per kg of body weight was recommended. The needs of other groups (e.g., adolescents, lactating women) were also estimated. In order to convert these figures into safe practical allowances that would cover the needs of members of the population with higher than average requirements, it was suggested that the estimates of minimum requirements of reference protein should be increased by 50% for all groups other than infants and 25-30% for infants. On the assumption that the nutritive value of the mixed proteins of the diet is likely to be less than that of the reference protein, a further correction based on the chemical score of the dietary protein was recommended. In a country with a high standard of living, a safe practical allowance might thus have been 0.66 g of dietary protein per kg, whereas in a country where vegetable sources provided almost all of the dietary protein, the allowance could have been as high as 0.84 g per kg of body weight for adults.

An FAO/WHO Joint Expert Group on Protein Requirements was convened in 1963 and published its findings in 1965.[4] Its estimates of the protein requirements of infants did not differ appreciably from those of the FAO committee. The Group based its estimates for adults on the amounts of N that continue to be lost by way of the urine, faeces, and skin by adults consuming a diet providing little or no protein. It was argued that an adequate diet must provide enough protein to compensate for these N losses, on the assumption that replacing these losses would bring the adult into N equilibrium. The Group estimated the obligatory N losses of adults on a protein-free diet at 86 mg per kg of body weight. This was increased by 10% (to 95 mg per kg) to allow for periodic stress in ordinary living, due to minor infections, psychological factors, and the like, which result in an extra demand for protein. This figure described the obligatory N loss of the average adult, to which 20% was then added to allow for individuals with protein requirements in excess of the average. As a result, the obligatory N losses of 97.5% of a population were estimated at less than 134 mg per kg of body weight, equivalent to 0.71 g of protein per kg of body weight. Since dietary proteins are not utilized with complete efficiency, a further correction was made for the nutritive value of the mixed proteins of the diet. Thus, if utilization were assumed to be 70%, intake was to be increased to 1.01 g of protein per kg body weight in order to provide for the obligatory N losses of 97.5% of the population. This estimate of the protein requirements of adults is considerably higher than that arrived at by the FAO Committee in 1957, and is similar to the estimate made by the League of Nations in 1935 and by the United States Food and Nutrition Board in 1945.

4.2 Energy protein interrelationships

A critical review [18] showed that energy intake affects protein utilization and metabolism in two ways. First, there is a general interrelationship between level of energy intake and N balance, so that some reduction in energy intake below requirement results in a loss of body protein in the adult or a reduction in growth rate of the young. In addition, a severe reduction in energy intake impairs the utilization of proteins added to the diet. The practical implications of these experimental findings have to be considered in respect of both adults and children.

In adults, prolonged restriction of both energy and protein intake results in some adaptation through a reduction in energy output. In severely restricted subjects, body composition undergoes changes that tend to compensate partially for the factors relating to protein loss. In countries where there is a seasonal reduction in energy intake, these adaptations may occur rapidly,[19, 20] and energy and protein equilibrium are achieved at lower levels of intake, provided that the reduction of intake is not too great.

In growing animals the first effect of reducing energy intake is to reduce growth. In young rats whose growth rate is limited by the energy available from the diet, increasing the percentage of protein in the diet above that ordinarily required is ineffective in stimulating further growth.[21] This implies that either increasing protein without energy or increasing energy without protein will be ineffective in restoring normal growth in malnourished children.

It is emphasized in several sections of this report that when energy intakes are deficient, part of the dietary protein is used to provide energy. The practical implications are clear: the adequacy of energy intakes must receive first consideration, so that any additional protein supplied to meet the estimated protein needs will be efficiently utilized for this purpose.

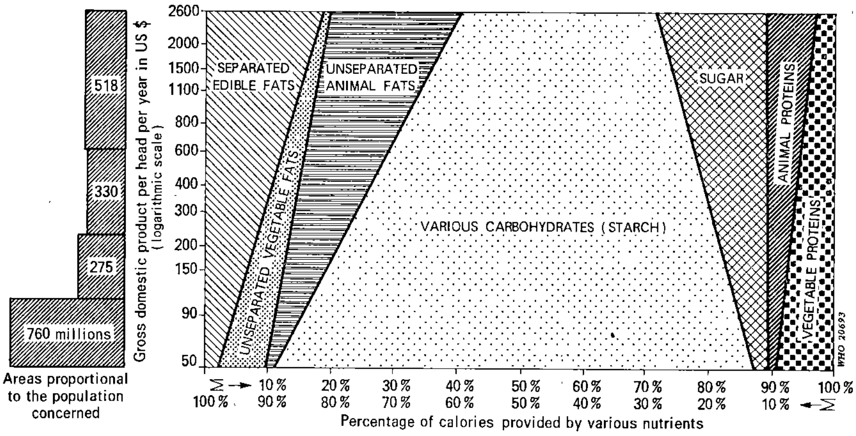
When intakes of both energy and protein are grossly inadequate, the provision of protein concentrates or protein-rich food of animal origin may be a costly and inefficient way of improving the diets, since energy can generally be provided more cheaply than protein of good quality. This is an important point in planning programmes for meeting the needs of vulnerable groups in developing countries. Clearly, energy and protein needs should be considered together in planning for the nutritional improvement of populations whose diets are deficient in either.

4.3 The share of nutrients in the energy supply

Present epidemiological evidence indicates that the contribution of the three main energy nutrients — carbohydrate, fat, and protein — to the total consumed at the national level varies with national wealth.

With the aid of national food balance sheet data on 85 countries, an attempt was made to identify these general trends of consumption patterns as a function of income [a] (Fig. 1).[22]

FIG. 1. CALORIES DERIVED FROM FATS, CARBOHYDRATES, PROTEINS AS PERCENTAGE OF TOTAL CALORIES ACCORDING TO THE INCOME OF THE COUNTRIES (1962) *



* Correlation based on 85 countries.
Source: Périssé, J., Sizaret, F. & François, P. (1969) *FAO Nutr. Newsletter*, **7**, 3, p. 1.

The proportion of energy derived from fats rises steeply with income. This difference is the result of two opposing phenomena:

(*a*) a steep rise in the consumption of separated fats (oils, butter, margarine, shortenings, and lards) and of unseparated edible animal fats because of increased consumption of meat, milk, and some fish; and

(*b*) a reduction in the consumption of unseparated vegetable fats (in cereals, nuts, and oilseeds).

The latter constitute the major sources of fat in the low-income countries, but their contribution is, on the whole, negligible in the industrialized countries. In fact, the proportion of cereals in the diet varies inversely with income, and there is substitution of nuts and oilseeds by industrially prepared fats and oils, while cooking practices shift from boiling to frying.

There are, of course, deviations from this pattern. In the countries of Asia with rice-based diets, fat intake is apparently lower, on the average,

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[a] The gross domestic product per head per year is shown in a logarithmic scale along the ordinate, while the percentage of calories provided by the various nutrients is shown along the abscissa. The areas enclosed by the regression lines represent the energy supplied by the different nutrients in the diet as percentages of total energy. They obey semilogarithmic functions of the type $y = a + b \log_n x$.

than in other low-income countries. Fat intake is still very moderate in Japan despite the relatively high income there, a situation that must be attributed to dietary traditions, but in most other countries with higher *per caput* incomes daily fat consumption has reached very high levels (above 110 g per person). These countries have arrived at, or are near, the saturation level for separated fats and oils, but the proportion of fats goes on rising because of the sustained demand for products of animal origin, which provide unseparated fats.

The proportion of energy supplied by carbohydrates, as opposed to fats, declines as income rises; it ranges from 75% in low-income countries to 50–60% in those with high incomes. This trend actually conceals the opposing phenomena occurring with a rise in income: a diminished proportion of starchy staples (cereals, roots, tubers, plantains, and pulses) and a sharp increase in the consumption of sucrose in sugar and sugar-sweetened foods. Since the former trend is stronger than the latter, the carbohydrate/energy ratio of the diet falls when income rises.

These correlations with income show one main trend. Here again, there is on either side of the regression line a scattering of points that reflects ecological conditions and dietary habits. For example, certain countries on the Saharan periphery and in the Eastern Mediterranean have, despite a low income, a sugar consumption in excess of 25 kg per person per year, largely attributable to their tea drinking. In many of the tropical countries of Latin America, sugar consumption is higher than income would lead one to expect and plays a much more significant role than in the other developing countries because of the former traditional attachment to crude cane sugar products, for which refined sugar is becoming the substitute.

The proportion of dietary energy from proteins of animal origin is closely linked to income. Inversely, the proportion of energy supplied by plant proteins diminishes as income rises. As the two trends offset each other, the proportion of energy supplied by total protein (protein-energy ratio) at the level of aggregation of the data appears to be independent of income and reflects, in all countries, values around 11% of energy from protein.

The scatter around this figure (11%) diminishes as one moves from the developing countries to the affluent ones. Among rural populations with low cash incomes, purchased food constitutes only a small part of the dietary intake, most of the diet consisting of home-produced foods. Because of this, there is a close correlation between the type of diet and the ecological environment. On the other hand, since staple foods supply 60–80% of the energy in the diet, the percentage of energy derived from dietary protein is largely dependent on the concentration of protein in the staple food and varies with it within very wide limits — from 6% for diets based on roots and tubers up to 30% for diets with animal foods of certain fishing and hunting populations.

As countries change to a money economy, the populations have a wider choice of foods and their diet is less subject to constraints imposed by the environment; changes in dietary components are therefore favoured (substitution of protein from animal products for those of plant origin, and of carbohydrate by fat).

The increased consumption of products of animal origin, which should lead to a noticeable increase in the percentage of energy derived from protein, is offset by a corresponding increase in fats and sugar. The result is that there is only a very slight change in the protein-energy ratio, which thus proves not to be a sensitive indicator of changes in component foods. Nevertheless, surveys show that even when economic conditions permit access to a wider choice of foods, the percentage is only slightly modified and seems in the long run to attain an equilibrium around figures of between 11 and 13%.

It is impossible to state whether this level of 11–13% of energy from protein is nutritionally desirable. The trends in the data do not depend on proteins alone, and there continues to be a change in the structure of the diet in the developed countries, owing to the substitution of polysaccharides by fats and sugars that come to supply practically half of the energy. These changes, linked with a rise in income, apparently meet consumer tastes. Nevertheless, we may rightly wonder — in face of the growing incidence of nutrition-related disorders (obesity, diabetes, cardiovascular diseases) — whether they are not, in the long run, harmful trends. It is, in any case, certainly not necessary to take the diet of the developed countries as a model of a satisfactory state of nutrition.

5. ENERGY

The recommendations for energy intake are intended to reflect the average of the true requirements of stipulated populations. They are therefore too high for some and too low for other individuals within these populations.

The energy requirements of individuals depend on 4 variables interrelated in a complex way: (*a*) physical activity, (*b*) body size and composition, (*c*) age, and (*d*) climate and other ecological factors.

Individuals of the same size living in the same environment and with the same mode of life have a similar energy requirement whatever their ethnic origin. (There is much experience to support this statement for the major ethnic groups, but some primitive and isolated groups have not been studied sufficiently.) In childhood and adolescence there are additional energy needs for growth, and needs are increased during pregnancy and lactation.

Among individuals of the same sex and similar body size and age, the amount of physical activity is usually the most important factor in causing variations in energy expenditure. Much of the energy utilized by the body is expended in the basal or resting metabolism [a] and most people spend a large proportion of the 24 hours "at rest".[23, 24] As total resting energy output (which includes the increased metabolic rate resulting from the ingestion of food) in any one individual is relatively fixed, the factor that most alters the total daily energy expenditure is physical activity.

The effects of body size and composition, and of age, may be large and it is possible to suggest approximate correction factors to be applied for these variables. The climate influences the energy expenditure indirectly through variation in physical activity although, on occasion, when hard physical exercise is performed in the heat, a direct increase in energy expenditure may occur.

The method of scaling energy requirements adopted in the reports of the first and second Committees on Calorie Requirements [1, 2] has been followed, with modifications, by the present Committee. Requirements for populations are derived from the requirements of a reference man and a reference woman, who are defined with respect to weight and age. To each is ascribed an energy expenditure that appears sufficient for both occupational and recreational activities. The reference man and reference woman are arbitrarily selected convenient starting points for extrapolation. They have no other significance and are not intended to suggest ideal standards. They were originally chosen as being representative of groups of men and women whose food consumption and energy expenditure had been carefully studied. They are a man and a woman aged between 20 and 39 years who are adequately clothed and housed so that the air immediately surrounding the body is comfortably warm, i.e. the microclimate is thermally neutral.[b] Their body weights are not necessarily ideal, but they consume an adequate, well balanced diet and are neither gaining nor losing weight.

The effects of variations in body size, age, and climate on reference requirements are considered later in this section and are treated as independent variables. The requirements of large populations can be "built up" by allowing for the effect of these variables on reference requirements.

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[a] Basal metabolism refers to the energy expenditure of a person who is relaxed and comfortable in the morning soon after awakening and 14 hours after the last meal. Resting metabolism is the energy expenditure of a person at rest in a normal life situation (different times of day and intervals after eating).[23] See Annex 4.

[b] The term "thermally neutral microclimate" refers to the sum total of climatic factors—radiation, air temperature, humidity, air flow velocity—that allows the customarily clothed man to remain in thermal balance, without other thermoregulatory measures than the control of skin circulation. A thermally neutral microclimate, as thus defined, is generally compatible with a mean skin temperature of 34°C and with subjective thermal comfort at rest.

The energy needs for growth, pregnancy, and lactation are assessed in separate sections.

Most of the recommendations on energy requirements in this report are based on measurements of food intake, sometimes of individuals, often of groups. If food intake is used as the criterion of requirements, certain assumptions are made. One is that the population is healthy, and this may not be quite true. Many groups of people — even young people — living in the industrialized countries are obese. On the other hand, some groups in developing countries are small in stature, light, and thin, yet they may not be physically less healthy because of their different body size.

Measurements of energy expenditure are not necessarily more informative than diet surveys for assessing energy needs. Energy expenditure is known to be increased in groups of people who are heavy because they have large amounts of adipose tissue. A heavier man doing the same work as a lighter man expends more energy, but his total energy expenditure may be influenced by a reduction in his physical activity in leisure; fat people are often less active than thin people.[25, 26, 27] It is not known whether these opposing influences cancel each other. Many individuals do not usually sit quietly, and many commonly shift around on their chairs or gesticulate freely when speaking, whereas others are much more passive. Measurements by indirect calorimetry may not distinguish these two types of people. The making of a measurement may also modify natural activity in small ways. These factors may cause small errors in determining the energy balance in some individuals, but they are not likely to be of significance in estimating energy requirements of a population. In assessing energy expenditure measurements the same care is needed, in regard to the type of individuals studied, as with food intake studies, when the total energy requirements of populations are being considered.

5.1 Physical activity

In any population, individuals vary greatly in the extent of their physical activity. Even in any single occupation, for example, in men who work in an office or in a factory, there are large differences in the way in which the leisure or non-occupational time is spent, with, as a result, large variations in the energy expended outside the work period. Opportunities for physical activity during leisure time for communities living in a large city in an industrialized country are very different from those for rural communities in a developing country. Nevertheless, studies of both food intake and energy expenditure in groups of people show that by far the most important intergroup variable is the energy expenditure in the physical activity required by the occupation. There are many reports that show the differences between the energy expenditures of men in light industry, in agriculture, and so on.[23, 28]

There are still insufficient data to categorize occupations in any precise fashion, but a rough classification is given below.

Light activity

Men : Office workers, most professional men (such as lawyers, doctors, accountants, teachers, architects, etc.), shop workers, unemployed men.

Women : Office workers, housewives in houses with mechanical household appliances, teachers, and most other professional women.

Moderately active

Men : Most men in light industry, students, building workers (excluding heavy labourers), many farm workers, soldiers not on active service, fishermen.

Women : Light industry, housewives without mechanical household appliances, students, department store workers.

Very active

Men : Some agricultural workers, unskilled labourers, forestry workers, army recruits and soldiers on active service, mine workers, steel workers.

Women : Some farm workers (especially peasant agriculture), dancers, athletes.

Exceptionally active

Men : Lumberjacks, blacksmiths, rickshaw-pullers.

Women : Construction workers.

This classification may need to be modified for use in individual countries. Such classifications should be used with care, since the work performed in many occupations varies greatly and there are many jobs that do not easily fit into any one category. A farmer may be a peasant doing physical labour for much of his working day or the manager of a highly mechanized farm whose work involves little physical activity. In many light industries there are some jobs that require heavy work, and levels of mechanization in both light and heavy industry are changing.

There is little doubt that a reasonable amount of physical exercise is beneficial to health.[29] Obesity, which is so common in many industrialized countries and which is indisputably associated with a wide range of disabilities of metabolic, mechanical, and degenerative origin, is less common in people who are physically active. Exercise of a moderately strenuous nature is necessary to maintain satisfactory cardiovascular, respiratory, and muscular function. There are many other less easily defined social and psychological benefits to be derived from leading a physically active life; however, it is recognized that lack of physical exercise is mainly a problem of the industrialized countries.

5.2 Body size and body composition

Body size and composition may affect energy expenditure by an effect on (*a*) resting metabolism, (*b*) the physical work of moving the whole body or large parts of the body, and (*c*) the work of standing, maintaining posture, and small movement of limbs. Also, the total physical activity of an individual may be influenced by the quantity of adipose tissue.

The resting metabolic rate is correlated with the fat-free body mass. As a result, the resting metabolic rate of an obese person when expressed in relation to gross body weight is usually lower than that of a thin person. Unless obesity is marked, this does not greatly affect energy requirements.

Many laboratory studies show that the energy expended in moving the whole body, as in walking, or in moving large muscle masses, such as in cycling, has a high correlation with body weight.[23] The correlation exists because those parts of the body concerned in such movements — the legs and the arms — are related to the body mass. There is a less marked, but still significant, relationship with gross body weight when the movements involve smaller muscle masses, e.g., the limited arm movements with only a minor degree of physical effort characteristic of many forms of housework and light industry.

Anthropometric tables giving "ideal" weight for height, even if they give data for individuals of large, medium, and small body frames, do not take full account of variability in the amount of adipose tissue. The weight-for-height relationship may not be the same for different communities and ethnic groups, and there is a need for standards for each population. Requirements for both energy and protein should be related to the expected weight for height of the adult population.

The quantity of fat in different population groups may be a factor accounting for varying body weight. In a study on groups of men weighing about 55 kg the total body fat was shown to be 10% of the body weight.[166] The amount of fat in these men is about 5 kg and the mean fat-free mass about 50 kg. In populations where the mean body weight of men is 65 kg, the fat content is usually about 11 kg and the fat-free mass about 54 kg, which is not so different from that of the smaller men as the difference in body weights suggests. Therefore, until better anthropometric data are available it cannot be assumed that a low body weight, by itself, implies undernutrition.

In the report of the second FAO Committee on Calorie Requirements [2] formulae were given for relating energy requirements to body weight that implied much greater accuracy than is justified. The present Committee chose simply to express energy requirements, like those for protein, in relation to body weight. However, caution is needed in applying this correction to a population. The mean weight of the people may be high if obesity is common or low if undernutrition is common, and if the actual weights rather than ideal weights are used, estimates of requirements may be too high or too low. Correction for this is difficult with the information now available. Measurement of skinfold thickness at selected sites of the body is practicable for field use and gives a reasonable indication of the fat content of the body. With such techniques, useful information that can be applied at national levels could be obtained, and the collection of such data should be encouraged.

5.3 Climate

Man, like other mammals, has the capacity to increase his heat production as a response to a cold environment, but while this mechanism is important in many species, it is not normally and continuously active in the human being. On casual exposures to cold, shivering leads to heat production in the muscles ; non-shivering thermogenesis develops after more prolonged exposure. Instead of depending solely on his physiological responses, man tries to achieve thermal comfort by creating a microclimate that allows his mean skin temperature to be at 33°C or near it. Clothes and housing with ventilation, heating and/or cooling serve his purpose. When these means do not suffice, man tends to modify his behaviour, increasing or reducing physical activity according to thermal needs.

The first and second FAO Committees on Calorie Requirements defined the reference man and reference woman as living in the temperate zone at a mean annual temperature of 10°C. The first Committee recommended that the energy requirements assigned to the reference man and woman should be increased by 5% for every 10 degrees C of mean annual external temperature below the reference temperature. This adjustment for cold exposure was reduced to 3% by the second Committee. However, both the first and the second Committee recommended a decrease by 5% for every 10 degrees C of mean annual external temperature above the reference temperature.

In several tropical communities the basal metabolic rate has been shown to be lower than the norms set by Benedict.[30] However, in other communities this is not so. The energy expended in standard tasks is the same in different climates, except possibly in extreme and unusual environments. Moreover, the thermal environment cannot be defined accurately by any single meteorological characteristic. To relate physiological parameters with the mean annual external temperature may be misleading.

However, climate may have a marked effect on the amount and timing of physical work and recreation. The social adaptations to climate vary and, where necessary, this fact should be taken into account for different communities by adjusting the contribution of physical activity to the total energy expenditure.

The Committee considered that there was no quantifiable basis for correcting the resting and exercise energy requirements according to the climate. When physical activity is restricted by environmental factors, the category of activity should be adjusted accordingly.

5.4 Energy requirements of reference adults

5.4.1 *The moderately active reference adults*

(*a*) *Man*. He is between 20 and 39 years of age and weighs 65 kg. He is healthy, that is, free from disease and physically fit for active work. On each working day he is employed for 8 hours in an occupation that usually involves moderate activity. When not at work, he spends 8 hours in bed, 4–6 hours sitting or moving around in only very light activity, and 2 hours in walking, in active recreation, or in household duties.

Studies on energy expenditure and food intake of moderately active healthy adult males with an average weight of 65 kg show that 3000 kcal per day (12.5 MJ) adequately cover this average expenditure, and this figure is taken as the requirement.

(*b*) *Woman*. She is between 20 and 39 years of age, similarly healthy, and weighs 55 kg. She may be engaged for 8 hours in general household work, in light industry, or in other moderately active work. Apart from 8 hours in bed, she spends 4–6 hours sitting or moving around in only very light activity, and 2 hours in walking, in active recreation, or in household duties.

Studies on the energy expenditure and food intake of such women show that 2200 kcal per day (9.2 MJ) cover average energy expenditure, and this figure is taken as the requirement.

The first and second FAO Committees on Calorie Requirements [1, 2] used an energy expenditure of 3200 kcal for the reference man and 2300 kcal for the reference woman. These figures have been reduced as above to bring them in line with recent observations.

5.4.2 *Total daily energy expenditure in different occupations*

The total daily energy output can be subdivided into three parts according to the time spent (*a*) in bed, (*b*) at work, and (*c*) in non-occupational activities. Tables 1 and 2 give illustrations of how this can be carried out

TABLE 1. ILLUSTRATIONS OF HOW THE ENERGY EXPENDITURE OF THE 65-kg REFERENCE MAN MAY BE DISTRIBUTED OVER THE 24 HOURS AND THE EFFECT OF OCCUPATION

	Light activity		Moderately active		Very active		Exceptionally active	
	kcal	MJ	kcal	MJ	kcal	MJ	kcal	MJ
In bed (8 hours)	500	2.1	500	2.1	500	2.1	500	2.1
At work (8 hours)	1 100	4.6	1 400	5.8	1 900	8.0	2 400	10.0
Non-occupational activities (8 hours)	700–1 500	3.0–6.3	700–1 500	3.0–6.3	700–1 500	3.0–6.3	700–1 500	3.0–6.3
Range of energy expenditure (24 hours)	2 300–3 100	9.7–13.0	2 600–3 400	10.9–14.2	3 100–3 900	13.0–16.3	3 600–4 400	15.1–18.4
Mean (24 hours)	2 700	11.3	3 000	12.5	3 500	14.6	4 000	16.7
Mean (per kg body weight)	42	0.17	46	0.19	54	0.23	62	0.26

TABLE 2. ILLUSTRATIONS OF HOW THE ENERGY EXPENDITURE OF THE 55-kg REFERENCE WOMAN MAY BE DISTRIBUTED OVER THE 24 HOURS AND THE EFFECT OF OCCUPATION

	Light activity		Moderately active		Very active		Exceptionally active	
	kcal	MJ	kcal	JM	kcal	MJ	kcal	MJ
In bed (8 hours)	420	1.8	420	1.8	420	1.8	420	1.8
At work (8 hours)	800	3.3	1 000	4.2	1 400	5.9	1 800	7.5
Non-occupational activities (8 hours)	580–980	2.4–4.1	580–980	2.4–4.1	580–980	2.4–4.1	580–980	2.4–4.1
Range of energy expenditure (24 hours)	1 800 2 200	7.5–9.2	2 000–2 400	8.4–10.1	2 400–2 700	10.1–11.8	2 800–3 200	11.7–13.4
Mean (24 hours)	2 000	8.4	2 200	9.2	2 600	10.9	3 000	12.5
Mean (per kg body weight)	36	0.15	40	0.17	47	0.20	55	0.23

for occupational subdivisions. A more detailed list of energy cost of activities is given in Annex 5.

In bed, the energy expended approximates to the basal metabolic rate and for a 65-kg man is 500 kcal (2.1 MJ) and for a 55-kg woman is 420 kcal (1.8 MJ).

At work, the energy used by the reference man is 1400 kcal (5.8 MJ) and by the reference woman is 1000 kcal (4.2 MJ). For a man in a light occupation, the value for work is 1100 kcal (4.6 MJ), for the very active man it is

1900 kcal (8.0 MJ) and for the exceptionally active man 2400 kcal (10.0 MJ). For a woman in a light occupation the value for work is 800 kcal (3.3 MJ). For the very active woman it is 1400 kcal (5.9 MJ), and for the exceptionally active woman 1800 kcal (7.5 MJ).

For individuals within occupations, the variability in daily energy expenditure depends to a large degree on the activity undertaken in leisure time. The tables therefore give indications of the ranges that may be encountered in groups of individuals. These ranges probably cover the majority of people. There is little evidence that even very active or sedentary workers vary significantly in recreational activities, although exceptionally active occupations probably inhibit active leisure. The ranges may be useful for small groups of men and women, e.g., those living in a workers' camp or in an institution, where more detailed information may be available than would be the case for a large population.

Tables 1 and 2 show that the difference between the various occupational groups is apparently small. Only 300 kcal (1.2 MJ) separates men in a light occupation from those who are in a moderately active one. Similarly, 500 kcal (2.1 MJ) differentiates the moderately active from the very active men. The provision of these extra amounts of energy to a particular population may allow the men to do extra physical work, but this also depends on many social and environmental factors and on the physical capacity of the men to undertake the increased work.

These tables give a pattern of activity for a working day. In some countries the working week consists of 5 days, in others of 6 days, and occasionally a 7-day week is worked for part of the year. Energy expended on non-working days may be more or less than on work days. However, unless there is reason to believe that activity varies markedly between working and non-working days, corrections are probably unwarranted.

For calculations of national energy requirements, the average activity of the adults of a country might be considered as that of the reference adults, or half the adult male population might be considered to be in "moderately active" occupations and half in "light" occupations. The table allows calculations to be made on these bases.

5.4.3 *Adjustment for body weight*

Tables 3 and 4 give the average energy requirements of men and women in different occupational groups according to body weight (the requirements for the reference man and the reference woman are shown in bold type).

The deduction of energy needs from those of the reference man to be applied to a man working in a light occupation and the addition to be made for very active and exceptionally active men are greater than those to be applied in the case of women. The energy requirements per unit of body weight for men are higher than those for women of the same total weight in

TABLE 3. THE EFFECTS OF BODY WEIGHT AND OCCUPATION ON ENERGY REQUIREMENTS OF MEN

Body weight	Light activity		Moderately active		Very active		Exceptionally active	
(kg)	(kcal)	(MJ)	(kcal)	(MJ)	(kcal)	(MJ)	(kcal	(MJ)
50	2 100	8.8	2 300	9.6	2 700	11.3	3 100	13.0
55	2 310	9.7	2 530	10.6	2 970	12.4	3 410	14.3
60	2 520	10.5	2 760	11.5	3 240	13.6	3 720	15.6
65	2 700	11.3	**3 000**	**12.5**	3 500	14.6	4 000	16.7
70	2 940	12.3	3 220	13.5	3 780	15.8	4 340	18.2
75	3 150	13.2	3 450	14.4	4 050	16.9	4 650	19.5
80	3 360	14.1	3 680	15.4	4 320	18.1	4 960	20.8

TABLE 4. THE EFFECTS OF BODY WEIGHT AND OCCUPATION ON ENERGY REQUIREMENTS OF WOMEN

Body weight	Light activity		Moderately active		Very active		Exceptionally active	
(kg)	(kcal)	(MJ)	(kcal)	(MJ)	(kcal)	(MJ	(kcal)	(MJ)
40	1 440	6.0	1 600	6.7	1 880	7.9	2 200	9.2
45	1 620	6.8	1 800	7.5	2 120	8.9	2 480	10.4
50	1 800	7.5	2 000	8.4	2 350	9.8	2 750	11.5
55	2 000	8.4	**2 200**	**9.2**	2 600	10.9	3 000	12.6
60	2 160	9.0	2 400	10.0	2 820	11.8	3 300	13.8
65	2 340	9.8	2 600	10.9	3 055	12.8	3 575	15.0
70	2 520	10.5	2 800	11.7	3 290	13.8	3 850	16.1

the same occupational categories. This is partly due to the fact that women have a larger proportion of fat in their bodies, and also that women tend to work, particularly in heavy physical work, at lower loads than men. Many physiological studies give supporting evidence for these statements.[31] Moreover, the values in the tables fit well with results from field observations.[23]

5.4.4 *The effect of aging on energy requirement in adults*

The energy expenditure of adults may alter with age because of (*a*) changes in body weight or body composition, (*b*) a decrease in the basal metabolic rate, (*c*) a decline in physical activity, and (*d*) an increased prevalence of diseases and disabilities.

The general topic of body weight and body composition has already been discussed. The active cell mass decreases beyond middle age, and this is reflected in a fall in the resting metabolic rate. In many populations the amount of body fat and the total body weight tend to increase with age.

There is little evidence that physical activity alters significantly, either at work or at leisure, between the ages of 20 and 39. From the age of 40 onwards, several changes may occur. Older people tend to leave work that requires high energy expenditure or to be less active in such occupations. Even in occupations with moderate requirements, the physical activity at work may be slightly reduced; the amount of movement during an average working day may be a little less than formerly for a man or woman of 50 than at the age of 30. The physical activity during the non-occupational time is likely to be reduced with advancing age. Most people further reduce their physical activity after the age of 60.

In people of 60–69 years of age, the limitation of physical activity attributable to disease or disability is highly variable and becomes even more so after the age of 70.

The second FAO Committee on Calorie Requirements [2] considered appropriate a decrement of energy requirement by 3% for each decade between 25 and 45 years of age. Between the ages of 45 and 65 the suggested decrement for each decade was 7.5% of the value at 25 years, and 10% of that value for the decade between 65 and 75 years. The present Committee recommends that the average energy requirement of men and women be regarded as unchanged from 20 up to 39 years of age. Energy requirement is thought to decrease by 5% for each decade between the ages of 40 and 59 years, and by 10% from 60 to 69 years; for age 70 and above another reduction of 10% is suggested (see Table 5).

TABLE 5. AVERAGE ENERGY REQUIREMENT OF MODERATELY ACTIVE ADULTS OF REFERENCE BODY WEIGHT AT DIFFERENT AGES

Age (years)	65-kg man		55-kg woman		% of reference
	(kcal)	(MJ)	(kcal)	(MJ)	
20–39	3 000	12.5	2 200	9.2	100
40–49	2 850	11.9	2 090	8.7	95
50–59	2 700	11.3	1 980	8.3	90
60–69	2 400	10.0	1 760	7.4	80
70–79	2 100	8.8	1 540	6.4	70

5.5 Energy requirements of infants, children, and adolescents

During the period of growth, energy requirements should be related to some measure of body size. The Committee found no advantage in referring requirements to surface area and recommends that weight should be used as the basis of reference.

Infants. The energy requirements of infants during the first 6 months of life can be estimated from the observed intakes of breastfed infants growing normally.[32, 33] It is recognized that there is much variation in energy intake, both between babies and in the same baby from day to day, caused by variations in the volume and energy content of milk. From 0 to 3 months an intake of 850 ml per day of human milk will provide on average 120 kcal (500 kJ) per kg. During the second 3 months of life the intake per kg is somewhat lower. After 6 months of age the infant is unable to obtain his full energy needs from breast milk alone. The individual requirement depends largely on the activity of the child. The average requirement during the first year is shown in Table 6.

TABLE 6. ENERGY REQUIREMENTS OF INFANTS

Age	kcal per kg	kJ per kg
< 3 months	120	500
3–5 months	115	480
6–8 months	110	460
9–11 months	105	440
Average during first year	112	470

Children and adolescents. Table 7 sets out the energy requirements year by year, and Table 8 presents the same data grouped according to age and sex categories.

The figures for both sexes up to the age of 10 are based on a memorandum by Leitch & Widdowson put before the second FAO Committee on Calorie Requirements in 1956 and used for making its recommendations, but not set out in full in the previous report. The figures are based on consumption data on healthy children in the USA and the United Kingdom. Subsequent surveys, in particular that covering 11 regions of the European Community, confirm that the figures represent the average needs of children who are growing normally.[34] The total increment for both boys and girls over the 5-year period from age 10 to 15 years has been somewhat reduced from that suggested in the 1957 Calorie Requirements Report.

In the age group 16–19 years, the figures for boys have been drastically reduced and those for girls have been slightly reduced. The first FAO Committee on Calorie Requirements recommended 3800 kcal for boys aged 16–19. This figure was based largely on observations on army cadets. The second FAO Committee on Calorie Requirements was unable to justify this figure but made only a small reduction to 3600 kcal. The figure of 3070 kcal (12.8 MJ) given here is supported by surveys in the European Community,[34] in Australia,[35] and in California.[36]

A practical problem arises concerning the requirements of a community where a significant proportion of the children are underweight because of previous malnutrition. Since the intention is to provide for catch-up

TABLE 7. ENERGY REQUIREMENTS OF CHILDREN AND ADOLESCENTS BY YEAR

Age (years)	Males					Females				
	Weight	Energy per kg per day		Energy per person per day		Weight	Energy per kg per day		Energy per person per day	
	(kg)	(kcal)	(kJ)	(kcal)	(MJ)	(kg)	(kcal)	(kJ)	(kcal	(MJ)
< 1	7.3	112	470	820	3.4	7.3	112	470	820	3.4
1	11.4	103	431	1 180	4.9	11.1	106	444	1 180	4.9
2	13.6	100	418	1 360	5.7	13.4	100	418	1 350	5.6
3	15.6	100	418	1 560	6.5	15.4	99	414	1 520	6.4
4	17.4	99	414	1 720	7.2	17.5	96	402	1 670	7.0
5	20.7	91	381	1 870	7.8	20.0	90	377	1 790	7.5
6	23.2	87	364	2 010	8.4	22.4	85	356	1 900	7.9
7	25.9	83	347	2 140	9.0	25.0	80	335	2 010	8.4
8	28.6	79	331	2 260	9.5	27.6	76	318	2 110	8.8
9	31.3	76	318	2 380	10.0	30.4	73	305	2 210	9.2
10	33.9	74	310	2 500	10.5	33.8	68	285	2 300	9.6
11	36.7	71	297	2 600	10.9	37.7	62	259	2 350	9.8
12	40.2	67	280	2 700	11.3	42.4	57	238	2 400	10.0
13	45.5	61	255	2 800	11.7	47.0	52	218	2 450	10.3
14	51.7	56	234	2 900	12.1	50.3	50	209	2 500	10.5
15	56.6	53	222	3 000	12.6	52.3	48	201	2 500	10.5
16	60.3	51	213	3 050	12.8	53.6	45	188	2 420	10.1
17	62.4	50	209	3 100	13.0	54.2	43	180	2 340	9.8
18	63.7	49	205	3 100	13.0	54.6	42	176	2 270	9.5
19	65.0	47	197	3 020	12.6	55.0	40	167	2 200	9.2
Reference adult (moderately active)	65.0	46	192	3 000	12.6	55.0	40	167	2 200	9.2

growth and a return to the normal height and weight, it might be thought that allowances should be calculated on an age basis rather than on a weight basis. This applies to children up to the age of puberty. However, older children who have been malnourished are unlikely ever to catch up and reach normal size; the consumption of extra food would lead to obesity. It is therefore suggested that after the thirteenth birthday the recommended intake should be corrected for body weight in both sexes in the same way as for adults (section 5.4.3).

5.6 Energy requirements during pregnancy and lactation

During pregnancy extra energy is needed for the growth of the fetus and of the placenta and the associated maternal tissues, and for the increased cost of the movement of the heavier mother. Basal metabolism rises by 20% in the last trimester of pregnancy. The total energy cost of a pregnancy is about 80 000 kcal (335 MJ), of which about 36 000 kcal (150 MJ) is

TABLE 8. ENERGY REQUIREMENTS OF CHILDREN AND ADOLESCENTS BY AGE PERIODS

Age (years)	Body weight (kg)	Energy per kg per day (kcal)	Energy per kg per day (kJ)	Energy per person per day (kcal)	Energy per person per day (MJ)
Children					
<1	7.3	112	470	820	3.4
1–3	13.4	101	424	1 360	5.7
4–6	20.2	91	382	1 830	7.6
7–9	28.1	78	326	2 190	9.2
Male adolescents					
10–12	36.9	71	297	2 600	10.9
13–15	51.3	57	238	2 900	12.1
16–19	62.9	49	205	3 070	12.8
Female adolescents					
10–12	38.0	62	259	2 350	9.8
13–15	49.9	50	209	2 490	10.4
16–19	54.4	43	179	2 310	9.7
Adult man (moderately active)	65.0	46	192	3 000	12.6
Adult woman (moderately active)	55.0	40	167	2 200	9.2

thought to be accounted for by lipid storage. Fat deposition accounts for about 4 kg out of a total weight gain of 12.5 kg in well-nourished women of reference body weight (55 kg).[37]

Fat deposition begins early in pregnancy and is a physiological increase in the energy reserve. This reserve provides protection against a possible food shortage at a later stage of pregnancy, when the needs of the fetus are increasing rapidly, or it may be utilized during lactation, when maternal energy needs are high.

In many countries there are women for whom the burden of pregnancy is added to the physical work of running a home and caring for several small children. Such women need additional food to meet all the energy requirements of pregnancy. On the other hand, in many countries there are some women with little or no household work who, when they become pregnant, give up a job or active recreation and lead a sedentary instead of an active life. Such women may actually need less food than formerly. In many women some curtailment of activity occurs and the total 80 000 kcal (335 MJ) of extra dietary energy may not be needed.

Previously an allowance of 40 000 kcal (170 MJ) per pregnancy was recommended for calculating the energy requirements of countries. However, a safe level of energy intake is a basic requirement to ensure satisfactory nutrition for the fetus and breastfed infant. The present Committee, recognizing that this recommendation differs from other estimates for energy that are average requirements, recommends 80 000 kcal (335 MJ) for pregnancy. The full energy allowance requires an average increase of 285 kcal (1.2 MJ) per day over the 280 days of pregnancy, or about 150 kcal (0.6 MJ) per day in the first trimester and 350 kcal (1.5 MJ) per day in the second and third trimesters.

There are physiological, hygienic, and psychological arguments favouring breastfeeding. In the developing countries its practice is of paramount importance. The average daily milk production is about 850 ml (range up to 1200 ml), and breast milk has an energy content of the order of 0.72 kcal (3 kJ) per ml. Previously the efficiency of milk production was taken to be about 60%, but evidence now suggests that the efficiency of milk production is at least 80%.[38] When producing an average of 850 ml of milk per day with an energy value of roughly 600 kcal (2.5 MJ), a mother would need 750 kcal (3.1 MJ) from food (at 80% efficiency). During 6 months of lactation the energy requirement is about 135 000 kcal (565 MJ). If the pregnant woman has laid down fat according to the full allowance for pregnancy, she has a reserve of about 36 000 kcal (151 MJ) that will be available for lactation. The additional energy requirement for lactation would then be 100 000 kcal (415 MJ), or about 550 kcal (2.3 MJ) per day. Mothers with less stored fat need a correspondingly greater food intake during lactation, as do women who continue breastfeeding beyond 6 months.

In populations in which breastfeeding is not the rule, the normal weight gain during pregnancy favours normal fetal growth, and no attempt should be made to prevent it. For twin pregnancy and for the simultaneous breastfeeding of more than one child, additional requirements should be taken into account.

5.7 Relative energy requirements for maintenance, growth, and activity

The values for energy requirements given in Tables 1–8 are based on the average observed intakes of groups of normal healthy individuals. It would be of interest to compare these with calculated estimates of requirements based upon separate estimates of the cost of maintenance and of growth.

5.7.1 *Maintenance*

The heat production under resting, fasting conditions (BMR) is a measure of the rate at which body substance is oxidized in order to support the continued maintenance of life. However, in non-fasting subjects the amount of metabolizable food energy needed to ensure constant body energy is always found experimentally to be greater than the basal metabolic rate. The difference is accounted for partly by the heat increment above basal following the absorption of food (sometimes refered to as the specific dynamic action), partly by the energy cost of re-synthesizing those tissue components that under fasting conditions would be oxidized and lost to the body, and partly by a minimum level of voluntary muscular activity, which is obligatory for such functions as dressing, washing, etc.

The food energy intake necessary to maintain constant body energy content has been estimated in a number of different animals. The values shown in Table 9 are the intakes corresponding to zero balance calculated from the regression of energy balance on energy intake in a manner exactly equivalent to the estimation of N requirements for maintenance from N balance experiments.

TABLE 9. MINIMUM ENERGY INTAKES NECESSARY FOR MAINTENANCE OF BODY ENERGY AND NITROGEN CONTENT

Subject	Energy per kg (kcal)	Energy per kg (MJ)	Energy per kg $^{0.75}$ (kcal)	Energy per kg $^{0.75}$ (MJ)	Reference
Constant body energy					
Lambs	70	0.29	105	0.44	39
Calves	42	0.18	107	0.45	40
Pigs	35	0.15	103	0.43	41
Cows	22	0.09	104	0.44	42
Mean value			105	0.44	
Constant body nitrogen					
Adult men	34	0.14	97	0.41	43
Young rats	250	1.05	118	0.49	44
Young rats	220	0.92	107	0.45	45

Table 9 also shows that similar values are obtained for the energy intakes needed for maintenance of body N content, in these cases calculated from the regression of N balance on energy intake. For all these animals, the minimum dietary energy needed for maintenance is very similar when expressed as units per kg of body weight to the power 0.75 (average 105 kcal (0.44 MJ) per kg $^{0.75}$). The basal metabolic rates of these animals are also similar when related to the 0.75 power of body weight and have a value of 70 kcal (0.29 MJ) per kg $^{0.75}$. It can therefore be said that for practical purposes the energy cost of maintenance is $1.5 \times$ BMR.

5.7.2 *Growth*

The energy cost of growth can be estimated from the effect on N retention of increasing energy intakes under conditions when energy is the factor limiting N gain. Values ranging from 5.4 to 6.8 mg of N stored in new tissue per additional kcal can be calculated for young and adult rats and for adult men from data given in the literature.[45] If one assumes 18% for the protein content of tissue gain, these values correspond to 4.3–5.4 kcal (18–23 kJ) per g of lean wet soft tissue gained. Independent estimates by Kielanowski [41] of the energy costs of deposition of protein and of fat are

15.9 kcal (67 kJ) and 12.9 (54 kJ) per g deposited, respectively. Assuming that normal tissue gained during growth contains 16% fat and 18% protein, these figures would imply a cost of 5.0 kcal (21 kJ) per g of tissue. These different estimates are in reasonably close agreement. The composition of weight is not uniform throughout infancy, childhood, and adolescence, but the estimate of 5 kcal (21 kJ)/g has been used for the calculations that follow.

Ashworth [46] and Ashworth et al.[47] obtained from measurements on infants recovering from malnutrition a value of 10 kcal (42 kJ) per g for the excess energy required above basal for each g of tissue formed. If the maintenance energy requirement is assumed to be 1.5 × BMR, this is equivalent to a cost above maintenance of 8.3 kcal (35 kJ) per g of tissue gain. This figure is likely to be an overestimate of the cost of growth, since it includes the cost of physical activity, which under the conditions of measurement was probably not inconsiderable.

5.7.3 *The requirements for maintenance and growth compared with observed intakes*

Table 10 shows the energy needs for maintenance and growth of boys at different ages. The weights and weight gains have been derived from the Harvard standards.[10] The difference between the estimate of maintenance, plus growth needs, and the observed intakes represents the amounts of energy potentially available to the average individual for activity. There

TABLE 10. ESTIMATED COMPONENTS OF ENERGY EXPENDITURE OF MALES AT SELECTED AGES

Age	Weight (kg)	Energy cost per day				Observed average intake		Energy available for activity	
		Maintenance		Growth					
		(kcal)	(MJ)	(kcal)	(MJ)	(kcal)	(MJ)	(kcal)	(MJ)
< 3 months	4.6	365	1.53	128	0.54	550	2.3	57	0.2
9–12 months	9.6	800	3.35	60	0.25	1 010	4.2	150	0.6
2–3 years	13.6	1 020	4.27	30	0.13	1 360	5.7	310	1.3
4–5 years	17.4	1 200	5.02	35	0.15	1 720	7.2	485	2.0
9–10 years	31.3	1 750	7.32	30	0.13	2 420	10.3	640	2.7
16–17 years	60.3	2 500	10.46	60	0.25	3 100	13.0	540	2.3
Adult (light activity)	65	2 600	10.88	—	—	2 700	11.3	100	0.4
Adult (moderate activity)	65	2 600	10.88	—	—	3 000	12.6	400	1.7
Adult (very active)	65	2 600	10.88	—	—	3 500	14.6	900	3.8

are few direct estimates of the energy costs of activities in children, and none in infants. However, in the adult the energy available for activity calculated by this method is in reasonable agreement with direct estimates of energy expenditure.

5.8 Food energy in relation to other nutrients

(1) *Foods low in essential nutrients per unit of energy*

Food provides not only energy but also other nutrients. Some processed or refined foods are rich in energy but poor in other nutrients. They have been called "empty calories"; notable examples are refined sugar, wines, and spirits. Malnutrition may result if too high a proportion of energy is derived from foods of this type.

(2) *Nutritive quality of low-energy diets*

Persons incapacitated by disease or due to any reason restricting physical activity or dietary intake may subsist for long periods on diets providing only about 1500 kcal (6.3 MJ) per day. This may meet their energy needs, but unless the foods providing the energy are carefully chosen, these persons are likely to become deficient in calcium, iron, and probably protein and the B group of vitamins. This problem is likely to arise in planning diets for elderly populations.

(3) *Contribution of alcohol to energy intake*

A healthy, well-fed adult who consumes ethanol in quantities of less than 2 g per kg per 24 hours oxidizes it without specific dynamic action at a constant but limited rate: about 100 mg per kg per hour. Ethanol could thus replace other energy foods, mainly fat, even up to a limit of about 70% of the basal metabolic rate — 1 g of ethanol provides 7.1 kcal (29.8 kJ). The rate of ethanol oxidation can be raised by about 25% with a carbohydrate and protein-rich diet and can be lowered by the same amount with a high-fat diet and fasting.[48] The rate of ethanol oxidation is not increased by muscular exercise or a cold environment but may be raised as a result of habituation. The data therefore indicate that a 65-kg man could obtain 700 kcal (2.9 MJ) daily from 100 g of ethanol (about 1 litre of 12% wine) and a 55-kg woman could obtain 525 kcal (2.2 MJ). These values are nearly 25 % of the average daily energy requirement and approach maximum physiological limits. There is much evidence showing that a regular intake of excessive amounts of alcohol leads to a deterioration of health.[48, 49]

(4) *Computation of energy from alcohol in national diets*

As long ago as 1953 a WHO Expert Committe on Alcohol[49] recommended that since the energy provided by ethanol is available for metabolic purposes it should be included in the tabulation of energy value of diets using the value 7.1 kcal (29.8 kJ) per g of ethanol. The present Committee concurs with this view. There is scientific evidence to justify the procedure, provided that the consumption of alcohol does not exceed physiological limits.

In national food balance sheets total energy *per caput* is calculated by adding the energy from different food groups. Hitherto it has been the practice not to include the energy from alcohol directly in the total but to show it separately. The Committee recommends that energy derived from alcohol be included in the energy from foods in estimates of national food supplies.

6. PROTEIN

6.1 Nitrogen requirements—methods of estimation

There are two physiological approaches to the problem of estimating nitrogen requirements for man. The factorial method, used in the 1965 report on protein requirements,[4] is based on estimates of the obligatory N losses [a] (the amount of N found in urine, faeces, sweat, etc., when the diet contains no protein) and of the amounts of N needed for the formation of new tissue. The second approach is based on measurements of the minimum N intake needed to maintain N equilibrium in adults or satisfactory growth in children. The evidence obtained by this second method was not considered in any detail by the previous committee. The results obtained by these two methods are now examined and compared.

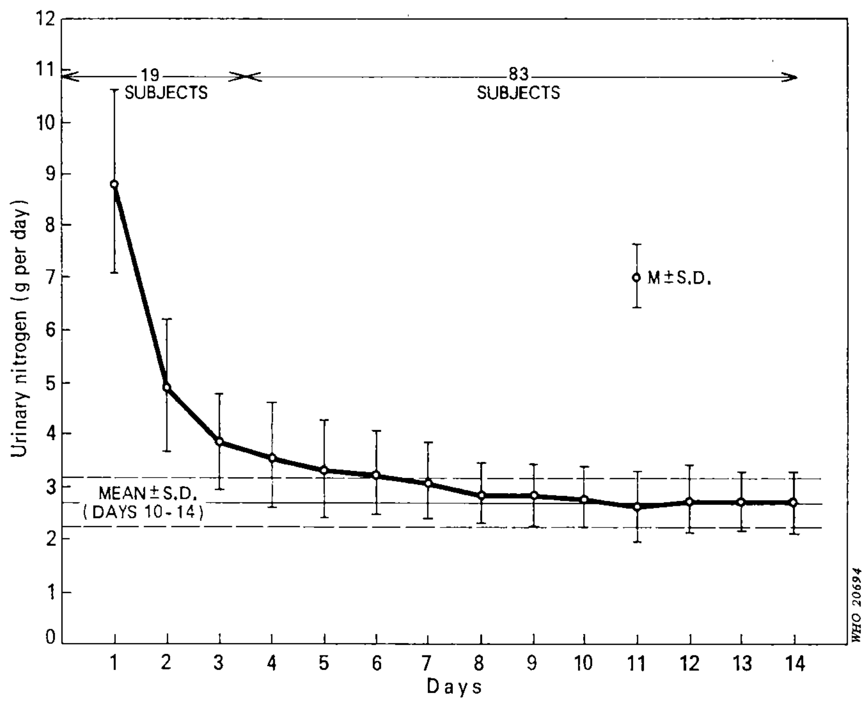
6.1.1 *The factorial method*

The principal questions that have to be considered for adults are the routes of obligatory N loss, the magnitude of the losses, and the conditions under which these losses are most reliably measured. Since 1965, additional information has been obtained on these losses. The N requirement of infants must be treated as a special case, since a substantial part of their requirement represents growth as well as maintenance.

(*a*) *Obligatory urinary N output*. After a change to a protein-free diet adequate in energy, the urinary N output falls rapidly for a few days, and then becomes nearly constant (Fig. 2). In the 1965 report [4] the point of inflection between these two phases was taken to represent the obligatory urinary N loss before depletion. Although this general pattern of N loss in response to a protein-free diet was known, the previous committee had

[a] Obligatory N loss is sometimes called "endogenous" N output or "maintenance" N, but these terms are less precise and are not interchangeable.

FIG. 2. EFFECT OF PROTEIN-FREE DIET, ADEQUATE IN ENERGY, ON URINARY NITROGEN EXCRETION



Source: Scrimshaw, N. S., Hussein, M. A., Murray, E., Rand, W. M. & Young, V. R. (1972) *J. Nutr.*, **102**, 1595.

little information about its magnitude and so they related the obligatory urinary N to the basal metabolic rate. The accepted ratio of 2 mg of N per basal kcal (0.48 mg N per kJ) [50] was used and gave a figure of 46 mg of N per kg of body weight for the obligatory urinary loss in man.

Fig. 2 shows that there is no easily identifiable sharp point of inflection between the two phases of the N output curve. Also, in the region between the phases there is high individual variability.[51] The constant level reached after 6–10 days, which is easily identifiable and reproducible, is taken as the measure of obligatory urinary N loss. New estimates made in this way gave a mean value for the obligatory urinary N output in men of 37 mg of N per kg of body weight.[51-54] For subjects whose basal metabolic rates were measured directly, mean obligatory urinary N loss was 1.4 mg of N per basal kcal (0.33 mg of N per basal kJ), a much lower value than that used previously.

The basal metabolic rate per kg of body weight is lower in women than in men because of the higher proportion of adipose tissue in the normal female body. The obligatory urinary N output per kg of body weight might be expected to be lower for women than for men, but the available data are not definitive. Several measurements [55-57] give a mean value for women of 25 mg of N per kg of body weight. Murlin et al.[58], however, compared the urinary outputs of 28 men and 7 women on the third day of a protein-free diet and presented the findings in the form of equations relating N output to body weight. Although the data were obtained before excretion became constant at the low level, the urinary N excretion was 36 and 34 mg of N per kg of body weight for men and women respectively. This is a trivial difference, and the value for men has been applied to adults of both sexes.

In infants less than 6 months of age, Fomon et al.[59] found an obligatory urinary N loss of 37 mg of N per kg, or 0.6 mg of N per basal kcal (0.14 mg of N per basal kJ). Measurements in children aged between 2 and 11 years gave values for obligatory urinary N output ranging from 0.96 to 1.5 mg of N per kcal (0.23 to 0.36 mg of N per basal kJ).[59-63] Several experimental conditions probably contribute to the variability in results. The periods of study in very young children were necessarily brief, the diets provided small amounts of N, and urinary N was higher in infants and children who had received diets of higher protein content before the study.[59] However, the evidence suggests that in infants the N output in relation to basal metabolic rate is lower than in adults. There are no data for adolescents or for elderly people.

A value of 1.4 mg of N per basal kcal (0.33 mg of N per basal kJ) can be used as an estimate of the obligatory urinary N loss in adults of both sexes and in older children, since it is recognized that there is a greater variation in the latter group.

(*b*) *Obligatory faecal N output*. There is a loss of N in the faeces even when no protein is consumed. The report of the Joint FAO/WHO Expert Group on Protein Requirements [4] allowed 20 mg of N per kg of body weight for this component of obligatory N loss. In the studies of obligatory urinary N output, obligatory faecal N output was also measured. Values for adult males range from 9 to 23 mg of N per kg of body weight, with a weighted mean of 12 mg of N per kg or 0.4 mg per basal kcal (0.1 mg per basal kJ). The average value for women is 9 mg of N per kg. For the children referred to above, the average value is 31 mg of N per kg of body weight, or 0.7 mg per basal kcal (0.17 mg per basal kJ). In infants less than 6 months old, faecal loss was reported to be 20 mg per kg, or 0.3 mg per basal kcal (0.08 mg of N per basal kJ). The Committee accepted a value of 0.4 mg of N per basal kcal (0.1 mg of N per basal kJ) for both sexes and all ages after infancy.

(*c*) *Skin N losses*. Nitrogen is lost from the skin in the form of desquamated cells, hair, and nails, and also in sweat. In early studies of nitrogen balance it was common practice to regard skin losses as negligible and in any case likely to be unaffected by diet. However, Mitchell[50] reported a long-term study of adults in which the dietary N exceeded the urinary and faecal N by 1.38 g per day without a corresponding gain in body weight. This positive balance was equated with skin N losses. On this evidence skin N losses were taken as 20 mg of N per kg of body weight in the 1965 report. New evidence shows that this figure is excessive. Several studies[64, 65, 66] show that, with a normal intake of protein, skin N loss in men is about 5 mg of N per kg of body weight (0.22 mg of N per basal kcal (0.05 mg of N per basal kJ)) and falls to 3 mg of N per kg (0.13 mg of N per basal kcal (0.03 mg of N per basal kJ)) with a protein-free diet.[64]

Published values for skin losses in women and children are scanty. In a small group of women on a normal diet, the loss was 3.6 mg of N per kg of body weight (0.12 mg of N per basal kcal (0.03 mg of N per basal kJ)) with an allowance for hair and nail losses.[65] Values for sweat N of girls aged 7–9 years were 15 mg per kg of body weight after their usual diets and 11 mg per kg after 20 days on a low-protein diet; these values were 6–10% of the total N excretion,[67] and double the value for men. Infants eating normally are reported to lose 40–250 mg of N per day from the total body surface,[68, 69] or 3–5% as much as the N output in urine and faeces.[68] This suggests a loss of 5–10 mg of N per kg body weight, which is somewhat higher than the loss by adults on a weight basis and may be due to the greater surface area per unit body weight of infants and young children.

Environmental conditions that cause heavy sweating may result in a much higher N loss. Consolazio et al.[70], in short-term studies on soldiers exposed to high temperatures, calculated from direct measurements of arm and body sweat that 3.8 g of N can be lost by this route; they found no compensatory reduction in urinary N loss, and concluded that under these conditions protein requirements might be increased by up to 14%. Objections to this view are that (*a*) a stress-induced increase in adrenocortical activity may have resulted in a negative N balance in their study, and (*b*) loss of N in the sweat is known to be partially compensated by a reduction in urinary N in some circumstances.[71-73]

Subjects accustomed to living and working in hot climates do not typically lose a large amount of N in the sweat. In the case of Africans doing light work, N loss from the skin was 10 mg per kg of body weight for those consuming a normal diet, and 6 mg per kg for those on a low-protein diet.[74] Other studies[71, 75, 76] on subjects eating a diet that was normal for the locality where they lived gave a combined average skin N loss of 10 mg per kg of body weight (0.4 mg of N per basal kcal, or 0.1 mg of N per basal kJ). Skin N loss may thus be twice as high in a tropical climate as in a temperate climate.

Sweating due to vigorous physical activity increases N loss by 0.5 mg per kcal per minute (0.13 mg per kJ per minute) over a wide range of work levels.[64]

It is concluded that in temperate climates 3 mg of N per kg per day may be taken as the normal value for obligatory cutaneous losses on a protein-free diet and 5 mg of N per kg per day on a normal diet. In hot climates or in heavy working conditions the figure may be somewhat higher, but at least half of this increase will be compensated by reduction in urinary N excretion. These conclusions are based on data from adult males, since insufficient information is available for women and children.

(*d*) *Other obligatory N losses*. Evolution of gaseous N has been suspected in animal experiments when measured increments of N in the body have been less than those predicted from balance data. [a] From measurements on human subjects in a metabolic chamber Costa et al.[74] claimed that 8–24 mg of N per kg per day might be lost in gaseous form. Similar studies on chicks and rats in an argon-oxygen atmosphere failed to show any release of nitrogen,[80] and Hoffmann & Schiemann[81] did not find any evidence of gaseous N loss in rats that had ingested large doses of ^{15}N-labelled ammonium sulfate. However, an output of 50 mg of ammonia N per day can be detected in the breath.[64]

There is also a small loss of body N due to menstruation, amounting to 1.5–3 g of N per menstrual period.[83] This increases the obligatory N output of women by 60–120 mg of N per day. An average loss of 37 mg of N per seminal ejaculation has been measured in males. Other minor losses include N in saliva and sputum expectorated, in nasal secretions, and in blood lost from trivial wounds.

A figure of 2 mg of N per kg for men and 3 mg of N per kg for women would account for these minor losses.

(*e*) *Total obligatory N losses*. Table 11 shows the average obligatory N losses for an adult man computed from the recent data discussed above. The total value is 54 mg per kg of body weight, i. e., much lower than the 86 mg per kg used to compute protein requirements in the 1965 report on protein requirements.[4] When the former value is calculated on the basis of basal energy metabolism, it approximates to a total loss of 2 mg of N per kcal (0.48 mg of N per kJ). To avoid possible confusion, it must be emphasized that this figure covers the total obligatory loss of N, whereas the 1965 Expert Group [4] used the same value for the urinary loss alone. Available data for women and for children are limited, but suggest that a figure of 2 mg of N per kcal (0.48 mg of N per kJ) also provides a good approximation to the sum of their obligatory losses, except in infants and perhaps in very young children. There is no information on the obligatory N losses of elderly subjects.

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[a] Fixation of gaseous N by intestinal bacteria has also been suggested,[77] and strains having this capacity have been identified in human faeces.[78] These enteric organisms use organic or ammonia N in preference to gaseous N and would be unlikely to fix N under conditions obtaining in the intestine, but the question is not settled.

TABLE 11. OBLIGATORY NITROGEN LOSSES IN ADULT MEN ON A PROTEIN-FREE DIET

Route	mg N per kg of body weight	mg N per unit of basal energy	
		(kcal)	(kJ)
Urine	37	1.4	0.33
Faeces	12	0.4	0.10
Skin	3 [a]	0.13	0.03
Miscellaneous	2	0.08	0.02
Total [b]	54	2.0	0.48

[a] Under temperate conditions; under tropical conditions or in heavy work situations this figure is somewhat higher. See text.

[b] These are approximate average figures. Since the coefficient of variation i.e., (standard deviation divided by the mean) × 100, is 15%, a value 30% larger should encompass the losses of nearly all healthy persons in a normal population.

In the report of the Joint FAO/WHO Expert Group on Protein Requirements [4] an additional 10% was added to the estimated N losses to allow for increased N output related to minor infections and other sources of stress in daily life; the final obligatory N loss was 95 mg of N per kg of body weight. However, subjects undergoing metabolic studies also suffer minor stresses, and the data derived from them need no correction for stress.

(*f*) *Variability of obligatory losses.* These estimates of obligatory N losses are averages, and an allowance should be made for individuals whose output differs from these mean figures. Previous studies, mainly those of Sherman [84] on subjects fed low protein diets, gave 10% as the coefficient of variation of N output. In the report of the Joint FAO/WHO Expert Group an addition of 20% to the estimated mean was considered sufficient to cover the obligatory N losses of all except the 2.5% of the population whose needs exceed two standard deviations above the mean. The new measurements of obligatory N loss in urine and faeces in a large number of adult men engaged in their usual activities give a coefficient of variation of approximately 15%. This range of variation includes technical error, differences among individuals, and differences in one individual from one period to another. However, in the Committee's judgement the major portion of the variation is attributable to biological variability. The value of 15% is accepted as an estimate of the coefficient of variation in an adult population.

(*g*) *N requirements for growth.* The N increment in the body during growth is made up of two components: the deposition of new tissue, as shown by weight gain; and an increase in the N concentration in the body, which is often referred to as maturation.

Data on the N content of the body at different ages, based on whole body analysis, have been collected by Holt et al.[85] and Widdowson & Dickerson.[86] Fomon[87] estimated body N content by extrapolation from measurements of body water. Data of Maresh & Groome[88] on whole body potassium content can also be used to estimate body N content of infants and young children (using the equivalence : 2.15 mEq of potassium per g of N). Considering the errors inherent in the various methods, the values[a] agree reasonably well. The rate of increase in body N is greatest during the first year of life, mature composition being attained by the fourth year.

The daily rate of weight gain per kg of body weight may be obtained from the Harvard data[10] given in Annex 1. The Committee estimated the daily N increment per kg from the body N content at different ages according to Fomon[87] and the cited weight gain data. The computed obligatory N losses in children and the amounts deposited during growth are summarized in Table 12. These values have been interpolated from curves drawn from few data, and can serve only as an approximation of the physiological N requirement of children. Because of the difference between the observed obligatory N losses in infants and older children and because of the uncertainty of N increment values, the Committee did not consider factorial computation to be appropriate in the case of infants.

(*h*) *N requirements in pregnancy*. The nitrogen content of the fetus, fetal membranes, and maternal tissues increases as pregnancy advances. Table 13 shows an estimate of the N increment of a woman gaining 12.5 kg and giving birth to an infant weighing 3.30 kg. The weight of tissues deposited during pregnancy, and hence the nitrogen accretion, is related to the size of the baby.[37] Birth weights have a coefficient of variation of about 15% in seemingly well-nourished populations, and the variability of protein deposition, and hence of nitrogen requirement, is probably the same.

It is widely recognized that the nutrition of the pregnant woman has an important influence on the course of the pregnancy and the health of the infant.[90] The average birth weight is relatively low in many poor countries ; however, birth weights in the upper socioeconomic groups of these countries are similar to the average birth weights characteristic of rich countries. Low birth weights are thus related to conditions of poverty, including poor nutrient intakes during pregnancy, and are not a justification for lower

[a] The total g of N in the infant body, as computed from three references, are as follows :

Age	*Ref. 85*	*Ref. 87*	*Ref. 88*
At birth	68	62	67
3 months	130	104	105
6 months	193	146	135
9 months	249	190	158
1 year	282	231	180

TABLE 12. COMPUTED OBLIGATORY NITROGEN LOSS AND NITROGEN INCREMENT FOR GROWTH OF CHILDREN

Age	Obligatory loss [a]		Nitrogen (mg per kg per day) Growth [b]		Total [c]	
	M	F	M	F	M	F
(months)						
6–8	112		42		154	
9–11	110		26		136	
(years)						
1	104		16		120	
2	100		12		112	
3	96		10		106	
4	92		8.5		100	
5	86		9.5		96	
6	83		9		92	
7	73		8.5		88	
8	76		7		83	
9	73		7		80	
10	72	68	6	9	78	77
11	70	64	7	8	77	72
12	66	60	8	10	74	70
13	62	57	11	7	73	64
14	59	55	9	4	68	59
15	57	54	6	2	63	56
16	57	54	4	1	61	55
17	56	53	2	1	58	54
Adult	54	49	0	0	54	49

[a] Calculated as 2 mg of N per basal kcal (0.48 mg of N per basal kJ). Basal metabolic rate data given in Annex 4 are from Talbot, [89] with values at intermediate ages obtained by interpolation.

[b] Weight increment from data for 50th percentile given in Annex 1[10] and the composition of gain according to references 87 and 88.

[c] These are approximate average figures. Coefficients of variation are assumed to be 15% for obligatory loss and 10% for growth, so a value 30% higher should encompass the values of nearly all healthy individuals in a normal population.

protein allowances. The Committee recognized that N balance studies conducted over long periods of pregnancy have suggested higher retentions than would be predicted by these accretion rates. These estimates are therefore somewhat conservative, but the Committee accepted the values given in Table 13 as a first approximation to the additional N storage associated with pregnancy. The data presented in Table 13 are considered appropriate for all areas, and should not be subjected to adjustment for lower average birth weight in a particular region.

(*i*) *N requirements in lactation.* The additional protein needed by the lactating woman can be estimated from a knowledge of the volume and composition of the milk secreted. There is no evidence that the synthesis of milk protein is either more or less efficient than the synthesis of other body proteins. During the first 6 months of full lactation the average volume of milk secreted is 850 ml per day.[90] Human milk contains an average of 1.2 g of protein par 100 ml,[91] so the average daily secretion is 10 g of protein. Thus, the average N cost of lactation is 1.6 g per day.

TABLE 13. PREDICTED NITROGEN ACCRETION DURING PREGNANCY ASSUMING THAT THE FETUS WEIGHS 3.30 kg AT TERM

Stage of gestation	mg N/day [a]
First quarter	80
Second quarter	400
Third quarter	740
Fourth quarter	860

[a] These are approximate average figures from reference 37. The coefficient of variation is assumed to be 15%, so a value 30% higher should encompass nearly all healthy individuals in a normal population.

Information about the variability of milk secretion is limited. Since the secretion of milk is largely governed by the size of the infant at the breast, the variability in infant size gives an estimate of the probable variability in milk volume. From the data presented in Annex 1, the coefficient of variation of infant weights, and therefore milk secretion, would seem to be about 15%. Hence, an increase of 30% would be expected to cover requirements of all but those 2.5% of individuals with the highest requirements.

"Wet nurses" or women suckling more than one infant secrete an appreciably greater volume of milk than normal, and their protein requirements are increased proportionately.

6.1.2 *Balance studies*

Direct evidence on N requirements is obtained from measurements of the lowest protein intake at which N equilibrium can be achieved in adults or satisfactory growth and N retention in children.

(*a*) *Adults*. A representative but not exhaustive list of values reported for adults is shown in Table 14. In most of the studies protein was fed at several levels near the point of balance, and the estimated average requirement for balance was obtained by interpolation. The amounts of N required per unit of body weight to maintain N equilibrium in men and women are not substantially different.

Inspection of the values in Table 14 reveals considerable uniformity of requirement in persons fed with animal protein, the proteins of mixed

TABLE 14. AVERAGE NITROGEN INTAKES FOUND TO MAINTAIN NITROGEN BALANCE IN ADULTS [a]

Source of protein	Subjects	mg N per kg	Efficiency of N utilization [c]	Reference
Egg	9M	74	65	52
Egg	6M	76 (102) [b]	54 (41)	92
Milk	4–5F	68	70	93
Casein	6M	81	63	94
Mixed animal and plant				
42% cereal, 33% meat, 25% miscellaneous plant	10M+F	80	72	95
80% vegetable, 20% milk	7F	89	72	96
70% cereal, 28% milk and meat	10F	74	61	55
Mixed foods	4–5F	77	59	93
50% rice, 45% miscellaneous plant, 5% fish	18M	77	68	54
Plant				
Soya flour	4–5F	71	60	93
Algae (*Chlorella*)	5M	84	60	94
Yeast (*Torula*)	4M	110	50	94
Rice	10M	90 (135)	58 (32)	92
White flour	4–5F	117	40	93
64% White flour, 36% soya	4–5F	84	52	93
62% Cereal, 38% other plant	26M + F	98	64	95
75% Cereal, 25% other plant	6M + F	99	64	95
42% Cereal, 33% wheat germ, 25% other plant	6M + F	85	76	95
Wheat, corn, oats	29M + 8F	80–90		84
42% Cereal, 33% soya, 25% other plant	6M + F	107	59	95

[a] Recalculated from the original data using regression equations and positive balance of 5 mg of N per kg to allow for cutaneous and miscellaneous losses, which were not measured in most studies.

[b] Figures in parentheses found when subjects were fed at lower energy intake and lost weight.

[c] Utilization in these subjects as computed by the authors, either from the regression of N balance with N intake at several levels or as the product of observed biological value and digestibility (NPU). NPU values in rats will be found in Table 22 and reference 14.

diets, and soya beans. The average N intake required to maintain balance, allowing 5 mg of N per kg for cutaneous and miscellaneous losses, is 77mg of N per kg per day when the nitrogen is derived from milk, egg, casein, or mixed diets containing animal protein. This value represents the results for 75 subjects of both sexes. The average value for subjects consuming cereals or vegetable diets, based on data from 114 subjects, is 93 mg of N per kg. Somewhat higher values are recorded for diets in which all the protein came from white flour, rice, or yeast. It is important to note that while differences in N requirements do exist when proteins from different sources are fed to the adult, the magnitude of the differences is often less than might be expected from either amino acid scores developed on the basis of the requirements of children or from conventional biological assays of protein quality. This is discussed at greater lenghth in later sections of the report. It is also important to recognize that in the studies reported in Table 14 none of the proteins was used with 100% efficiency. This is in contradiction to the assumption of the previous committees that either a hypothetical protein [3] or egg protein [4] could be used with 100% efficiency. Again, the implications of this observation will be discussed in section 6.2.

The variation in the values recorded is probably due in part to the difference in amino acid composition. However, the inherent variability in studies of this kind, even under constant conditions, is relatively large. Calloway & Margen [52] reported a coefficient of variation of 22% in subjects fed on egg protein. In most of these studies, the number of subjects tested has been small. Another factor that undoubtedly contributes to the variability is that the conditions of testing were not uniform, particularly the prior diet that the subjects received, the length of time during which they received the low protein diets, and the energy content of the diets. There are also systematic procedural errors that summate to indicate falsely high N retention; [97] in addition, procedures differ somewhat between laboratories.

(*b*) *Infants and children.* In infants and young children the most useful criterion of an adequate N intake is a growth rate that meets accepted paediatric standards. Table 15, based on the studies of Fomon [98-101], shows the N intakes of normal children whose growth rate was satisfactory, together with measurements of N retention. In these studies the children's intakes were determined by appetite and composition of the formulas fed, and so the values reported do not necessarily represent the minimum requirement for growth. The values in the table are average intakes during each month for the first 6 months of life, recalculated from the references cited. The table clearly shows a decreasing requirement with increasing age, as evidenced by a decreased voluntary intake in infants. Fomon [99] concluded that at 4–6 months of age 240 mg of N per kg per day as human or cow's milk was enough to maintain normal growth in healthy infants. At this age soya bean protein supported the same N retention as did milk at similar intake levels.

From studies of growth rate, Gopalan [102] concluded that an intake of 320 mg of N per kg was adequate for the first 3 months of life and that an intake of 176 mg of N per kg was below the requirement of infants 6 months of age given human milk. Using growth rate and serum albumin concentra-

TABLE 15. NITROGEN INTAKE AND RETENTION IN HEALTHY INFANTS FED ACCORDING TO APPETITE AND WHOSE GROWTH RATES WERE NORMAL (VALUES ARE MEAN AND STANDARD DEVIATION, EXPRESSED AS mg PER kg BODY WEIGHT) [a]

Approximate age (months) [b]	Pasteurized human milk 1.1% protein		Cow's milk formula 1.03% protein	
	NI [a]	NR [a]	NI	NR
1/4–3/4	385 ± 49	184 ± 36	310 ± 48	157 ± 76
1	339 ± 49	151 ± 37	303 ± 50	143 ± 52
2	273 ± 46	109 ± 39	268 ± 39	115 ± 31
3	276 ± 30	107 ± 27	246 ± 48	96 ± 36
4	248 ± 23	83 ± 20	232 ± 28	83 ± 35
5	233 ± 24	58 ± 16	241 ± 31	82 ± 33
References	98		100	

[a] Values for nitrogen intake (NI) and retention (NR) were recalculated from the reference cited.
[b] There are no published data on N intake and retention of healthy infants over 6 months of age fed controlled diets. N intake of 4146 healthy US infants 6–8 months of age and living at home was 720 mg per kg according to a one-day record; [105] this is unquestionably higher than the average need.

tion as criteria, Fomon et al.[103, 104] judged N intakes of 338 ± 42 and 298 ± 38 mg per kg from cow's milk protein to be adequate for male infants aged 8–56 and 56–112 days respectively, but intakes of 282 ± 26 and 238 ± 34 mg per kg failed to satisfy these criteria. Lindner et al.[33] report the intake of healthy breastfed infants to be 320–415 mg of N per kg during the first 6 months.

In several studies on young children, protein was fed at different levels. This method could give a more precise estimate of needs. However, most of these studies have involved previously malnourished children whose height was less than expected for age and many of whom were growing at accelerated rates for age.[106-109] In some studies only N balance or regression equations were reported, without measurements of growth rate or any other specified criterion of adequacy. In Table 16 the Committee has recalculated some of these data, taking as criteria of adequacy the observed N retention of children receiving high-quality protein. The criteria selected for different age ranges were as follows :

4–17 months [106, 107]	retention of 91 mg of N per kg per day
Preschool [111]	retention of 70 mg of N per kg per day
3–7 years [110]	retention of 40 mg of N per kg per day

These criteria may overestimate the requirements at a given age, but the data provide an indication of the levels of intake that may be expected to produce adequate N retention.

The values derived for high-quality proteins fit in well with the observed intakes that maintain satisfactory growth and N retention in younger infants (Table 15). They show a continuing but slower decline in protein need with age. Soya bean protein appears to be equal to milk in supporting N balance, but other plant proteins are clearly inferior to milk or egg. However, a study of normal girls aged 7–9 years indicated an average requirement of 188 mg of N per kg when only plant protein was fed; N balance was 31 mg per kg.[119]

(c) *The physiological requirement for N.* Tables 14, 15, and 16 give the intakes of N shown to be just adequate to maintain equilibrium in adults and maximum growth and N retention in children. These are averages for groups of subjects, and hence should be directly comparable with the estimates of average obligatory N losses, plus growth increments (Table 12). Comparison of the tables shows that the lowest estimates of N requirement

TABLE 16. NITROGEN INTAKES THAT MET VARIOUS CRITERIA OF ADEQUACY WHEN FED TO PREVIOUSLY MALNOURISHED CHILDREN

Source of protein	Chronological age	Average N intake (mg per kg per day)	Criteria of adequacy	Ref.
Animal:				
cow's milk	4–17 months	382 [a]	Observed N retention 91 mg per kg	106, 107
cow's milk	6–24 months	200	Growth, observed daily N retention 82 mg per kg	108
egg	2–3 years	163	Observed N retention, growth	109
cow's milk	preschool	153 [a]	Calculated to 70 mg N retained per kg	111
cow's milk	3–7 years	147 [a]	Calculated to 40 mg N retained per kg	110
human milk	3–7 years	124 [a]	Calculated to 40 mg N retained per kg	110
Legumes and seeds:				
groundnut flour	4–17 months	557 [a]	Calculated to 91 mg N retained per kg	106, 107
cottonseed flour	4–17 months	586 [a]	Calculated to 91 mg N retained per kg	106, 107
soya bean products	3–7 years	142, 151 [a]	Calculated to 40 mg N retained per kg	110
groundnut flour	3–7 years	260 [a]	Calculated to 40 mg N retained per kg	110
cottonseed flour	3–7 years	256 [a]	Calculated to 40 mg N retained per kg	110
sesame flour	3–7 years	262 [a]	Calculated to 40 mg N retained par kg	110
Cereals or cereal-based:				
refined wheat	4–17 months	735 [a]	Calculated to 91 mg N retained per kg	106, 107
wheat- or rice-based:	2–5 years	320	Observed N retention 100 mg per kg	112
wheat	3–5 years	280	Observed N retention 40 mg per kg or more	113
maize	preschool	286 [a]	Calculated to 70 mg N retained per kg	111
cereal-based	8–12 years	250 [a]	Observed N retention 30 mg per kg or more	61, 62 114–118

[a] Values shown were recalculated from the references cited.

to obtain equilibrium in adults or satisfactory growth in children (i.e., estimates with proteins of the best quality) are consistently higher than the predictions of N requirement based on obligatory losses and growth, by a factor of about one-third. It is important to realize that this difference exists even when high-quality proteins, such as those of milk or eggs, are fed. The difference is greater than would be expected from a simple observation that in animal studies even high-quality proteins are not used with quite the 100% efficiency assumed by the previous Expert Group. This suggests that at equilibrium in adults and at near maximal growth rates in children, the efficiency of N utilization is appreciably lower than when protein intake is low, the usual assay condition.

Because protein requirements must meet conditions of N balance in adults and adequate growth in children, the results of N balance studies have been used to estimate requirements. However, no balance data are available at many ages, particularly for well nourished individuals fed egg or milk proteins exclusively. The factorial method provides an estimate of the relative magnitude and variability of the different components of obligatory N loss, and was used to interpolate requirements in those age groups for which direct estimates from balance studies are not available. The estimates of average requirements finally adopted for adults and children are the factorial calculations corrected by a factor of 1.3, which agree with the few directly determined values for milk and egg proteins. The recommendations for infants below 6 months of age are based solely on observed intakes of healthy infants fed *ad libitum*.

It is emphasized that the figures for requirements given in the present report are based on the actual feeding of proteins of high quality. This is in contrast to the reports of the previous two committees, which expressed their recommendations in terms of a hypothetical reference protein that was assumed to be completely utilized under all conditions. In order to calculate the amounts of a particular food protein that will be needed to meet requirements, a correction should be made for the quality of the protein relative to that of egg or milk. How this is done is described in sections 6.3 and 7.

6.2 Amino acid requirements and amino acid patterns

Although the essentiality of amino acids was recognized early in the present century, it was not until the 1930s, after Rose and his associates had discovered threonine, that diets containing only purified amino acids in place of dietary protein could be used to identify all the amino acids needed by man and to quantify amino acid requirements. For adult man it is now accepted that 8 amino acids are essential: isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine. The infant requires histidine as well as the above 8 amino acids; although it has not been shown that it can be synthesized by mammalian tissues, there is no evidence that adult man requires histidine. In spite of intense interest in the matter, present information about the precise quantitative amino acid requirements of man is much less complete than information about the total N requirement. Nevertheless, it is known that the pattern of amino acids in foods is one of the important factors influencing the total amount of protein required by man. Thus, a knowledge of the pattern of amino acid requirements at various ages is important for predicting the relative quality (utilization) of dietary proteins (see section 6.3). For this reason, the Committee reviewed the data available to it, considered the probable pattern of amino acid requirements, and derived a provisional scoring pattern for use in preliminary evaluations of protein quality, based on a knowledge of the amino acid composition of the dietary proteins. The Committee stresses the tentative nature of its recommendations, which are based on very incomplete information.

The previous committees who considered protein requirements also proposed scoring systems based on probable patterns of amino acid requirements. Subsequent investigations have added new information that has influenced the approach used in this report. Of particular concern to some investigators has been the apparent change with age in the proportion of dietary protein that must be supplied as essential amino acids (E/T ratio). Here too, information remains incomplete although it is now certain that the ratio does fall with age ; the magnitude and rate of the fall is not established.

Lacking precise information on both the average amino acid requirements and the variability of requirement between individuals, the Committee related estimates of the upper range of amino acid requirement to the upper range of individual protein requirement (the safe level of intake of egg or milk protein, Table 23). This method was the most appropriate for use in view of the sparse information available, although it was recognized that it had major shortcomings. It is to be hoped that future committees may have available more precise information on average amino acid requirements, the variability of amino acid requirements, the interactions between amino acid requirements, the effects of total N intake on amino acid requirements, and the influence of other factors on the requirements for individual amino acids. Undoubtedly there are many uncontrolled variables in the studies from which the information used in this report has been drawn.

6.2.1 *Estimated amino acid requirements of adults*

Table 17 summarizes some of the information on adult amino acid requirements. The figures for men were derived from studies in which the criterion of adequacy was the attainment of a positive nitrogen balance. In the studies on women a positive balance was not necessarily attained ; the authors accepted a balance of $0 \pm 5\%$ of intake as a criterion of adequacy.

In both cases, the specific values shown are the lowest intakes tested that met the criterion of adequacy for all the subjects studied; these levels represent estimates of the upper range of individual amino acid requirements. The significance of the difference between the criterion of adequacy used for men and that used for women is illustrated by the recalculation of some of the data for women. Hegsted [122] applied regression analysis to the data to obtain estimates of the average requirements of women; the results are shown in Table 17. Comparison of the original estimates and the recalculated values would suggest that the original studies may have underestimated the true upper range of the requirements for women. It is important to recognize that these studies have not made any allowance for dermal losses of nitrogen and may constitute low estimates for that reason too.

Figures for the possible amino acid requirements per kg of body weight are shown in Table 17. These have been converted to mg of amino acid per g of protein by using the average safe level of protein intake for men and women, 0.55 g/kg.

TABLE 17. ESTIMATED AMINO ACID REQUIREMENTS OF ADULTS

Amino acid	Some reported amino acid requirements (mg per day)			Combined adult value [d] (mg per kg per day)	Suggested pattern [e] (mg per g protein)
	Men [a]	Women			
		Observed [b]	Recalculated [c]		
Histidine	0	0	0	0	0
Isoleucine	700	450	550	10	18
Leucine	1 100	710	730	14	25
Lysine	800	700	545	12	22
Methionine + cystine	1 100	550	700	13	24
Phenylalanine + tyrosine	1 100	700	—	14	25
Threonine	500	310	375	7	13
Tryptophan	250	160	168	3.5	6.5
Valine	800	650	622	10	18

[a] Taken from Rose. [120] The values represent the highest estimate of individual requirement to achieve positive nitrogen balance.

[b] Taken from Leverton, Swendseid, Jones, Reynolds, Clark, Linksweiler, Burrill and their coworkers (the references have been summarized by Irwin & Hegsted [121]). The values represent the highest estimate of individual requirement to achieve the zone of nitrogen equilibrium (balance of $0 \pm 5\%$ of intake).

[c] Data of some of the above authors recalculated by Hegsted [122] using regression analysis to estimate the average requirement to achieve nitrogen equilibrium.

[d] Derived estimate emphasizing the upper range of individual requirements.

[e] Assuming a safe level of protein intake of 0.55 g per kg per day (averaged value for men and women).

6.2.2 *Estimated amino acid requirements of infants*

Two types of information have been used in arriving at the estimates of the amino acid requirements of infants in Table 18. Holt & Snyderman [123] have reported studies on the amounts of individual amino acids required to

TABLE 18. ESTIMATED AMINO ACID REQUIREMENTS OF INFANTS

Amino acid	Estimated requirements		Composite of lower values (mg per kg per day)	Suggested pattern [c] (mg per g of protein)
	Holt & Synderman [a] (mg per kg per day)	Fomon & Filer [b] (mg per kg per day)		
Histidine	34	28	28	14
Isoleucine	119	70	70	35
Leucine	229	161	161	80
Lysine	103	161	103	52
Methionine + cystine	45 + Cys	58 [d]	58	29
Phenylalanine + tyrosine	90 + Tyr	125 [d]	125	63
Threonine	87	116	87	44
Tryptophan	22	17	17	8.5
Valine	105	93	93	47

[a] Requirements estimated when amino acids were fed or incorporated in basal formulas. The values represent estimates of maximal individual requirements to achieve normal growth. [123]

[b] Calculated intakes of amino acids when formulas were fed in amounts sufficient to maintain good growth in all the infants studied ; the amino acids were not varied independently. [124]

[c] Based on a safe level of intake of 2 g protein per kg per day, the average of suggested levels for the period 0–6 months.

[d] The values for cystine and tyrosine were estimated on the basis of the methionine : cystine and phenylalanine : tyrosine ratios in human milk (see Table 20).

achieve normal growth in young infants. The values shown in the table represent the lowest level of intake that was adequate for all the infants tested. In a different type of study, Fomon & Filer [124] calculated the intakes of amino acids by infants fed a variety of formulas at levels that maintained adequate growth. The values shown in the table represent the lowest intake that had been demonstrated to maintain growth in all the infants studied. In general, there is good agreement between the two sets of estimates. In considering the two studies, the Committee accepted that a composite of the lower estimates of the two sets of data would provide an estimate of the upper range of amino acid requirements of infants aged 0–6 months. The estimates of requirements per kg of body weight were converted to mg of amino acid per g of protein on the basis that the average safe level of intake of milk protein appeared to be about 2 g per kg over this age range.

6.2.3 *Estimated amino acid requirements of children*

Nakagawa et al.[125-128] have examined the amino acid requirements of boys aged 10–12 years. Their observations on the lowest amount of amino acid demonstrated to bring all subjects into positive N balance are shown in Table 19. These workers also demonstrated that such levels of intake were adequate, or more than adequate, for girls of comparable age. To

TABLE 19. ESTIMATED AMINO ACID REQUIREMENTS OF CHILDREN

Amino acid	Schoolchildren, 10–12 years	
	Observed requirement [a] (mg per kg per day)	Suggested pattern [b] (mg per g of protein)
Histidine	0	0
Isoleucine	30	37
Leucine	45	56
Lysine	60	75
Methione + cystine	27	34
Phenylalanine + tyrosine	27	34
Threonine	35	44
Tryptophan	4	4.6
Valine	33	41

[a] Based on Nakagawa et al.[125-128] The values represent estimates of the upper range of individual requirements for the achievement of positive nitrogen balance in boys.

[b] Based on a safe level of protein intake of 0.8 g per kg per day, the average of safe levels of protein for boys and girls in that age group.

convert these requirements into concentrations in protein, the safe level of intake for this age was taken as 0.8 g per kg. It should be noted that this was much less than the actual levels fed in the original study; as in many of the other studies of amino acid requirements, total protein (N) intakes were kept quite high.

6.2.4 *Amino acid patterns*

In Table 20, the derived patterns of amino acid requirements, expressed per g of protein, are compared with the concentrations of these amino acids in egg and milk protein and with the 1957 FAO provisional pattern. As would be expected, the derived pattern of requirement for infants closely resembles the reported composition of breast milk. The Committee agreed that for infants, breast milk was the appropriate food and that the amino acid requirements of infants should be excluded from the application of any tentative guide to protein scoring that might be developed for older children and adults.

The data on composition reported in the table imply that while the amino acid requirements of children and adults bear a general resemblance to the relative concentrations of the amino acids in egg and milk protein, neither food protein provides an entirely satisfactory reference pattern. It was recognized also that if either natural protein were to be selected as a reference standard, it would still be necessary to define a specific composition, since the amino acid content of these proteins varies from one report to another. The Committee therefore saw a limited advantage in the adoption of a natural protein as a reference pattern of amino acid requirements, but for the purposes of biological testing either protein would seem to be suitable as a reference standard.

The estimates of requirements presented in Table 20 show considerable consistency in the relative amounts of the various amino acids that appear

TABLE 20. COMPARISON OF SUGGESTED PATTERNS OF AMINO ACID REQUIREMENTS WITH THE COMPOSITION OF MILK AND EGG PROTEIN
(mg per g of protein)

Amino acid	Suggested patterns of requirement [a]			1957 FAO pattern	Reported composition			
	Infant	School-child 10–12 years	Adult		Human milk: Range [b]	Human milk: Mean	Cow's milk [c]	Egg [d]
Histidine	14	—	—	—	18– 36	26	27	22
Isoleucine	35	37	18	42	41– 53	46	47	54
Leucine	80	56	25	48	83–107	93	95	86
Lysine	52	75	22	42	53– 76	66	78	70
Methionine + cystine	29	34	24	42	29– 60	42	33	57
Phenylalanine + tyrosine	63	34	25	56	68–118	72	102	93
Threonine	44	44	13	28	40– 45	43	44	47
Tryptophan	8.5	4.6	6.5	14	16– 17	17	14	17
Valine	47	41	18	42	44– 77	55	64	66
Total								
+ histidine	373				408–588	460	504	512
— histidine		326	152	314	390–552	434	477	490

[a] See preceding tables. There is no evidence for or against a histidine requirement for young children.
[b] Compositions reported by FAO,[14] Lindner et al.,[33] and Soupart et al.[129]
[c] Composition reported by FAO;[14] value for tryptophan by microbiological assay.
[d] Composition reported by Lunven et al.[130]

to be required at various ages, but there are some inconsistencies. Whether these differences are attributable to true age-dependent differences in the requirements for individual amino acids or to differences in methodology is not known. Present information is insufficient to provide precise figures for requirements.

However, it is apparent from the table that the adult requirement for total essential amino acids falls more sharply than does the protein requirement. Thus, the proportion of total amino acids that must be supplied as essential amino acids (the E/T ratio) falls with age. The apparent E/T ratio derived in the manner adopted in the present report must be interpreted with caution. There have been only a few studies, conducted in adults, that have examined this phenomenon by direct dilution of egg protein with nitrogen sources free of essential amino acids. These studies confirm that the E/T ratio of egg protein is considerably higher than is required by the adult, but they do not establish that the ratio is as low as would be implied in Table 20, nor are there studies that directly examine the rate at which the E/T ratio falls with age.

The significance of this problem must be emphasized. The observation that the E/T ratio falls with age implies that an evaluation of protein quality based on the amino acid requirements (and E/T ratio) of infants or young children may underestimate the effectiveness of that protein in meeting adult requirements. This is consistent with the observation that many cereal proteins appear to be somewhat better utilized by the adult than would be predicted from conventional methods of assessing protein quality (see section 6.1.2), while agreement between predicted and observed utilization is much better in the case of infants and young children. However, in the absence of more precise data it was not possible to offer specific corrections for evaluations appropriate to particular ages. Rather, it was the opinion of the Committee that since protein quality was most critical in the young age groups, scoring patterns appropriate to those age groups should be employed.

The report of the Joint FAO/WHO Expert Group on Protein Requirements [4] drew attention to the problem presented by the E/T ratio and the absence of direct information that would establish the rate of change with age, and it therefore recommended that proteins be scored on the basis of the ratio of individual amino acids to total essential amino acids without fixing the E/T ratio. The present Committee was aware of the practical disadvantage of this method, which required analysis of all the essential amino acids of a protein before any one amino acid could be scored.

6.2.5 *Provisional scoring pattern*

There is abundant evidence of a relationship between amino acid composition and various measures of protein quality. It is certain that proteins that are adequate in composition to meet the needs of young children will also be adequate for adults, whereas the reverse may not be true. The Committee was in unanimous agreement that any scoring pattern suggested should be designed to meet the needs of children in the preschool age group but not those of infants.

However, at least two distinctly different approaches can be made to derive such a scoring pattern. The Committee was not unanimous as to which approach should be followed. On the one hand there is now a large volume of data, based largely on rat studies but with supporting human studies, concerning the NPU values of various food proteins and diets. Taken together, these data can be used to adjust the amino acid pattern so that chemical scores and NPU values are in reasonably good agreement, and the score becomes a predictor of NPU. On the other hand the amino acid pattern can be based primarily on the estimates of human amino acid requirements, expressed in proportion to the safe level of protein intake, as described in the previous section. Because of the way in which estimates of protein requirements have been derived (based on egg and milk rather than on a theoretical protein of NPU = 100), the scores so designed are not directly comparable with the absolute NPU ; they should be compared only with the relative NPU. The majority opinion of the Committee was that the scoring pattern should be based, as far as possible, on a knowledge of human amino acid requirements as outlined in the following pages, but a minority maintained that the scoring pattern should closely predict the observed NPU. It should be noted that these two approaches yield different levels of certain amino acids in the pattern. The approach adopted in the report, which is based on the majority opinion, gives a higher estimation of quality for many proteins than does the direct approach favoured by the minority. The level of methionine + cystine is the value that shows the greatest difference. The provisional pattern is shown in Table 21. Its application is discussed in section 6.3.1.

This provisional pattern is based on the derived estimates of amino acid requirements shown in Table 20. Consideration was also given to the amounts of amino acids contributed by milk and various cereal proteins when fed at levels adequate for the normal growth of young children.[112, 113] The pattern was then adjusted in the light of experience gained in the application of the 1957 FAO reference pattern of amino acids. In comparison with the 1957 pattern, significant changes included a lowering of tryptophan and methionine.[4] Threonine levels were raised. Lysine levels were raised in accordance with the suggestion that scores for lysine-limited foods overestimated the actual nutritive value of these proteins when fed to young children ; estimation of lysine requirements is complicated by the fact that not all chemically determined lysine in a food is necessarily biologically available.

The Committee draws attention to the provisional nature of this pattern, which is based upon very incomplete information. The pattern must be subject to further modification as additional information becomes available.

The E/T ratio of this pattern (360 mg of essential amino acids per g of protein ; 2.25 g of essential amino acids per g of N) is comparable with that suggested for infants, a fact consistent with the belief that the young child requires a high concentration of essential amino acids. It is somewhat higher than the estimate for older children and also above the experimentally derived values for the E/T ratio for adults,[131] which are appreciably higher than the figures derived from the theoretical consideration of adult amino acid requirements (Table 20). The proposed pattern has an E/T ratio moderately higher than the 1957 FAO pattern.

In the absence of specific information, the Committee assumes that pregnant and lactating women have amino acid requirements more closely resembling the pattern in young children than that in non-pregnant, non-lactating adults.

While there may be an overestimation of adult protein requirements when this pattern is applied, the Committee does not consider this to be of major practical significance. However, the Committee cautions that the pattern is not intended to cover the needs of very young infants ; histidine would have to be included, and adjustments of other levels might be required.

6.3 Evaluation of dietary protein quality

The efficiency with which a protein is used for growth or maintenance is a measure of its quality. The quality of a protein is determined in the first place by its amino acid composition, but other factors now to be discussed also affect protein utilization.

The quantity of protein obtained from a diet depends on the amount of food consumed and on the protein content of the food. Foods with a low protein content may provide useful amounts of protein if consumed in sufficient quantity, but as the amount of food eaten is determined largely by the requirement for energy rather than by the requirement for protein (except in the case of protein deficiency, which may induce anorexia), consumption of these foods may be curtailed before enough is eaten to meet the protein requirement. For example, if the protein and energy requirements of a child aged 18 months are taken as 14.5 g of egg protein or its equivalent (safe level of intake) and 1180 kcal (4.9 MJ) per day, it is possible to consider what will happen when a food such as cassava is offered. Cassava provides 1.2 g of protein and 338 kcal (1.41 MJ) of energy per 100 g. When energy requirements have been fully met by 350 g of cassava, the intake of protein would be 5.25 g. In this situation the child cannot be expected to eat enough of the food to meet his protein requirement, irrespective of the quality of the protein.

The concentration of protein in foodstuffs is obtained by multiplying the N content by 6.25, since most proteins contain about 16% nitrogen. The value so obtained is designated "crude protein" and includes not only the N of protein and amino acids but also a variable quantity, usually small, of other non-protein N. Some proteins contain more or less than 16% N so factors other than 6.25 have been used in calculating the protein content of these (see Annex 3). The actual protein content of foodstuffs is rarely known. Since estimates of "protein requirements" are based only on measurements of N intake and excretion, it is recommended that a constant factor of 6.25 be used in all calculations concerning protein requirements or the evaluation of protein quality. All values in this report refer to crude protein (N $\times$ 6.25), irrespective of the food sources.

The dietary amino acids are not necessarily all available to the body. Availability is reduced when either digestion or absorption is incomplete. Usually over 90% of the amino acids of animal proteins are absorbed, but the value may be 80% or even less for the amino acids from some proteins of vegetable origin.

The availability of the amino acids of food proteins may be reduced as a result of excessive heat-processing, as may happen in the production of milk powder, meat meal, fish-protein concentrates, oil-seed meals, and protein-enriched biscuits. This is most likely to occur in a carbohydrate-rich food and to affect lysine and the sulfur-containing amino acids. However, home cooking and commercial canning methods usually cause little or no loss.

As changes in amino acid availability may occur with little change in amino acid composition as determined by chemical methods, the use of biological tests of protein quality continues to be necessary.

Evidence of an imbalance in the pattern of amino acids may also be revealed by biological tests. The results of animal experiments indicate that the main effect of amino acid imbalances is to reduce food intake.[132] However, there is at least one recognized example in man of the effect of an excess of one essential amino acid being to increase the requirement for another essential amino acid: the high leucine content of sorghum[133] and maize[134] apparently increases the need for tryptophan and isoleucine.

6.3.1 *Amino acid score (chemical score)*

The quality of a protein may be estimated from its amino acid composition as compared with the reference pattern of amino acids (Table 21). Block & Mitchell[135] suggested that since all amino acids must be present at the site of protein synthesis in adequate amounts for protein synthesis to proceed, an equal percentage deficit of any essential amino acid would limit protein synthesis to a comparable degree. Thus, if the compostion of an "ideal protein", i.e., one containing all the essential amino acids in sufficient amounts to meet requirements without any excess, were known, then it should be possible to compute the nutritive quality of a protein by calculating the deficit of each essential amino acid from the amount in the

TABLE 21. PROVISIONAL AMINO ACID SCORING PATTERN

Amino acid	Suggested level	
	mg per g of protein	mg per g of nitrogen
Isoleucine	40	250
Leucine	70	440
Lysine	55	340
Methionine + cystine	35	220
Phenylalanine + tyrosine	60	380
Threonine	40	250
Tryptophan	10	60
Valine	50	310
Total	360	2 250

"ideal protein". The "most limiting amino acid", i.e., the one in greatest deficit, would presumably determine the nutritive value. In practice they suggested the protein of whole egg as the "ideal", since this was known to have a biological value closely approaching 100. Block & Mitchell compared biological values with "amino acid deficits" calculated using egg protein as a standard. A high correlation between the two suggested that the procedure was valid.

Since that time amino acid scores have been much used. Generally they have been calculated as the "percentage of adequacy" rather than as deficits as suggested by Block & Mitchell. The new scoring pattern given in Table 21 is considered preferable to the use of the protein of whole egg or human milk. The amino acid score of a protein or mixture of proteins is calculated as follows :

$$\text{Amino acid score} = \frac{\text{mg of amino acid in 1 g of test protein}}{\text{mg of amino acid in reference pattern}} \times 100$$

Provided that the lowest score obtained for any of the essential amino acids is used (i.e., the "most limiting amino acid"), the score may be taken as a first approximation to the probable efficiency of utilization of the test protein or mixture by children and may permit a rough correction of protein requirement for the quality of dietary protein. This score may underestimate the quality of the protein for adults, whose essential amino acid needs per g of protein are lower (see section 6.2.5). Although certain proteins may yield an apparent score above 100, the value cannot be used to adjust dietary protein requirements, since N intakes would then be less than required to meet N requirements. The predicted dietary requirement equals the safe level of intake of egg or milk protein multiplied by 100 and divided by the amino acid score.

So far, only scores based on the amounts of lysine, total sulfur-containing amino acids, or tryptophan have been subjected to adequate biological testing, since these are the amino acids found to be first limiting in most foods and diets. In practice, for calculating the scores of ordinary foodstuffs, only those 3 amino acids may need to be considered. A knowledge of the entire pattern is useful in predicting the second and third limiting amino acids. Such predictions require biological confirmation until reliable information about the availability of the other essential amino acids is obtained. Table 22 shows scores for common foods calculated according to the new pattern.

6.3.2 *Biological evaluation*

Protein quality may be evaluated by a biological test of N utilization. Many procedures have been tried, but the one most used now is the determination of NPU ; this is the proportion of ingested N that is retained in the body under specified conditions. NPU is a combined measure of digestibility and of the efficiency of utilization of the absorbed amino acids. In some tests the digestibility and retention of absorbed nitrogen are evaluated separately, the latter being termed biological value (BV).

These methods have been criticized. First, some dietary proteins totally lacking in one or more essential amino acids still show a measureable NPU or BV in rats. Secondly, it is costly and time-consuming to determine the NPU and BV of a food in experiments on man, and few centres are equipped to do so. Ethical considerations prohibit the deliberate limiting of infants' and children's development. Therefore, most estimations are made using growing rats, whose amino acid requirements are different and, in general, higher than human needs. This has the effect of underestimating the quality of some proteins for man. However, results using the two species do rank proteins in the same order as regards quality ; quantitatively, agreement is better for the growing subject than for the adult.

NPU values used to assess the nutritional quality of proteins are ordinarily determined under conditions in which the intake of protein limits the growth to an appreciable extent or, in the adult, results in a distinctly negative N balance. NPU values tend to fall as the intake of protein is increased. In the present report it is accepted that in man no protein is utilized with 100% efficiency when fed at a level that will maintain N equilibrium in the adult or adequate growth in the child.

Since the Committee has made its recommendations in terms of the intake of egg or milk protein that will meet N requirements, it is necessary to consider the NPU of other proteins in comparison with that of milk or egg protein in estimating the amounts of those proteins that would be required to meet human requirements. Since, as noted above, the observed value of NPU may change with the experimental conditions, it is important that the NPU values of egg or milk and the test protein be established under identical conditions for valid comparisons.

The safe level of intake of food protein would be predicted from the formula :

$$\frac{\text{NPU of egg or milk}}{\text{NPU of test food}} \times \text{Safe level of intake of egg or milk protein}$$

When the rat is used as the test organism, the Committee recommends that egg rather than milk be the reference protein for assay purposes. The Committee specifically notes that a correction of this type should not be applied to its suggestions concerning the protein requirements of young infants, for whom breast feeding has been assumed.

Other biological methods that have been used include the protein efficiency ratio (PER). This is defined as the weight gain of a growing animal divided by its protein intake. The PER has been determined chiefly in feeding experiments on small animals but is also of value in studies on human infants. It is the simplest method of determining quality, since it requires no chemical measurements. However, PER has been criticized as a measure of protein quality,[136-138] since the values are not directly proportional to the nutritive quality of the proteins tested. This means that a protein with a PER of 1.5 cannot be assumed to have 50% of the value of a protein with a PER of 3.0.

A variety of other methods of evaluating protein quality with experimental animals or human subjects have been developed and suggested to be of value. These methods include the net protein ratio,[139] the relative nutritive value,[140] and the nitrogen balance index,[141] as well as changes in plasma amino acids ratios,[142] the regeneration of tissues in animals,[143-146] and microbiological tests.[147-150]

6.3.3 *Comments on protein evaluation*

A distinction has to be made between protein quality, which is an attribute of the protein *per se*, depending mainly on its amino acid pattern, and the efficiency of utilization, which depends on both the quality and quantity of protein in the diet and the adequacy of the total diet, as well as on environmental conditions and the age and physiological state of the recipient. As the efficiency of protein utilization is reduced if the energy intake is too low or if the protein is fed in too large amounts, measurements of NPU should be made under standardized conditions, i.e., with proteins fed to adults below maintenance levels, or to growing animals at levels that limit growth to about half the maximum rate, in a diet supplying adequate quantities of energy and other nutrients. Such measurements give maximal values and can be used to compare the quality of proteins. A detailed discussion of methods will be found in the United States National Research Council's publication, *Evaluation of protein quality*.[151]

In contrast, if the NPU of the proteins in a mixed diet, e.g., a weaning food, is measured, the values obtained are subject to the influence of other dietary factors present (e.g., fibre, trace minerals, non-nutrient substances) and may not be as high as would be obtained under standardized conditions. Further, if the measurements are made at or above a level of intake at which requirements are met, then protein is no longer the limiting factor in the diet; the resulting values are low and do not reflect the quality of the protein *per se*. Although these lower values may be meaningful estimates under conditions of actual use, they will not be suitable for the evaluation of foods under development. The Committee recognizes that conventionally measured NPU values may overestimate amounts of dietary protein for adults, but a margin of safety is deemed necessary in view of the needs of young children and perhaps pregnant women.

Selected values for the chemical score and NPU obtained in children and young rats are shown in Table 22. Direct comparison of the values is not possible since, as stated above, the chemical scores should be compared with the ratio

$$\frac{\text{NPU of test food}}{\text{NPU of egg or milk}}$$

determined under the same assay conditions at the same time; the corrected values would be somewhat higher than the NPU values shown. Nevertheless, the reported values show an agreement consistent with the general concept that the content of essential amino acids determines protein quality. However, there are significant variations in the amino acid content (and availability) that would affect the amino acid scores and biological evaluations. The scores shown in Table 22 are based on average composition. These and the NPU values are subject to both biological and methodological variability.

6.4 Factors influencing protein requirements

6.4.1 *Stress*

In the 1965 report on protein requirements[4] an allowance of 10% was added to the estimated obligatory losses and growth increments to compensate for the effects of ordinary sources of stress in daily life, such as minor infections and trauma, pain, anxiety and loss of sleep. As the information on obligatory losses in urine and faeces is obtained from studies in individuals going about their normal activities, there is no doubt that they are exposed to such stresses. All studies indicate a coefficient of variation of the order of 15%, which presumably includes the effects of the minor

TABLE 22. CHEMICAL SCORE AND NET PROTEIN UTILIZATION VALUES OF COMMON FOODS

Protein	New pattern chemical score [a]	Net protein utilization						
		% of energy from protein						
		2–3	4–5	6–7	8–10	11–14	18–21	
		Children aged 3–7 years [113]						*Rats* [b]
Whole egg	100	87						94 ± 4 [14]
Human milk	100	95	85	95				87 [152]
Cow's milk	95	81	79	81	74			82 ± 4 [14]
Soya bean	74							65 ± 7 [14]
milk		78	76	75				
flour				54				
toasted grits		72	80	67	71			
Sesame	50			*54*		*53*		*54*; [153] 54 ± 1 [14]
Groundnut	65			57		*53*	*52*	*47*; [153] 47 ± 6 [14]
Cottonseed	81			*41*		*47*	*38*	*59*; [153] 54 ± 10 [14]
		Children aged 8–12 years						*Rats* [b]
Maize	49					36 [62]		52 ± 6 [14]
Millet	63					43 [154]		44 (12%) [155]
Rice, polished	67				63 [61]			59 ± 4 [14]
Wheat, whole	53					49 [114]		48 ± 9 [14]

[a] Pattern given in Table 21. Calculated as amino acid in test protein divided by amino acid in reference pattern and multiplied by 100 (compositions taken from reference 14).

[b] Rat values measured at or adjusted to 10% of dietary energy from protein. Values from reference 14 are the mean and standard deviation of the tabulated experimental means from different studies.

stressful experiences of everyday life. For this reason the allowance for variation is now 30% instead of the 20% used previously, and no additional correction for stress is required.

6.4.2 *Heat*

Unacclimatized individuals can lose additional N in sweat when exposed to a high environmental temperature. For the reasons discussed in section 6.1.1, however, it is not likely that these estimates apply to populations adapted to hot environments. The N lost as sweat is less in fully adapted individuals, and there is evidence of urinary compensation for some of this N. However, this compensation is probably not complete when sweating rates are high, e.g., in heavy physical work, and there may then be an increment in total N loss. No exact estimate of this can be made in the present state of knowledge, but the amount is thought to be small.

6.4.3 *Heavy work*

Since energy needs are increased by physical work, total food intake is consequently greater and normally there is an increased intake of protein. Yet there is no satisfactory evidence of increased protein need as a result of increased physical activity *per se*. However, athletes in training and others who increase their physical activity also increase their muscle mass and so need some additional protein during this period.[156, 157] The amount needed is not likely not be large.

Yoshimura et al.[157-159] have reported decreased haemoglobin and serum proteins in subjects performing very heavy treadmill exercise when consuming 1 g of protein per kg of body weight. This may well have been a temporary result of stress during training, but the changes were not seen if the diet provided 2.5 g of protein per kg of body weight.

A review by Keller & Kraut[160] quotes several examples in Germany where the capacity for work appears to be related to protein intake and a daily intake of over 1 g of protein per kg of body weight for heavy workers is recommended. It is difficult to be certain that other factors besides the additional protein intake were not, at least in part, responsible for the improved performance. The German recommendation may lack physiological support, but is probably sound industrial practice.

6.4.4 *Energy intake*

All estimates of protein requirements are valid only when energy requirements are fully met. When the total energy intake is inadequate, some dietary protein is used for energy and is not available to satisfy protein needs. The further increasing of protein intakes to meet safe levels is of limited effectiveness, and wasteful if energy needs are not met at the same time.

6.4.5 *Infection*

Infections affect protein requirements by inducing some degree of depletion of body N during acute episodes. Infections increase N losses as a result of the increased urinary excretion secondary to increased adrenocortical activity, and often as a result of interference with intestinal absorption, especially during bouts of diarrhoea. At the same time protein intake is generally reduced owing to anorexia, and often owing to improper therapeutic practices. Every grade of response occurs. Very mild infections that do not cause a detectable febrile response or systemic reactions may be associated with a period of negative nitrogen balance.[161, 162] These losses cannot be prevented by feeding protein-rich diets while the infection persists, but they need to be replaced by an adequate intake later. During recovery persons retain additional N for periods much longer than those during which the depletion occurred.[163] The same considerations do not necessarily apply to chronic infections, because of various adaptive mechanisms.

The quantitative effects of infections on the protein needs of an individual cannot be stated, since they are likely to vary with the frequency, severity, and nature of the infection and other host factors, including nutritional status. Since the negative N balance is lower in malnourished individuals, the consequences of the extra N loss may be more serious. Apart from protein, infections may also modify requirements for energy and for other nutrients.

6.5 The safe level of intake of egg or milk protein

In section 6.1 estimates were made of the average physiological requirements for N. The procedure used involved two steps : the first consisted of quantifying as accurately as possible (*a*) all the obligatory losses of N when a protein-free diet is eaten and (*b*) the amounts of N laid down during growth or pregnancy or secreted in milk during lactation. Secondly, the factorial values were increased by 30% in recognition of the fact that even with an excellent protein source, such as milk or egg, larger amounts of N are needed to secure N equilibrium or maintain growth than the amount calculated by the factorial method. Since the empirical factor of 30% was applied in estimating the N requirements for both the maintenance of adults and the growth of children, the same factor was used in estimating the additional N needs in pregnancy and lactation. Thus, the amount given by the factorial method has been increased by 30% to obtain the final values for physiological N requirements for all healthy people except infants less than 6 months of age. These values are accepted by the Committee as the best available estimates of the average N requirement when high-quality protein is fed to children above 6 months of age and to healthy adults (Table 23, column B). For infants below 6 months of age, the requirement is based on the observed intake of infants fed on breast milk.

The values so obtained are estimates of the average physiological requirement. To derive safe levels of N intake, an allowance is needed for individual variation. From the evidence discussed in section 6.1 the Committee concluded that the requirements for maintenance and growth, including pregnancy and lactation, have about the same coefficient of variation, approximately 15%. A value that is 30% above the average would thus cover the needs of the great majority of individuals (Table 23, column C).

The factor 6.25 is then applied to convert the safe levels of N intake to safe levels of protein intake, expressed in terms of milk or egg protein, as recommended by the Committee. It is emphasized that these are not estimates of average requirements but estimates of the upper range of individual requirements (only 2.5% of individuals might be expected to have physiological requirements above these levels).

The safe levels of protein intake in terms of egg or milk derived in this way for persons over 6 months of age are set out in column D of Table 23. The derived estimates for infants over 6 months of age tend to be slightly higher than the observed intakes that allow satisfactory growth and N

TABLE 23. SAFE LEVELS OF INTAKE OF EGG OR MILK PROTEIN

Age	A		B		C		D	
	Total nitrogen requirements – obligatory losses and growth (mg nitrogen per kg per day)		Adjusted nitrogen requirements – increased by 30% in accordance with balance and growth data (mg nitrogen per kg per day)		Safe level of intake (adjusted requirement + 30% to allow for individual variability) (mg nitrogen per kg per day)		Safe level of intake (adjusted requirement + 30% to allow for individual variability) (g protein per kg per day)	
(Months)								
< 3					384 [a]		2.40 [a]	
3–6					96 [a]		1.85 [a]	
6–9	154		200		260		1.62	
9–11	136		177		230		1.44	
(Years)								
1	120		156		203		1.27	
2	112		146		190		1.19	
3	106		138		179		1.12	
4	100		130		169		1.06	
5	96		125		162		1.01	
6	92		120		156		0.98	
7	88		114		148		0.92	
8	83		108		140		0.87	
9	80		104		135		0.85	
	M	F	M	F	M	F	M	F
10	78	77	101	100	132	130	0.82	0.81
11	77	72	100	94	130	122	0.81	0.76
12	74	70	96	91	125	118	0.78	0.74
13	73	64	95	83	123	108	0.77	0.68
14	68	59	88	77	115	100	0.72	0.62
15	63	56	82	73	107	95	0.67	0.59
16	61	55	79	71	103	93	0.64	0.58
17	58	54	75	70	98	91	0.61	0.57
Adult	54	49	70	64	91	83	0.57	0.52

[a] Based on observed intakes (mean + 2 standard deviations) of healthy infants. [100]

retention in previously malnourished individuals and are intended to provide for the full range of individual variability.

For infants up to 6 months, reliable data are available on the actual intakes of breast milk or cow's milk that support satisfactory growth (see Table 15). These values are accepted for young infants and are included in Table 23. The additional protein estimated to be needed during pregnancy and lactation, as calculated from fetal tissue composition and breast milk composition, is shown in Table 24.

TABLE 24. ADDITIONAL REQUIREMENT FOR EGG OR MILK PROTEIN DURING PREGNANCY AND LACTATION [a]

		Average N increment or loss (mg N per day)	Adjusted (+ 30%) for utilization of dietary protein (mg N per day)	Adjusted (+ 30%) for individual variability: safe level of intake [b]	
				(mg N per day)	(g protein per day)
Pregnancy:	1st quarter	80	104	135	1
	2nd quarter	400	520	675	4
	3rd quarter	740	960	1 250	8
	4th quarter	860	1 120	1 460	9
Lactation:	1st 6 months	1 600 [c]	2 080	2 700	17

[a] To be added to the predicted safe level of daily intake of egg or milk protein derived from Table 23.

[b] Expressed as egg or milk protein; must be adjusted for quality of dietary protein.

[c] Nitrogen content of milk secreted per day.

In practice, it is probable that all persons except young infants consume diets with proteins that are less well utilized, at least by children, than are egg or milk protein. While this may not be true in all cases for adults, who seem to be less sensitive to apparent changes in protein quality as conventionally measured, the Committee recognizes that the safe levels of protein intake suggested in Table 23 must be adjusted in accordance with estimates of the quality of the protein consumed for most of the age and sex categories. In the absence of precise methods for adjusting the correction for various age groups and in view of the practicalities of applying its recommendations, the Committee considers it advisable to apply the same correction to adult requirements as to children's. The method of adjusting the safe levels of intake for protein quality is discussed in section 7.2.

6.6 Adjustments for the quality of protein in the diet

The safe levels of intake of protein given in Tables 23 and 24 are expressed in terms of egg or milk proteins, whereas the previous report [4] used the concept of a "reference protein", a hypothetical protein assumed to be

100% utilizable. When these figures are being used for assessing needs in terms of dietary protein, a correction for protein quality may be necessary for some age groups and some diets (see section 6.3.)

Diets ordinarily contain a mixture of proteins that usually have complementary patterns of amino acids (e.g., rice and fish, maize and beans), so that the quality of the dietary mixture is better than that of the proteins of the individual foodstuffs. Mixtures of plant and animal proteins tested have proved not to be different from egg or milk protein when fed to men and women in amounts that maintain N balance (Table 14). Because of the relatively greater needs of children, a correction for the quality of dietary protein is warranted as an additional precautionary measure, and for reasons stated earlier the Committee recommends that the same correction for protein quality, based on a knowledge of the total diet consumed, be applied to all age groups except breastfed infants.

Section 6.3 describes various procedures for the calculation of correction factors for the adjustment of the safe level of intake for proteins of lower quality than egg or milk protein. It is re-emphasized that when biological assays of protein quality are used to make this correction, they must be referred to a comparable assay of egg or milk protein. Thus, for example, if the measured NPU of a food or mixed diet is 60 and that of egg used in the same biological assay is 90, then the correction factor will be 90/60 = 1.50.

A first approximation to the relative protein value of a diet may be obtained on the basis of its amino acid composition. An analysis of its amino acid composition (based on the reported compositions of foods), weighted in terms of the amount of each food normally consumed, permits computation of the degree of deficit of the most limiting amino acid and the amino acid score. For a number of reasons (see section 7.5) it is difficult to describe a single mixture of protein foods that can be accepted as representing the usual diets, even of particular age, sex, and income groups within a population. It is virtually impossible to deal with the individual and day-to-day variation in diets. This fact limits the use of any method of evaluating the quality of national or regional diets. In this situation, the approximation provided by the amino acid scoring approach may be as meaningful as a biological assay of the composite diet and is potentially easier to carry out (biological assays of the individual foods cannot be added together in a weighted formula). An advantage of working with the amino acid data, when available, is the facility with which the probable effects of modifying the pattern of food usage can be examined. However, such predictions must be made in the knowledge that the provisional pattern of amino acid requirements is of a very tentative nature and that chemical analyses of foods do not take into account possible differences in biological availability. Of necessity, predictions based on amino acid composition are predictions only; they should, as far as possible, be subject to testing and verification. It should also be recognized that the extreme monotony and lack of variety in the diets of many underprivileged areas, especially the diets of farmers living at subsistence level, as compared with those of developed communities, may make the formulation of representative composite diets more meaningful and direct biological assay of such composite diets more feasible.

In the development of new protein mixtures, or even in the prediction of the quality of existing mixtures, calculation of the amino acid score is a logical initial or screening procedure. Data on the approximate amino acid composition of a wide range of foodstuffs are now available.[14] However, this method provides a first approximation only and should be followed by animal testing and finally by human trials. Animal testing will not only check the availability of the amino acids, which may not be apparent from the chemical scoring techniques, but will also detect toxic factors that may be present in the food or mixture. In the case of protein mixtures proposed for distribution to a population on a trial basis, prior animal evaluation is mandatory.

When there is no information about the protein quality of a diet, a correction for quality must be arbitrary. Available information on amino acid scores of national diets supports the assumption that the diets of rich countries have a quality relative to that of milk or eggs of about 80%, and those of poor countries about 70%. Situations may exist, particularly with diets in which 70–80% of the protein comes from such foods as cassava and maize and virtually none from animal foods, where the relative quality may be as low as 60%.

Table 25 gives the safe levels of intake of protein in terms of diets having protein qualities of 60%, 70%, and 80% relative to milk or eggs. Because the composition of diets taken by groups or individuals within a population is usually unknown, more precise corrections for the quality of national food supplies cannot be made. However, as mentioned in section 7.1, in planning intervention programmes, it is important to seek more specific information about the target populations. Depending on the reliability of food consumption data, more precise corrections for protein quality may or may not be warranted in these studies of subpopulations.

7. PRACTICAL APPLICATIONS

7.1 Interpretation of energy and protein requirements

When the requirement figures proposed in this report are to be applied to populations, as in the assessment or planning of national food supplies, certain problems of interpretation arise. As has been pointed out earlier in this report, the application of energy requirement figures and suggested safe

TABLE 25. SAFE LEVEL OF PROTEIN IN TERMS OF DIETS OF PROTEIN QUALITIES OF 60%, 70%, AND 80% RELATIVE TO MILK OR EGGS

Age group	Body weight (kg)	Safe level of protein intake		Adjusted level for proteins of different quality (g per person per day)		
		(g protein per kg per day)	(g protein per person per day)	Score [a] 80	Score 70	Score 60
Infants						
6–11 months	9.0	1.53	14	17	20	23
Children						
1–3 years	13.4	1.19	16	20	23	27
4–6 years	20.2	1.01	20	26	29	34
7–9 years	28.1	0.88	25	31	35	41
Male adolescents						
10–12 years	36.9	0.81	30	37	43	50
13–15 years	51.3	0.72	37	46	53	62
16–19 years	62.9	0.60	38	47	54	63
Female adolescents						
10–12 years	38.0	0.76	29	36	41	48
13–15 years	49.9	0.63	31	39	45	52
16–19 years	54.4	0.55	30	37	43	50
Adult man	65.0	0.57	37	46 [b]	53 [b]	62 [b]
Adult woman	55.0	0.52	29	36 [b]	41 [b]	48 [b]
Pregnant woman, latter half of pregnancy			Add 9	Add 11	Add 13	Add 15
Lactating woman, first 6 months			Add 17	Add 21	Add 24	Add 28

[a] Scores are estimates of the quality of the protein usually consumed relative to that of egg or milk (see section 6.3 for methods of determination). The safe level of protein intake is adjusted by multiplying it by 100 divided by the score of the food protein. For example, 100/60 = 1.67, and for a child of 1–4 years the safe level of protein intake would be 16 × 1.67, or 27 g of protein having a relative quality of 60.

[b] The correction may overestimate adult protein requirements.

levels of protein intake must be on different theoretical bases. In 1970 the Joint FAO/WHO Expert Committee on Nutrition [164] considered this matter as it related to the recommendations of previous committees. It should be noted that while previous FAO/WHO committees on nutrient requirements had used the term "recommended intake" and the present committee has preferred to adopt the term "safe level of intake" to refer to suggested levels of protein intake, for the reasons given in section 2, the manner in which the final figures have been derived are comparable. It is appropriate to quote from the discussion of the Joint FAO/WHO Expert Committee on Nutrition,[164] since the comments apply equally well to the recommendations found in the present report:

Nutritional requirements : interpretation of nutrient intakes and planning of food supplies

The Joint FAO/WHO Expert Groups on the requirements for calcium, protein, vitamin A, thiamine, riboflavine, and niacin, and ascorbic acid, vitamin D, vitamin B_{12}, folate and iron have adopted the concept of " recommended intake ", which is defined as "the amount considered sufficient for the maintenance of health in nearly all people".[a] Whenever data permitted, the Groups predicted the average requirement of a population group and then estimated the variability of this requirement within subgroups of similar age, sex and physiological state. They then recommended an intake that they felt would meet the requirements of all but a small proportion of individuals.

Thus an individual regularly ingesting the recommended intake of a nutrient must be considered at low risk of receiving less than his true requirement. As his intake falls, the risk of inadequate intake (i.e., of dietary deficiency) increases. Thus, it may be stated that :

(1) dietary intakes can be interpreted only in terms of the risk of deficiency to the individual that might be associated with a particular level of habitual intake ;

(2) the long-term objective of a nutrition programme is the maintenance of all individuals at as low a risk of deficiency as is consistent with national resources.

At the individual level dietary intakes can be assessed in relation to the "recommended intakes", as outlined above. However, other considerations must be taken into account in judging the adequacy of the average intake of a population. In a population, both the requirement for and the usual intake of a nutrient vary among individuals. In the case of calories, there is evidence that, if there are no limitations with regard to food supply or socio-economic or other factors, the intake is proportional to the requirements. Thus the average calorie intake of a population can be compared directly with the predicted average requirement. On the other hand, in the case of almost all nutrients there is no reason to believe that the intake parallels the requirements. In general, the distribution of intakes and of requirements for specific nutrients within a population are quite unrelated. Therefore, in assessing the risk of deficiency in a population (i.e., the proportion of persons who are predicted to ingest less than their true requirements) it is necessary to consider :

(1) the variation of nutrient requirements among individuals ; and

(2) the variation of habitual nutrient intake among individuals.

The Committee noted that FAO had attempted to investigate the variation of habitual intake of nutrients and hoped that these efforts would continue. However, it drew attention to the need for the further investigation of methods of dietary study that will provide reliable estimates of the usual intakes of individuals ; the variation of daily intakes depends upon the nutrient and probably also upon age or socio-economic group. It recommended that both FAO and WHO increase their efforts to obtain information about individual variation as regards nutrient requirements and habitual nutrient intakes, so that both factors can be considered simultaneously in interpreting the adequacy of reported nutrient supplies.

A Joint FAO/WHO Expert Group [6] recommended that "in order to ensure that nearly all individuals in the population are adequately nourished, it would be advisable for the average intakes of population groups to be in general higher than the weighted average recommended intake". The question of how much higher requires consideration

[a] The "recommended intakes" are not intended to be adequate under extreme environmental conditions, nor to cover any additional requirements that may result from abnormal conditions, such as infections, malabsorption syndromes, metabolic abnormalities, or the effects of food additives or other chemicals.

of both the above independent variables (calorie intakes excepted) as well as of predicted wastage.

The predictions of the calorie content of gross food supplies and of the quality of nutrients must be based on different theoretical considerations.

A commonly held view is that an increase in protein food production will result in an increased average consumption and a reduction in the prevalence of "protein deficiency" in a population. In a real population, however, this is most unlikely to be the case, owing to the inequitable nature of food distribution and consumption, which arises from a number of factors. Communities with low levels of malnutrition will be found to consume diets that provide on average more protein than the "safe level" as defined in this report. However, the existence of such a surplus reveals little about the actual food consumption of households and individuals in that community. Such apparently satisfactory average intakes cannot be regarded as a target towards which planners, agronomists, and public health administrators should direct their efforts. The proper basis for planning should not be from the national level downwards, for instance by the setting of national production targets for protein, but should proceed from the study of individual and household food consumption upwards. The nutritional status and the protein intakes of individuals in the different physiological groups of a population should be assessed in relation to the "safe level", first, as a means of analysing the problem, which may not be in any way related to the overall availability of protein foods ; secondly, for establishing priorities between programmes for action, which may include employment policies affecting purchasing power, the control of food prices, food distribution programmes for vulnerable groups, the education of consumers, etc. ; and thirdly, to provide a continuous monitoring of the progress made by such programmes.

The present Committee again emphasizes the conclusion of the Joint FAO/WHO Expert Committee on Nutrition [164] that the variability of both intake and requirement must be considered in deriving any conclusions about the probable adequacy or inadequacy of present protein supplies. FAO is encouraged to continue its efforts to gather data on the variability of protein intake in populations under consideration, so that better assessments of the adequacy of present or projected food supplies can be made.

When predictions are being made about food demands at a national level it should also be borne in mind that man seems to have a desire for protein foods, so that individuals' intakes are often considerably above those suggested as safe in the present report. Such demands on the part of the wealthier sections of a community may well influence the economic availability of preferred foods, and hence the distribution of intakes between population groups. When man is not restricted by the availability of foodstuffs or by economic circumstances he tends to choose a diet that provides about 11% of its energy value from proteins (see section 4.3).[a]

Many authors have calculated protein/energy ratios from recommendations such as are found in this report. These are then compared with the same ratios for diets in assessing the quality of the diets. While the Committee recognizes the merit of establishing a desirable protein/energy ratio, it also recognizes that a simple calculation based on the present recommendations is erroneous. As is stipulated in the opening paragraphs of this section, consideration of variability of requirement and of intake is mandatory. The simple ratio based on the present recommendations takes only the variability of protein requirement into consideration; it ignores variability of energy requirements, covariance between energy and protein requirements and, indeed, the variability of the ratio itself in freely selected diets.

These points have been emphasized as a caution against oversimplified calculations of the adequacy or inadequacy of national food supplies. It is recognized that such calculations form an important part of national planning. Because information on the variability of individual intake cannot be included in the calculations, the results must be interpreted with great care. It is re-emphasized that the examination of the quantitative (energy supply) and qualitative (nutrient supply) aspects of food supplies have different theoretical bases.

Having considered these matters, the Committee realizes that while it can offer guidelines for the estimation of target *per caput* energy intakes (section 7.2), the data currently available to the Committee do not permit it to translate the prediction of individual protein requirements into meaningful guidelines for population feeding. Later in this report will be found a calculation of national protein needs, prepared in the manner of previous reports. It is emphasized that this calculation is of dubious validity for reasons already stated and should be interpreted with extreme caution. It probably represents an underestimation of the practical protein needs of a population. It must be stressed that information available to the Committee does not permit further refinement of this estimate.

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[a] Dr R. Passmore wished to record the following reservations in regard to the safe levels of protein intake recommended by the Committee. If these levels are related to the recommended energy intakes, it could be concluded that diets in which only 8% of the total energy is provided by protein may be considered safe. There is no evidence, however, that such a low protein-derived energy intake is compatible with a healthy, vigorous life: in the diets of healthy communities 10% or more of the energy is provided by protein. It is possible that epidemiological studies on the continued use of low-protein diets might uncover metabolic changes that were not detectable in the short-term studies on which the safe levels recommended by the Committee were based. Furthermore, there is a risk that diets low in protein might be deficient in other essential nutrients and that they might lead to undesirably high proportions of sugar and starchy roots in some national diets. Dr Passmore considered that in national planning the aim should be a food supply in which at least 10% of the energy is provided by a mixture of proteins.

Comment might also be offered on the limitation of any calculation of national protein needs. In practice, major concern about protein intake is restricted to the younger age groups in a population. It has been repeatedly stressed that examination of national protein supplies tells relatively little about the supply of protein (or other nutrients) to specific population groups. Planning should be based upon an examination of the nutrient intake by the vulnerable groups and then calculation upwards to the national level, not the reverse. The need to consider protein and energy together is also emphasized.

7.2 Estimation of energy requirements at the national or population level

7.2.1 *Approach and interpretation*

As indicated in section 7.1, reasonably valid estimates of national energy needs can be derived since there is reason to believe that if the total supply of food is adequate and social factors are not limiting, individuals will tend to consume energy in proportion to their own needs. A reasonably equitable distribution of energy might be expected. However, caution must be expressed, since if the total food supply is even slightly low, then social and other factors may produce a very inequitable distribution within some segments of the population.

In the previous report,[2] the various adjustments proposed for weight, age, and climate were presented in a series of 11 tables in which the effect of each variable was shown separately. The result was that the user had great difficulty in calculating the cumulative effects of the several variables in order to adapt energy requirements to the conditions of a country or to a population group.

The Committee now proposes a simpler model that will enable the different parameters to be incorporated in a single calculation table. Table 26 comprises five vertical columns : column 1 shows the reference age and sex groups ; column 2 is used for computing adjustments for weight and age for classes between 13 and 70 years of age ; column 3 is designed for estimating the modifications of energy requirements when part of the population is known to have activities that differ from those of the reference adults ; column 4 supplies the population distribution by sex and age group ; and column 5 is used for weighting the results so as to express the *per caput* energy requirements.

7.2.2 *Energy requirements of children aged up to 1 year, and allowance for pregnancy and lactation*

It is convenient to include in the average energy requirements for children below the age of one year the requirements of pregnant women, nursing mothers, and children during their first year of life. For this purpose, it is postulated that during any year the number of pregnant women exceeds by 10% that of children aged less than 12 months. The total energy supplement for pregnancy is 80 000 kcal (335 MJ), as indicated in section 5.6. The total supplement therefore works out at 80 000 kcal × 1.1 per infant for the whole year, or about 240 kcal (1.0 MJ) per infant per day to allow for the pregnant women.

In this same section, the requirements resulting from lactation are estimated at 750 kcal (3.1 MJ) a day for 6 months, and those of an infant from 6 to 12 months are estimated at 960 kcal (4.0 MJ). If we assume that in the population being considered half the infants are below 6 months of age, the requirements resulting from lactation and from the supplement necessary for the child during its first year of life average 850 kcal (3.5 MJ) per day.

In total, the figure of 850 kcal + 240 kcal = 1090 kcal (4.5 MJ) per day for infants under the age of one year represents the energy allowance for infants and the supplementary needs of pregnant and lactating women.

7.2.3 *Energy requirements of children and adolescents*

The requirements of children and adolescents are grouped in 6 classes, as in previous reports : 1–3 years, 4–6 years, 7–9 years, 10–12 years, 13–15 years, and 16–19 years. When the weight of the children in a given national population is below that of the reference children, it is recommended that the requirements of the reference children should be maintained in order to allow for catch-up growth, and that the adjustments for weight should not be made (see section 5.5). These figures are therefore entered unchanged in column 2 of Table 26 : 1–3 years, 1360 kcal (5.7 MJ) ; 4–6 years, 1830 kcal (7.6 MJ) ; 7–9 years, 2190 kcal (9.2 MJ) ; 10–12 years, boys 2600 kcal (10.9 MJ), girls 2350 kcal (9.8 MJ). On the other hand, it is recommended that the requirements of adolescents (age groups 13–15 and 16–19 years) be adjusted according to the weight of the adults in the population group being considered, because these adolescents would probably not increase in height with additional dietary energy. For boys the requirements are fixed respectively at 97% and 102% of those of men between 20 and 39 years of age, and for girls at 113% and 105% of those for women between 20 and 39 years of age.

7.2.4 *Requirements of adults*

The requirements of the reference man and reference woman from 20 to 39 years of age engaged in moderate activity and weighing 65 kg and 55 kg respectively are estimated at 3000 kcal and 2200 kcal (12.5 and 9.2 MJ), or 46 kcal (0.19 MJ) per kg of body weight for the man and 40 kcal (0.17 MJ) per kg of body weight for the woman. To estimate the requirements of adults aged from 20 to 39 years differing in weight from those of the reference adults, it is sufficient to multiply their weight by the above values. These

TABLE 26. CALCULATION OF *PER CAPUT* ENERGY REQUIREMENTS

Age group (years)	Requirements according to weight and age (kcal)	(MJ)	Requirements adjusted according to activity (kcal)	(MJ)	Population distribution (%)	Total energy
< 1	1090	(4.5)	1090	(4.5)		
1–3	1360	(5.7)	1360	(5.7)		
4–6	1830	(7.6)	1830	(7.6)		
7–9	2190	(9.2)	2190	(9.2)		
Male : adolescent, adult						
10–12	2600	(10.9)	2600	(10.9)		
13–15	0.97 *M*		0.97	× $\frac{M[(100-p)+pA]}{100}$		
16–19	1.02 *M*		1.02			
20–39	1.00 *M*		1.00			
40–49	0.95 *M*		0.95			
50–59	0.90 *M*		0.90			
60–69	0.80 *M*		0.80			
70 +	0.70 *M*		0.70			
Female : adolescent, adult						
10–12	2350	(9.8)	2350	(9.8)		
13–15	1.13 *F*		1.13	× $\frac{F[(100-p)+pA]}{100}$		
16–19	1.05 *F*		1.05			
20–39	1.00 *F*		1.00			
40–49	0.95 *F*		0.95			
50–59	0.90 *F*		0.90			
60–69	0.80 *F*		0.80			
70 +	0.70 *F*		0.70			
					Total	
					Per caput	

M = body weight × 46 kcal (0.19 MJ) = requirement of moderately active adult male at given weight.
F = body weight × 40 kcal (0.17 MJ) = requirement of moderately active adult female at given weight.
A = index of adjustment for activities other than moderate : light 0.90, very active 1.17, exceptionally active 1.34.
p = percentage of population that in a given group is not moderately active.

values are entered in column 2 of Table 26 on the line corresponding to men and woman aged 20–39 years.

Hence, for example, in a given country the daily energy requirements of adult men who are identical as regards age and activity with the reference man but who weigh 53 kg will be 53 × 46 kcal (0.19 MJ) = 2440 kcal (10.2 MJ), and those of women weighing 46 kg will be 46 × 40 kcal (0.17 MJ) = 1840 kcal (7.7 MJ). The requirements of adolescents from 16 to

19 years corresponding to this population group will be respectively 2440 kcal (10.2 MJ) × 1.02 = 2490 kcal (10.4 MJ) for males and 1840 kcal (7.7 MJ) × 1.05 = 1930 kcal (8.1 MJ) for females. These figures relating to weight adjustment are entered in column 2 of Table 26.

7.2.5 *Adjustment for age*

The drop in energy requirements with age has been examined in section 5.4.4. With respect to adults aged 20–39 years, the level of requirements per age group is as follows :

	As a percentage with respect to age group 20–39
40–49 years	95
50–59 years	90
60–69 years	80
70 years and over	70

To return to the previous example, the requirements of men weighing 53 kg, will be at age 50–59 2440 kcal (10.2 MJ) × 0.90 = 2200 kcal (9.2 MJ), and at ages over 70 years 2440 kcal (10.2 MJ) × 0.70 = 1700 kcal (7.1 MJ). These figures, which represent the requirements of adults, adjusted for weight and age, are entered in column 2 of Table 26. If it appears that for the population being considered the activity corresponds to moderate activity by the reference man and woman, it will be necessary merely to multiply the energy requirements of each age and sex class (column 2) by the corresponding figures in column 4 and to add up the results of the sex and age groups (column 5).

7.2.6 *Average daily* per caput *requirement*

If the population of the various age classes is indicated as a percentage, the total is divided by 100 to obtain the daily *per caput* energy requirement. If the population figures are given as absolute values, the average energy requirement is obtained by dividing the total energy requirements of the group by the total population. The average, weighted for the various sex and age groups, is thus obtained (see Table 27, for example).

7.2.7 *Adjustment for activity*

When the energy requirements of a country are being considered, it is unlikely that the average activity of the working portion of the population differs very markedly from the moderate activity referred to in the definition of the reference adult. In this case calculation of the requirements is performed as indicated above. Table 27 gives as examples calculations for two countries in which the weight of the adults and the sex and age structure differ.

TABLE 27. EFFECT OF BODY SIZE, AGE, AND SEX ON ESTIMATION OF *PER CAPUT* ENERGY REQUIREMENTS IN A MODERATELY ACTIVE POPULATION

Age group (years)	Country 1 : Adult males 53 kg Adult females 46 kg			Country 2 : Adult males 65 kg Adult females 55 kg		
	Individual require-ments (kcal)	Distri-bution (%)	Contribution to total require-ments per 100 persons (kcal)	Individual require- (kcal)	Distribution (%)	Contribution to total require-ments per 100 persons (kcal)
Children, both sexes, < 1 year, including allowance for pregnancy and lactation	1 090	2.5	2 725	1 090	2.0	2 180
1–3	1 360	11.4	15 504	1 360	5.8	7 888
4–6	1 830	10.5	19 215	1 830	5.8	10 614
7–9	2 190	8.7	19 053	2 190	5.9	12 921
Male : adolescent, adult						
10–12	26 00	3.9	10 140	2 600	3.2	8 320
13–15	2 370	3.4	8 058	2 900	3.0	8 700
16–19	2 490	3.8	9 462	3 070	3.5	10 745
20–39	2 440	13.6	33 184	3 000	15.6	46 800
40–49	2 318	3.8	8 808	2 850	4.3	12 255
50–59	2 196	2.6	5 710	2 700	4.6	12 420
60–69	1 952	1.5	2 928	2 400	3.2	7 680
70 and over	1 708	0.7	1 196	2 100	1.6	3 360
Female : adolescent, adult						
10–12	2 350	3.9	9 165	2 350	3.1	7 285
13–15	2 080	3.4	7 072	2 480	2.9	7 192
16–19	1 932	3.7	7 148	2 310	3.3	7 623
20–39	1 840	13.5	24 840	2 200	15.7	34 540
40–49	1 748	3.8	6 642	2 090	5.3	11 077
50–59	1 656	2.7	4 471	1 980	5.1	10 098
60–69	1 472	1.6	2 355	1 760	3.7	6 512
70 and over	1 288	0.9	1 159	1 540	2.3	3 542
		Total	198 835		Total	231 752
		per caput	1 990 kcal (8.33 MJ)		*per caput*	2 320 kcal (9.71 MJ)

Countries 1 and 2 have a weight and age structure typical of a developing and a developed country respectively.

However, if precise data are available on the various occupational categories, on the times and nature of the work, and on certain leisure activities, it may be necessary to make corrections for the activity of certain segments of the population. This will apply particularly to consumption surveys for populations in which some members are engaged in heavy occupational activities, such as, for instance, surveys of the needs of rural villages during tilling or harvesting periods or during rest periods.

In this case, in accordance with the recommendations in section 5.4.2, it is necessary to correct the energy requirements for the part of the population that does not participate in moderate activity, by means of the following correction factors :

	Correction factor : percentage of moderate activity
Light activity	90
Moderately active	100
Very active	117
Exceptionally active	134

These factors apply to the various age and sex groups from 13 years onwards.

The adjusted requirement, when part of the group is not moderately active, is calculated as follows :

$$\frac{KM}{100}\,[(100\text{-}p) \div pA] \text{ for males}$$

$$\frac{KF}{100}\,[(100\text{-}p) + pA] \text{ for females}$$

In these formulae :

K = coefficient of adjustment for age ;
p = percentage of persons engaged in activities other than moderate in the age group concerned ;
M = requirement of the moderately active adult male (46 × weight) ;
F = requirement of the moderately active adult female (40 × weight) ;
A = index of adjustment for activities other than moderate.

To return to the previous example in which the 53-kg male adult aged 20–39 years has a requirement of 2440 kcal (10.2 MJ), and assuming that 12% of the male population aged 20–39 years are very active, the energy requirement of male adults aged 20–39 years is :

$$\frac{2440}{100}\,[(100\text{-}12) + 12 \times 1.17] = 2490 \text{ kcal } (10.4 \text{ MJ})$$

If 6% of the female population aged 20–39 years, whose body weight is 46 kg, is very active, the energy requirement for this age group is :

$$\frac{1840}{100}[(100\text{-}6) + 6 \times 1.17] = 1860 \text{ kcal } (7.8 \text{ MJ})$$

If it is assumed also that 40% of the population of the male group aged 60–69 years performs light work and that 60% is moderately active, with an average requirement of 1952 kcal (8.2 MJ) at that age, the adjusted requirement of this age group becomes :

$$\frac{2440 \times 0.8}{100}[(100\text{-}40) + 40 \times 0.9] = 1874 \text{ kcal } (7.9 \text{ MJ})$$

If these three modifications relating to activity were introduced in Table 27, as in the example of country 1, the lines corresponding to age groups 20–39 male and female adults and 60–69 male adults would be modified as follows :

20–39, male adults : 2490 × 13.6 = 33 864 kcal, instead of 33 184 kcal.
20–39, female adults : 1860 × 13.5 = 25 110 kcal, instead of 24 840 kcal.
60–69, male adults : 1874 × 1.5 = 2811 kcal, instead of 2928 kcal.

These relatively small differences have little effect on the energy requirements of the total population calculated *per caput*, which becomes 2000 kcal instead of 1990 kcal.

7.3 Estimation of protein needs at the national or population level

7.3.1 *Approach and interpretation*

It has already been pointed out (section 7.1) that the Committee does not have sufficient information to permit a valid translation of the estimates of individual protein requirements, as opposed to energy requirements, into population needs. There is no reason to believe that available protein would be equitably distributed in proportion to need, even if the national protein intake equalled or slightly exceeded the national need as calculated in the conventional manner. Rather, experience in most areas of the world suggests that people tend to select protein intakes such that they contribute 10–12% of the dietary energy (see section 4.3) ; this level is higher than would seem to be required to meet the physiological protein needs predicted in this report. If national food supplies provide a low ratio of protein to energy, inequalities in distribution and consumption are likely to exist.

Nevertheless, calculation of national protein needs, even with the partial information available — information which fails to take into account the need to include an allowance for variability of intake — has some practical value as an indication of a lower limit of supply. However, the need for extreme caution in interpretation must be stressed.

In the preceding sections, figures have been expressed for the protein requirements of both sexes in different age groups for the purpose of estimating the requirements of population groups. Initially, figures for the physiological requirement for dietary protein were obtained. To allow for individual variation, a factor of 30% was added to these figures, giving a safe level of intake, i.e., the amount of high quality protein considered adequate to meet the physiological needs and maintain the health of nearly all healthy individuals in the specified category. Factors that may influence such needs have been considered.

For the application of these principles to population groups it is necessary to have reliable data on the average weights of the various age groups for both sexes, and data on the age and sex distribution of the population, as well as data on the proportion of pregnant and lactating women, since their higher requirements will increase those of the population as a whole. As in the computation of energy needs, when the weight of children in a given national population is below that of the reference children, it is recommended that the requirements of the reference children be maintained to allow for catch-up growth.

7.3.2 *Allowances for pregnancy and lactation and for infants below one year*

Additional amounts of protein must be allowed for pregnant and lactating women as discussed in section 6.5. When the number of pregnant women in a population group is not known, it can be assumed that there are 10% more pregnant women than infants below 12 months of age, allowing for pregnancy wastage and perinatal mortality. For example, where the number of infants of both sexes aged below 12 months in a country is 200 000, then the number of pregnant women will be 220 000. An additional 5.5 g of protein per day is required as an average over the entire pregnancy, which will amount to 220 000 × 5.5 = 1 210 000 g of additional egg or milk protein to be included in the total daily requirements of the population being considerd. The extra need may be larger than this, depending on the nutritional quality of the dietary protein, as mentioned below.

If the number of lactating women is not known, it can be approximately deduced from the number of infants under 12 months of age, taking into account the duration of lactation. However, it is very often impossible to get accurate information on the exact length of lactation, and in the calculation of protein requirements the assumption that all infants below one year of age are being breastfed can be made for the following reason : the daily protein needs of infants are lower than the daily allowance for lactation, i.e., 17 g, and consequently any substitute feeding of the infant will be within the limits of the allowance for lactation. The figure of 17 g can therefore safely be used as covering the needs of all infants whether they are breastfed or not.

For example, if in a given community the number of infants under 12 months of age is 200 000, the combined protein allowance per day for lactation and infants under one year will be calculated as follows : 200 000 × 17 = 3 400 000 g of protein equivalent to egg or milk in quality.

7.3.3 *Allowances for climate qnd other conditions*

It is unlikely that additional N need be provided for sweating due to high environmental temperature in fully acclimatized populations unless they are engaged in heavy labour. The amount lost in sweat may be about 10 mg of N per kg (see sections 6.1.1 and 6.4), but in the present state of knowledge no firm recommendation can be made. There is no convincing evidence of an increased protein need for work *per se* in an adapted individual, although need is larger during training.

7.3.4 *Adjustments for the quality of protein in the diet*

The present report introduced the concept of "relative protein value". This is the quality of the dietary protein relative to that of high quality protein and is described in sections 6.3 and 7.2. Thus, if the relative quality is 60%, 70%, or 80% of that of egg, correction factors of 1.67, 1.43, or 1.25 will be needed to adjust the safe levels of protein intake shown in Tables 23 and 24. For example, the value for a girl aged 10 years and weighing 30 kg is 0.84 g of milk or egg protein per kg, or 25 g per day. If the dietary protein has a relative quality only 60% of that of milk or egg, the daily amount will be increased to 25 × 1.67 = 42 g per day. The procedures for deriving the relative qualities on the basis of either amino acid composition or biological assay are described in section 6.3. As discussed earlier, these corrections may overestimate the needs of adults but are a necessary factor for children and pregnant or lactating women.

7.3.5 *Calculation of* per caput *requirements of population*

Since protein requirements vary among different age groups in a population, the *per caput* requirements will be the weighted average of the requirements of the different sex and age groups. An example of the calculation of a computed *per caput* per day requirement for population is given in Table 28. These figures do not take into account the variability of intake distribution within the population. They are therefore valid only if each person receives, according to his need, the amount of protein specified and the same quality of protein as is assumed. Such a situation does not exist within countries at present, and commonly does not exist even within households. How much higher the *per caput* allowance must be will depend on the magnitude of the variability of intake distribution. This problem has been discussed in section 7.1.

TABLE 28. CALCULATION OF THE THEORETICAL SAFE LEVEL OF PROTEIN INTAKE

	Population (thousands)	Average body weight (kg)	Requirement per kg body weight per day (g)	Requirement *per caput* per day (g)	Total requirement (kg)
Infants					
0–1 year	108 [a]				
Children					
1–3 years	231	13.4	1.19	15.9	3 673
4–6 years	200.2	20.2	1.01	20.4	4 084
7–9 years	184	28.1	0.88	24.7	4 545
Male adolescents					
10–12 years	80	36.9	0.81	29.9	2 392
13–15 years	83.6	51.3	0.72	36.9	3 084
16–19 years	113.6	62.9	0.60	37.7	4 283
Female adolescents					
10–12 years	80.8	38.0	0.76	28.9	2 335
13–15 years	84.6	49.9	0.63	31.4	2 656
16–19 years	132	54.4	0.35	29.9	3 947
Adults : men	670	65.0	0.57	37.1	24 857
women	705	55.0	0.52	28.6	20 163
Allowance for pregnancy	(119) [c]			5.5	655
Allowance for lactation	(108) [a]			17.0	1 836
TOTALS	2 672.8				78 510 [b]

[a] No requirements are indicated for infants for the reasons given in section 7.4.2.

[b] Requirement for egg or milk protein $\frac{78\,510}{2672.8} = 29$ g *per caput* per day. This value must be adjusted for the relative quality of the protein in the national diet. There will also need to be allowances for wastage and for the distribution of intakes within the population. See text.

[c] The number of pregnant women in a population group is not known, and it is assumed that there are 10% more pregnant women than infants aged 0–12 months, allowing for pregnancy wastage and perinatal mortality. Pregnant women : 108 (thousand) × 1.1 = 119 (thousand).

7.3.6 *Adjustment for waste*

Data on food consumption derived from national food balance sheets are based on weights at the retail level rather than on food as consumed. An appropriate allowance must therefore be made for wastage of food between the "retail" and consumption or "physiological" level, i.e., during and after domestic preparation. The wastage is of two kinds, of edible and of inedible material. Wastage of inedible material, such as bone of meat and peelings of roots, is accounted for when protein contents are calculated by the use of appropriate food composition tables. Losses of edible material are more difficult to estimate because they vary from country to country —

even in the same country among different sections of the population — and also from season to season. Such losses can be substantial : 10% would be a tentative allowance.

7.4 Identification of needs

7.4.1 *Approach to the problem*

Section 7.1 emphasized the need to examine the nature and magnitude of the nutritional problems within groups of the population and then to work upward in the planning of solutions. Reliance on calculations of national or regional food supplies is potentially misleading (unless they are grossly inadequate), since they do not take into account problems of distribution. Two approaches may be made in the investigation of conditions within the group ; preferably they should be undertaken together. One is the investigation of individual nutrient intakes and comparison of these with the levels of intake suggested in this report. The other is the examination of clinical and biochemical indicators of nutritional status among individuals in the groups. In proposing solutions, this information must be considered in the context of the social and physical environment of the population. These approaches are discussed briefly below.

7.4.2 *Dietary intake data*

Average intakes of energy and protein derived from household surveys have often been misused as indicators of the adequacy of intake of individuals. They are of little or no value in assessing the adequacy of the diets of preschool children, which are likely to be lower than estimated because the children do not receive a proportionate share of the available food. Similarly, inadequate intakes by pregnant and nursing mothers may be concealed. The males of the family often get a disproportionate share of the desirable foods, so that their actual intake may be better than is indicated.

There is no substitute for obtaining good data on the dietary intake of a representative sample of individual preschool children and pregnant or nursing mothers. The distribution of intakes of energy and protein derived from a properly selected sample is the best available way of estimating the relative adequacy of the diets of persons in those vulnerable groups. Home visits to obtain individual dietary data are the usual procedure followed for young children. It is possible to obtain partial but useful information on the diets of pregnant and nursing mothers and other adults by interview at a health centre or clinic. In the collection and interpretation of such data, however, many problems arise. For example, when the child is being breastfed beyond 6 months of age, it is difficult to determine the amount of breast milk received. The presence of observers may influence the amount of food given and thereby lead to an overestimate of normal intakes. In addition, it is necessary to take into account seasonal effects and the effects of frequent infections on nutrient intakes. Care must be taken to obtain complete records of food consumed between meals, and in the case of children the mother may not always be aware of the snacks that they take. Such surveys are also very costly in time for the observers. Moreover, there are limitations to the accuracy with which food intakes can be converted into intakes of energy, protein, and other nutrients, because of the limitations of tables of food composition. Suggestions on the collection of survey data are discussed in the FAO *Manual on household food consumption surveys*.[165]

Data from individual surveys cannot be used to estimate the number of persons with various qualities of diet in the larger population unless strict statistical controls have been exercised in sample selection. Under field conditions, especially in areas where census data are poor, it is difficult to obtain a properly randomized or stratified sample. However, this type of information is required to develop programme objectives that will provide for the needs of most of the population according to the intake distribution. Dietary surveys, if they are well designed and conducted, are the best approach presently available to identify needs at the country level. The observers' organizing and educating abilities and the willingness of subjects to collaborate are very important.

7.4.3 *Use of anthropometric and biochemical data*

Anthropometric data offer the most reliable means of assessing subclinical protein-calorie malnutrition in preschool children. For children of school age, satisfactory gains in height and weight are indicators of adequacy of intakes of energy and protein. When gains are not satisfactory, a number of factors may be involved, nutritional as well as others, and anthropometric measurements are helpful in elucidating the nature of the problem.

The best indicators of an adequate energy intake are weight gain during pregnancy, and maintenance of body weight during lactation. Neither clinical nor biochemical measures are available to detect mild to moderate degrees of subclinical protein deficiency that may have undesirable consequences for mothers and children.

7.4.4 *Consideration of other factors*

To assess the nature and cause of nutritional problems relative to protein and energy consumption requires more than the measurement of food availability and nutritional status. It requires an ecological approach that takes into account the environmental factors influencing food production, food availability, food requirements and food consumption. These in turn are physical (climate, soil, terrain), biological (plants and animals adapted to the region; plant, animal, and human diseases present), and social (cultural, economic, and political). Knowledge of food beliefs as well as practices is particularly important for understanding the nutrition problems of the preschool child and the pregnant and nursing mother, because food prejudice or taboos may prevent them from receiving their full share of the family diet. The following are all relevant: concepts of the relationship between food and health; attitudes to classes of foods like milk, meat, eggs, and green or yellow vegetables; fluctuations in the demand for various foods with changes in price and supply; and alterations in food habits and demands associated with social changes. Environmental sanitation and personal hygiene influence the prevalence and distribution of infectious disease, which may in turn affect nutrient intakes and needs. Programmes and policies arising outside the community may also be major factors as, for example, the adequacy of preventive medicine and health care programmes provided by the government, supplementary feeding programmes for vulnerable groups, agricultural extension activities, national food enrichment and fortification policies, food subsidies, etc. Others, such as systems of land tenure and land use, may be local factors outside the direct control of the people most in need.

Clearly, the significance of the protein and energy intakes of an individual cannot properly be interpreted without a knowledge of the environmental and host factors influencing his requirements. Similarly, the interpretation of the data on protein and energy intakes for a community requires knowledge or pertinent ecological factors. The appraisal of such problems at national and international levels needs an even broader understanding of the factors discussed in this section.

7.5 Long-term planning for energy and protein supplies

In long-term food production planning, production targets are generally based on projections of economic demand. This demand is related to the economic situation of the country and to family income. It is assumed that demand will increase with a rise in purchasing power but at different rates for different commodities.

The nutritional needs of the population, and particularly of vulnerable groups, are often not fully taken into account when food production is being planned. Nutrition must be considered as a factor conditioning the speed of development in many countries, because only a healthy population has a high working capacity. At the same time, an improvement in nutritional status leads to a reduction in the cost of health care. Planners should therefore give much greater attention to nutritional needs in planning food production. For the reasons discussed in this report, attention to the needs of children, in terms of kind, quality, and quantity of foods, should be given priority. The expenditure necessary to provide sufficient supplies of nutritionally desirable commodities may seem high in comparison with some other foodstuffs. Here, the nutritionist can help not only in setting up targets in terms of nutrients but also in recommending economical ways of meeting nutritional needs, and in weighing the cost of promoting more nutritious foods against the benefits, measured in terms of better health and greater working efficiency. Nutritional factors, as well as economical and ecological factors, should be taken into consideration in agriculture development planning as well as in public health improvement programmes. In addition, however, any policy measures related to agricultural development or to food production must be carefully assessed in relation to the effects they themselves may have on employment, and therefore on income distribution.

Measures for the treatment and rehabilitation of malnourished children, as well as those aimed at the long-term protection and promotion of the health of vulnerable groups, have been extensively reviewed in the report of the Joint FAO/WHO Expert Comittee on Nutrition.[164] These measures include a broad range of action programmes, such as the improvement of the nutritional status of the mother, the promotion of breast feeding, environmental sanitation, immunization against the infectious diseases of childhood, and the development of low-cost protein-rich weaning foods. While an increase in total supplies is not the complete answer, nonetheless an increase in the production of key commodities will be necessary if rises in prices on the local market are to be prevented. Thus, internal regulations and external food aid may both be needed.

It must be stressed, however, that food policies that have the aim of simply increasing the average protein intake per head of the population may be totally ineffective in reducing the incidence of deficiency, since in practice the extra protein consumed will not be uniformly distributed. The only policy measures that are likely to be effective are those aimed at improving food distribution relative to needs, as well as ensuring an adequate overall supply of foods. Inasmuch as deficiency is often confined to a special and perhaps small group within the population, nutrition policies and planning must often be directed towards the identified needs of specific groups within the community rather than to the overall national level.

Long-term planning takes into account the increase in population and the improvement in diets *per caput* compared with the base year. This improvement is generally modest, particularly in terms of proteins, both quantitatively and qualitatively. In increasing food supplies, planners must be conscious of the necessity to increase the production of energy foods and protein foods according to the relative shortage of each in the region.

Even if it can be shown that the average level of consumption of energy or protein is equal to or greater than a suggested *per caput* requirement, this does not mean that there are no poorly nourished individuals in the population, since inequalities in income and resources will result in maldistribution of food. The vulnerable groups of the poor socioeconomic segments of the population are in this underprivileged situation. An increase in food production, for example, through the promotion of high-yielding varieties of cereals, will not necessarily improve the distribution of income at national level, and may have no effect on the income of poor farmers. An increase in total supplies to meet even a generous allowance or requirement level will not be the answer to this maldistribution problem so long as the disparity in purchasing power is not remedied. Therefore, any policy must be looked at from the point of view of distribution and the effect it may have upon employment and incomes, as well as from the point of view of production. Special measures for alleviating the effects of inequalities in the distribution of foods and income are needed, in addition to special support and incentives for properly oriented food production. These measures, in the form of feeding programmes, price reduction, food coupons, and family food allowances, should be included in development plans.

The Committee urges recognition by planners of the role that nutrition education can play in orientating food demand and in obtaining better utilization of supplies and better distribution of the available foods within the family.

8. FUTURE RESEARCH

8.1 Need for field data

A number of the unresolved issues reflected in the body of this report can be examined only by means of research conducted in or through large, well equipped laboratories or organizations. However, continuous appraisal of nutritional status depends on the interpretation of simple data collected accurately on a large scale at population level. An accurate census, anthropometric data on children and adults, birth weights and perinatal mortality figures, information on the prevalence of both major and minor diseases, simple biochemical and haematological parameters, and other similar field data, systematically collected, recorded and analysed, are invaluable for the epidemiological study of nutrition. The present report has stressed the importance of such epidemiological studies. Governments are encouraged to support activities of this kind.

8.2 Ethical considerations

Research questions posed with regard to energy and protein needs, particularly of infants and children and pregnant and lactating women, have led to extensive studies of these dietary variables, often in children who have been under treatment for malnutrition or are drawn from low socioeconomic groups in general. Serious ethical questions may be raised. The Committee emphasizes that the research studies proposed in this report must not be allowed to interfere with the provision of the best medical and nutritional care appropriate to the individual's condition, nor to impede, even briefly, the normal course of his development.

8.3 Gross energy supplies for the community

(1) The energy requirements of a community depend on its mode of life. The community has some choice in how much energy is expended in the work of manufacture and production and how leisure time is spent. Hence, energy requirements are subject to change. In every country there is a need for a continuing check on energy requirements by means of dietary surveys and physiological studies of energy expenditure. Such studies should be included in the public health programme.

(2) There is evidence that as the general levels of physical activity in a community fall, an increasing number of the individuals within the community fail to make the appropriate and essential reduction in energy intake, at least with sufficient precision to maintain a desirable energy balance. Obesity, with its associated increase in morbidity, consequently becomes more prevalent. There may be a minimum level of physical activity, with a corresponding level of energy intake, that is necessary for health. If so, this minimum has not been clearly defined. The factors underlying the poor correlations observed between body weight and energy intake and expenditure (i.e., the apparent variability of energy requirements between individuals performing similar duties) require investigation. These questions are being explored epidemiologically, and a few physiological studies in animals have been carried out, but much more information is required.

(3) Dietary energy is supplied from carbohydrate, fat, protein, and alcohol. While there is a clearly definable minimum intake of protein that is consistent with health, the precise limits over which the proportions of energy from carbohydrate, fat, and alcohol may vary without harm to health are very poorly defined. Research in this area will have to concern itself with interactions between the level of total energy intake (in relationship to expenditure), the proportions of individual energy sources (including, for example, the types of carbohydrate and fat), and genetically influenced metabolic differences. The relationship of these factors to the hyperlipoproteinaemias is but one of the many questions that must be answered before a satisfactory description of a desirable community dietary can be given. Since the nature of the diet tends to change as the wealth of a country increases, these questions are of major import in the long-term planning of food and agricultural policies and the related nutrition programmes.

(4) The extent to which low energy intake limits productivity and physical work in different occupations and different regions should be examined more closely than it has been in the past. Consideration should be given not only to the physiological aspects of work performance but also to the possible existence of social or other constraints that may limit increases in productivity.

8.4 Prediction of energy requirements

(1) Surveys have now indicated with reasonable precision the average intake of energy required by healthy children to allow normal growth. The question of what proportion of that energy is used for growth, for physiological maintenance, and for physical activity, has not been resolved and is of more than academic interest. The cause and magnitude of individual variability in total energy requirement and the component parts thereof remain virtually unstudied. All of this information is needed for the development of predictive equations for the estimation of energy needs under varying social and physical environmental conditions.

(2) There is little accurate information about the capacity of children whose growth has been retarded by undernutrition or infection to catch up when a fully adequate diet is provided *ad libitum*. The amounts of food energy (and protein) necessary for this purpose remain undefined. If too much food is consumed, there is a danger of obesity ; if too little is provided, recovery may be impaired. The answers to these questions must vary with the age of the child and with the length and severity of the period of growth impairment. Experimental study of this problem is difficult to organize, but where the opportunity arises, e.g., in suitable children's homes or in appropriate nutritional rehabilitation centres, research on this problem should be supported. Such investigations might profitably be directed to the development of criteria for the identification of children whose growth is irreversibly retarded ("nutritional dwarfing") and who would not be expected to respond to supplementary feeding.

(3) The effects of climate on energy requirements cannot be quantified at present. There is insufficient information on the activity pattern of normal, adapted populations in hot regions. Further, energy requirements are now related to persons who maintain a thermally neutral microclimate through adjustments of clothing and housing, yet conditions of poverty may cause these adjustments to be inadequate. Therefore, studies of the different socioeconomic groups of populations are clearly indicated.

(4) It has been observed in dietary surveys that pregnant women in many societies do not increase their energy intakes to the extent that physiological requirements are believed to increase. Although it has been suggested

that the explanation of this phenomenon may lie in a decrease in voluntary activity (and energy requirement) during pregnancy, there is very little direct information in developing countries about this problem. Field studies on the relationships between apparent energy intake, apparent energy expenditure, and the magnitude and composition of weight gain, as well as the outcome of pregnancy, should be undertaken, particularly in those agrarian societies where pregnant women continue to work in the fields. These studies should be extended to include lactating women wherever possible. The results of such research have important implications for antenatal programmes.

8.5 Gross protein supplies for the community

(1) The fact that many population groups prefer, and habitually consume, levels of protein in excess of the safe levels of protein intake computed in the present report, raises the question of the criteria used to judge a "safe" as opposed to an "optimal" level of intake. This question merits study in groups consuming different levels of protein ranging above and below the levels presently regarded as "safe", in terms of the effects of protein intake on growth and aging, protein pools and cellular turnover, endocrine regulation, functional capacity, ability to work, resistance to stress and infections, and energy expenditure.

It is recognized that such studies are extremely difficult to conduct and interpret in human subjects. Epidemiological observations suffer from the interplay of many variables that interfere with the interpretation of results in terms of cause-effect relationships. Nevertheless, long-term longitudinal studies may be designed in which these multiple variables may be identified and independently evaluated. In all epidemiological studies of protein needs, care must be taken to consider both the variability of requirement and the variability of intake, and comparisons should be drawn only in the full knowledge that the safe level of intake, as defined in the present report, takes into account only one of these variables.

(2) It has been commonly assumed that the amount of a particular protein needed to meet the requirements of man can be estimated with reasonable accuracy by multiplying the safe level of protein intake by $\frac{100}{\text{NPU of the protein, as measured in the rat}}$. Evidence from nitrogen balances studies on adult human subjects indicates that egg protein, when fed at intakes that maintain nitrogen equilibrium, is used much less efficiently than would be predicted from a knowledge of its NPU in the rat. Discrepancies between actual and predicted requirements for other proteins are also evident in the adult but are generally smaller than for egg protein. Since dose-response curves of biological systems are commonly observed

to obey the law of diminishing returns, there is an obvious need for measurements of protein utilization efficiencies of high- and low-quality proteins in human adults over ranges of intakes from inadequate to adequate, to determine the utility of protein quality correction factors when protein intake is varied. As in practice most protein evaluations will be done with experimental animals, these studies must obviously be correlated with measures of NPU in rats over a suitable range of intakes to provide a basis for comparison. There is reason to believe that the E/T ratio may be lower in adults than in children, and that this may affect the sensitivity of the adult to changes in protein quality; the human studies referred to above should therefore be repeated in younger age groups wherever feasible, bearing in mind what is said in section 8.2.

8.6 Prediction of nitrogen and amino acid requirements

(1) The present report suggests that the "obligatory" nitrogen losses observed during the feeding of protein-free diets underestimate the true nitrogen requirements to establish equilibrium. The reasons for this discrepancy are not clear. There is a need for studies to examine the status of the "labile proteins" under conditions of nitrogen equilibrium and at intakes between equilibrium and zero intake. Studies are also needed on the effects of low intakes of high-quality proteins on the nitrogen losses of man and to determine the amount of dietary nitrogen that is required to prevent a fall with time in the urinary nitrogen excretion such as is observed in subjects fed a protein-free diet.

There is an urgent need for information about the nitrogen requirements of older children, adolescents, elderly persons, and adults in a number of geographically and racially different populations. Such studies should be designed to afford an opportunity to examine the physiological determinants of nitrogen requirements (e.g., basal metabolic rate, lean body mass, growth rate, etc.).

Insufficient is known about the relationship between faecal nitrogen loss, the nature of the diets habitually consumed (e.g., crude fibre content, cooking practices, etc.), and the intestinal mucosal changes that may occur as a result of diet composition, genetic factors, and general health conditions.

It would also be desirable to undertake further studies on the dermal and sweat nitrogen losses of children and adapted adults living and working at different occupations in hot climates. In view of the evidence of adjustments between sweat and urinary losses, such studies must include determination of urinary nitrogen loss.

(2) The most complete information on essential amino acid requirements currently available concerns young adults, and even here the information is sparse. Values for children are particularly incomplete. The results of several types of studies suggest that the ratio of essential amino acid require-

ments to total nitrogen requirements changes with age, but the rate of change remains unknown. There is a need for studies to examine the effects of dilution of high quality proteins with nitrogen from sources not including essential amino acids, in an attempt to define more precisely the required proportion of essential amino acids. The provisional pattern of amino acid requirements suggested in this report must be subjected to actual trial in persons of various ages. There must be further examination, by means of both animal and human studies, of the effects of the balance of other amino acids, of the total nitrogen intake, and of age on the requirements for the individual essential amino acids.

At present there is almost no information on the variability of amino acid requirements between individuals. The present report assumes that the variability of amino acid requirements and total nitrogen requirement is closely correlated among individuals. This postulate must be tested before suitable or "safe" levels of amino acid intake can be recommended with confidence.

(3) Histidine is an essential nutrient for the human infant; although there is no evidence that histidine is synthesized by man, the human adult can be maintained in nitrogen equilibrium for as long as 60 days without a dietary source of histidine. Histidine is an important component of haemoglobin, which, together with the dipeptides anserine and carnosine in muscle, could provide a substantial reserve of histidine, particularly if this amino acid is re-utilized efficiently. It would be valuable to know whether or not biochemical changes, such as a fall in haemoglobin concentration or a change in haemopoiesis, occur in men maintained on histidine-free diets for long periods, and to establish clearly whether or not histidine is essential for the human adult. This may be particularly relevant to women of reproductive age and to populations suffering regular blood losses due to parasitic infections.

(4) In the present report, the nitrogen requirements suggested for pregnant and lactating women are based on predictions of nitrogen accretions (pregnancy) or secretions (lactation) and on the assumption that nitrogen utilization is comparable with the synthsis of any other tissue protein. There is a need to examine actual balance data and to conduct experiments that will test the validity of these assumptions. Such experimental design is complicated, at least in the case of pregnancy, by the need to define a satisfactory "endpoint" to assess adequacy of intake (i.e., comparable to nitrogen equilibrium in the adult or normal growth in the infant or child). Clearly, neither weight change nor maximal nitrogen retention is a satisfactory indicator in pregnancy. In lactation, nitrogen equilibrium, taking into account the nitrogen secreted in the milk, is a satisfactory theoretical criterion, but practical difficulties are encountered in the determination of the quantity of milk secreted under natural condi-

tions. Since it is possible that inadequate protein intake may limit milk secretion, care must be taken to ensure that the total volume secreted is kept at an adequate level; the mother should preferably be breastfeeding an infant during the studies.

(5) At present there is almost no information on the amino acid requirements of pregnant and lactating women — either in terms of the absolute requirements for the individual amino acids or in terms of the proportion of essential amino acids to total protein.

8.7 Significance of diets in pregnancy, lactation, and perinatal feeding

(1) Estimates of infant requirements for energy, protein, and other nutrients are usually based on the intakes of breastfed babies. Reports on the volume and composition of breast milk are available from some parts of the world, but additional information from other areas would be desirable. Factors that may affect lactation performance need to be investigated, e.g., protein and energy intakes during pregnancy and lactation, maternal age, and parity. The duration of breastfeeding and the time of introduction of supplementary foods, as well as the duration of the transition from full breastfeeding to full weaning, should be recorded for various populations, with particular attention to the effect of urbanization.

(2) In experimental work on animals correlations have been demonstrated between maximum growth velocity in the early weeks and shortened longevity, and between impaired growth in the early weeks and irreversible effects on subsequent growth and development (contrasted with the reversible effects of weight loss at later stages of development); these findings point to the importance of the conditioning effects of early nutritional experience on performance in subsequent periods of life.

8.8 Protein-energy interactions

It has been pointed out in this report that protein is used inefficiently if energy intake is grossly inadequate. The extent to which inadequacy of energy intake affects protein utilization, and the extent to which additional intakes of protein can be utilized to meet protein requirements in the presence of caloric inadequacy needs much further investigation, particularly in the borderline situation where energy intake is inadequate but not grossly inadequate. The role and effect of pre-existing energy stores (adipose tissue) on this relationship must be considered in studies of this phenomenon. Guidance on these relationships is needed in the planning of agricultural policies and child feeding programmes in areas where both energy and protein intakes appear to be inadequate at present. Data on these matters could also be useful in the design of weight reduction regimens.

Definition of a satisfactory protein/energy ratio would permit an approach to the appraisal of dietary quality that would find wide application and would resolve some of the difficulties referred to in the present report. This might be done by means of the epidemiological studies already recommended. However, it might also be derived from the basic recommendations of the present report if sufficient data were available. For reasons outlined in section 7.1 these data must include information on the variability of both protein and energy requirements, the covariance between them, and the probable variability of the protein/energy ratio in self-selected diets. It would be of relevance to examine these questions in both human and animal studies wherever possible.

8.9 Nutrition, infection, and parasitism

The nutritional levels suggested in this report are intended to apply to healthy individuals. However, acute and chronic infections of all degrees of severity, including parasitic infestations, are endemic in many regions of the world. Children and elderly people are more frequently ill, and for longer periods, than are young adults in most of these populations. Research is needed on the effect of these disorders on nitrogen and energy metabolism and requirements.

Annex 1

PERCENTILES FOR WEIGHT AND HEIGHT OF MALES AND FEMALES AGED 0-18 YEARS

These data have been used in a number of the calculations in the present report and are included for reference. However, the Committee does not intend that they should be considered a standard of normal growth and development.

The data in these tables are taken from Nelson, W. E., Vaughan, V. C. & McKay, R. J. (1969) *Textbook of pediatrics*, 9th ed., Philadelphia, Saunders. The values represent the heights and weights at the mid-point age of the specified interval. For ages below one year the values are extrapolated from data in the original source; for all other ages they are read directly. The increments shown are those recorded for the specified

TABLE 29. FIGURES FOR MALES

Age	Body weight (kg)				Height (cm)			
	3	50	97	Increment at 50th percentile	3	50	97	Increment at 50th percentile
(months)								
< 3	3.72	4.56	6.01	2.32	51.55	55.50	59.15	9.8
3–5	5.58	6.65	8.44	1.86	59.90	63.40	67.05	6.0
6–8	6.94	8.32	10.25	1.49	65.35	68.80	73.15	4.8
9–11	7.96	9.57	11.72	1.0	69.50	73.20	78.10	4.0
(years)								
1	9.57	11.43	14.29	2.49	77.50	81.80	88.2	12.3
2	11.43	13.61	16.78	2.05	86.90	92.10	99.50	8.7
3	12.93	15.56	18.82	1.90	94.30	99.80	106.50	7.2
4	14.33	17.42	21.50	1.86	100.60	106.70	114.30	5.3
5	16.56	20.68	25.92	2.50	105.30	114.40	122.85	6.2
6	18.48	23.22	29.71	2.63	111.25	120.80	129.80	6.6
7	20.64	25.90	33.86	2.72	116.80	127.10	136.80	5.9
8	22.79	28.62	38.38	2.68	121.90	132.80	142.75	5.5
9	24.78	31.30	43.04	2.67	126.45	137.90	147.80	4.8
10	26.90	33.93	48.02	2.59	131.05	142.30	152.35	3.9
11	29.26	36.74	53.50	3.08	135.75	146.90	158.15	5.4
12	31.57	40.23	59.47	3.90	140.15	152.30	165.70	5.4
13	34.43	45.50	65.46	6.63	144.30	158.90	173.30	7.7
14	38.80	51.66	70.80	5.67	149.05	165.30	180.90	5.1
15	44.16	56.65	75.32	4.35	154.10	169.70	183.70	3.8
16	48.51	60.33	78.50	2.95	157.75	172.70	186.10	2.1
17	50.69	62.41	80.42	1.27	159.30	174.10	187.10	0.8
Adult		65.00						

interval. Thus, for boys aged 0–3 months, the estimated average weight at 1.5 months is 4.56 kg, and the increment in weight between 0 and 3 months is 2.32 kg. The authors identify these data as being derived from the Harvard growth studies up to the age of 5 years and from the Iowa growth studies beyond that age.

TABLE 30. FIGURES FOR FEMALES

Age	Body weight (kg)				Height (cm)			
	3	50	97	Increment at 50th percentile	3	50	97	Increment at 50th percentile
(months)								
< 3	3.54	4.49	5.51	2.26	51.45	54.85	58.35	9.3
3–5	5.10	6.44	7.92	1.64	58.45	62.35	65.95	5.7
6–8	6.30	7.98	10.02	1.45	63.25	67.65	71.45	4.9
9–11	7.24	9.23	11.64	1.04	67.15	72.15	76.45	4.1
(years)								
1	8.80	11.11	14.02	2.54	74.90	80.90	86.70	12.4
2	10.70	13.43	17.33	2.13	84.50	91.40	98.70	9.1
3	12.47	15.38	20.55	2.00	92.00	99.50	108.00	7.5
4	13.98	17.46	23.09	1.95	98.10	106.80	116.20	5.9
5	16.08	19.96	25.06	2.31	105.30	112.80	121.70	6.2
6	17.30	22.41	28.58	2.59	111.00	119.10	128.55	6.4
7	19.64	25.04	33.16	2.67	116.55	125.20	134.55	5.7
8	21.41	27.67	38.28	2.59	121.35	130.50	140.40	4.9
9	23.20	30.44	43.50	2.95	125.65	135.80	146.35	5.7
10	25.20	33.79	48.72	3.85	130.00	141.70	153.35	6.1
11	27.56	37.74	54.56	4.00	135.05	148.10	161.00	7.2
12	30.80	42.37	61.24	5.21	140.75	154.30	166.50	5.2
13	35.22	47.04	66.48	4.22	145.95	158.40	169.55	2.5
14	39.03	50.35	69.40	2.31	149.20	160.40	171.15	1.5
15	41.00	52.30	70.96	1.59	150.50	161.70	171.80	1.1
16	42.12	53.57	71.94	0.95	150.90	162.40	172.10	0.3
17	42.73	54.20	72.62	0.37	151.00	162.50	172.00	0.0
Adult		55.00						

Annex 2

CALCULATION OF THE ENERGY VALUES OF FOOD OR FOOD GROUPS BY THE ATWATER SYSTEM

When energy intakes are calculated from diets that contain large amounts of roughage or unavailable carbohydrates, the energy from carbohydrate may be overestimated by the application of a single energy conversion factor to total carbohydrate. If the available monosaccharide content of a food is known, the factor of 3.75 kcal (16 kJ) can be used. Otherwise the specific energy values shown in the accompanying table should be used. If energy calculations are based on values reported in food composition tables, it should be ascertained how those values were derived. If the appropriate figures are not used, there may be errors of 5–10% in the calculated energy available from the diets eaten in many countries.

The values given in the following table were adapted from Merrill, A. L. & Watt, B. K. (1955) *Energy Value of Foods ... Basis and Derivation*, Washington, D.C., US Department of Agriculture (Handbook No. 74).

Food or food group	Protein				Fat				Carbohydrate			
	Coefficient of digestibility	Heat of combustion less 1.25 [b]	Factor to be applied to ingested nutrients		Coefficient of digestibility	Heat of combustion	Factor to be applied to ingested nutrients		Coefficient of digestibility	Heat of combustion	Factor to be applied to ingested nutrients	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
	%	kcal per g	kcal per g	kJ per g	%	kcal per g	kcal per g	kJ per g	%	kcal per g	kcal per g	kJ per g
EGGS, MEAT PRODUCTS, MILK PRODUCTS:												
Eggs	97	4.50	4.36	18.24	95	9.50	9.02	37.74	98	3.75	3.68	15.40
Gelatin	97	4.02	3.90	16.32	95	9.50	9.02	37.74	—	—	—	—
Glycogen	—	—	—	—	—	—	—	—	98	4.19	4.11	17.20
Meat, fish	97	4.40	4.27	17.87	95	9.50	9.02	37.74	—	—	—[c]	—
Milk, milk products	97	4.40	4.27	17.87	95	9.25	8.79	36.78	98	3.95	3.87	16.19
FATS, SEPARATED:												
Butter	97	4.40	4.27	17.87	95	9.25	8.79	36.78	98	3.95	3.87	16.19
Other animal fats	—	—	—	—	95	9.50	9.02	37.74	—	—	—	—
Margarine, vegetable	97	4.40	4.27	17.87	95	9.30	8.84	36.99	98	3.95	3.87	16.19
Other vegetable fats and oils	—	—	—	—	95	9.30	8.84	36.99	—	—	—	—
FRUITS:												
All (except lemons and limes)	85	3.95	3.36	14.06	90	9.30	8.37	35.02	90	4.00	3.60	15.06
Lemons, limes	85	3.95	3.36	14.06	90	9.30	8.37	35.02	98	2.75	2.70	11.30
GRAIN PRODUCTS:												
Barley, pearl	78	4.55	3.55	14.85	90	9.30	8.37	35.02	94	4.20	3.95	16.53
Buckwheat flour, dark	74	4.55	3.37	14.10	90	9.30	8.37	35.02	90	4.20	3.78	15.82
Buckwheat flour, light	78	4.55	3.55	14.85	90	9.30	8.37	35.02	94	4.20	3.95	16.53
Cornmeal, whole ground	60	4.55	2.73	11.42	90	9.30	8.37	35.02	96	4.20	4.03	16.86
Cornmeal, degermed	76	4.55	3.46	14.48	90	9.30	8.37	35.02	99	4.20	4.16	17.41
Dextrin	—	—	—	—	—	—	—	—	98	4.11	4.03	16.86
Macaroni, spaghetti	86	4.55	3.91	16.36	90	9.30	8.37	35.02	98	4.20	4.12	17.24
Oatmeal, rolled oats	76	4.55	3.46	14.48	90	9.30	8.37	35.02	98	4.20	4.12	17.24
Rice, brown	75	4.55	3.41	14.27	90	9.30	8.37	35.02	98	4.20	4.12	17.24
Rice, white or polished	84	4.55	3.82	15.98	90	9.30	8.37	35.02	99	4.20	4.16	17.41
Rye flour, dark	65	4.55	2.96	12.33	90	9.30	8.37	35.02	90	4.20	3.78	15.82
Rye flour, whole grain	67	4.55	3.05	12.76	90	9.30	8.37	35.02	92	4.20	3.86	16.15
Rye flour, medium	71	4.55	3.23	13.51	90	9.30	8.37	35.02	95	4.20	3.99	16.69
Rye flour, light	75	4.55	3.41	14.27	90	9.30	8.37	35.02	97	4.20	4.07	17.03

[a] In a few cases, values in columns 4, 8, and 12 are slightly different from those of Atwater because of a different method of rounding figures.

[b] The correction, 1.25 kcal, has been subtracted from the heat of combustion. This gives values applicable to g of digested protein and identical with Atwater's factors per g of available protein.

[c] Carbohydrate factor 3.87 for brain, heart, kidney, and liver; 4.11 for tongue and shellfish.

TABLE 31 (*cont.*)

Food or food group	Protein				Fat				Carbohydrate			
	Co-efficient of digesti-bility	Heat of combus-tion less 1.25 [b]	Factor to be applied to ingested nutrients		Co-efficient of digesti-bility	Heat of combus-tion	Factor to be applied to ingested nutrients		Co-efficient of digesti-bility	Heat of combus-tion	Factor to be applied to ingested nutrients	
	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
GRAIN PRODUCTS (*cont.*):	%	kcal per g	kcal per g	per g kJ	%	kcal per g	kcal per g	kJ per g	%	kcal per g	kcal per g	kJ per g
Sorghum vulgare	55 [d]	4.55	2.50	10.46	90	9.30	8.37	35.02	96	4.20	4.03	16.86
Wheat, 97–100% extraction	79	4.55	3.59	15.02	90	9.30	8.37	35.02	90	4.20	3.78	15.82
Wheat, 85–93% extraction	83	4.55	3.78	15.82	90	9.30	8.37	35.02	94	4.20	3.95	16.53
Wheat, 70–74% extraction	89	4.55	4.05	16.95	90	9.30	8.37	35.02	98	4.20	4.12	17.24
Wheat, flaked, puffed, rolled, shredded, whole meal	79	4.55	3.59	15.02	90	9.30	8.37	35.02	90	4.20	3.78	15.82
Wheat bran (100%)	40	4.55	1.82	7.61	90	9.30	8.37	35.02	56	4.20	2.35	9.83
Other cereals, refined	85	4.55	3.87	16.19	90	9.30	8.37	35.02	98	4.20	4.12	17.24
Wild rice	78	4.55	3.55	14.85	90	9.30	8.37	35.02	94	4.20	3.95	16.53
LEGUMES, NUTS:												
Mature dry beans, cowpeas, peas, other legumes; nuts	78	4.45	3.47	14.52	90	9.30	8.37	35.02	97	4.20	4.07	17.03
Immature lima beans, cowpeas, peas, other legumes	78	4.45	3.47	14.52	90	9.30	8.37	35.02	97	4.20	4.07	17.03
Soya beans, dry; soya flour, flakes, grits	78	4.45	3.47	14.52	90	9.30	8.37	35.02	97	4.20	4.07	17.03
SUGARS:												
Cane or beet sugar (sucrose)	—	—	—	—	—	—	—	—	98	3.95	3.87	16.19
Glucose	—	—	—	—	—	—	—	—	98	3.75	3.68	15.40
VEGETABLES:												
Mushrooms	70	3.75	2.62	10.96	90	9.30	8.37	35.02	85	4.10	3.48	14.56
Potatoes and starchy roots	74	3.75	2.78	11.63	90	9.30	8.37	35.02	96	4.20	4.03	16.86
Other underground crops [e]	74	3.75	2.78	11.63	90	9.30	8.37	35.02	96	4.00	3.84	16.07
Other vegetables	65	3.75	2.44	10.21	90	9.30	8.37	35.02	85	4.20	3.57	14.94
MISCELLANEOUS FOODS:												
Chocolate, cocoa	42	4.35	1.83	7.66	90	9.30	8.37	35.02	32	4.16	1.33	5.56
Vinegar	—	—	—	—	—	—	—	—	98	2.45	2.40	10.04
Yeast	80	3.75	3.00	12.55	90	9.30	8.37	35.02	80	4.20	3.35	14.02

[d] Kurien, P. P., Narayanarao, M., Swaminathan, M. & Subrahamanyan, V. (1960) *Brit. J. Nutr.*, **14**, 339.

Annex 3

CONVERSION OF NITROGEN TO PROTEIN

In the present report, protein requirements are expressed as "crude protein" (nitrogen × 6.25) and are derived from an examination of data on nitrogen intake rather than protein intake. However, most food composition tables derive estimates of protein content by applying different factors to the nitrogen content of individual foods. These factors are shown in the accompanying table. To compare the protein requirements suggested in the present report with the reported protein content of foods, a correction of the reported protein content must be made. The correction factors to convert reported protein to crude protein are shown in the table. Before these corrections are applied, it must be ascertained how the original values in the composition table were derived. The nitrogen conversion factors given in the table below are taken from Food and Agriculture Organization (1970) *Amino acid content of foods and biological data on proteins*, Rome (*FAO Nutritional Studies*, No. 24).

TABLE 32. FACTORS USED IN CONVERTING NITROGEN TO PROTEIN

Foodstuff	Conversion factor for protein content as reported in food composition tables	Correction factor for conversion of reported protein to "crude protein"
CEREALS		
Wheat, hard, medium, or soft		
Whole meal or flour or bulgur	5.83	1.07
Flour, medium or low extraction	5.70	1.10
Macaroni, spaghetti, wheat pastes	5.70	1.10
Bran	6.31	0.99
Rice		
Husked or brown (only hulls removed) } Home-pounded, undermilled, parboiled } Milled, white }	5.95	1.05
Rye		
Whole meal, dark flour		
Flour, medium extraction		
Flour, light, low extraction		
Barley } Rye, Barley, Oats	5.83	1.07
Whole seed, except hulls and groats		
Pearled, light or dark		
Oats		
Oatmeal, rolled oats		

TABLE 32 (*cont.*)

Foodstuff	Conversion factor for protein content as reported in food composition tables	Correction factor for conversion of reported protein to " crude protein "
PULSES, NUTS, AND SEEDS		
Groundnuts	5.46	1.14
Soya bean, seeds, flour or products	5.71	1.09
Treenuts		
Almond	5.18	1.21
Brazil nut	5.46	1.14
Coconuts (outer husk removed) old, ripe, in shell young, under-ripe, in shell Chestnuts fresh dry Treenuts, other	5.30	1.18
Seeds		
Sesame, safflower, sunflower	5.30	1.18
MILK AND CHEESE Milk, all species, fresh or dry Cheese, hard or soft Whey cheese	6.38	0.98
OIL AND FATS Margarine (either vegetable or animal) Butter	6.38	0.98
OTHER FOODS	6.25	1.00

Annex 4

STANDARD BASAL METABOLIC RATES OF INDIVIDUALS OF BOTH SEXES

In the present report, basal metabolic rates have been used in a number of calculations. Since a variety of values have been reported in the literature, the Committee reviewed the available compilations and agreed to adopt for its present purposes the values for basal metabolic rates given below. It should be noted that when reviewing individual research papers in which the author's calculations had been in terms of basal metabolic rates derived from the literature rather than directly determined, the Committee recalculated the author's figures on the basis of the values given below. The values given in the following table are from Talbot, F. B. (1938) *Amer. J. Dis. Child.*, **55**, 455. The standards are based on measurements of 2200 persons in one laboratory in Boston over 15 years. The values are not applicable to obese body weights.

TABLE 33. STANDARD BASAL METABOLIC RATES OF INDIVIDUALS OF BOTH SEXES

Body weight (kg)	kcal per 24 hours		MJ per 24 hours	
	Males	Females	Males	Females
3.0	150	136	0.6	0.6
4.0	210	205	0.9	0.8
5.0	270	274	1.1	1.1
6.0	330	336	1.4	1.4
7.0	390	395	1.6	1.6
8.0	445	448	1.9	1.9
9.0	495	496	2.1	2.1
10.0	545	541	2.3	2.3
11.0	590	582	2.5	2.4
12.0	625	620	2.5	2.6
13.0	665	655	2.8	2.7
14.0	700	687	2.9	2.9
15.0	725	718	3.0	3.0
16.0	750	747	3.1	3.1
17.0	780	775	3.3	3.2
18.0	810	802	3.4	3.3
19.0	840	827	3.5	3.5
20.0	870	852	3.6	3.6
22.0	910	898	3.8	3.8
24.0	980	942	4.1	3.9
26.0	1 070	984	4.5	4.1
28.0	1 100	1 025	4.6	4.3
30.0	1 140	1 063	4.8	4.4
32.0	1 190	1 101	5.0	4.6
34.0	1 230	1 137	5.1	4.8
36.0	1 270	1 173	5.3	4.9

TABLE 33 *(cont.)*

Body weight (kg)	kcal per 24 hours		MJ per 24 hours	
	Males	Females	Males	Females
38.0	1 305	1 207	5.5	5.0
40.0	1 340	1 241	5.6	5.2
42.0	1 370	1 274	5.7	5.3
44.0	1 400	1 306	5.9	5.5
46.0	1 430	1 338	6.0	5.6
48.0	1 460	1 369	6.1	5.7
50.0	1 485	1 399	6.2	5.8
52.0	1 505	1 429	6.3	6.0
54.0	1 555	1 458	6.5	6.1
56.0	1 580	1 487	6.6	6.2
58.0	1 600	1 516	6.7	6.3
60.0	1 630	1 544	6.8	6.5
62.0	1 660	1 572	6.9	6.6
64.0	1 690	1 599	7.1	6.7
66.0	1 725	1 626	7.2	6.8
68.0	1 765	1 653	7.4	6.9
70.0	1 785	1 679	7.5	7.0
72.0	1 815	1 705	7.6	7.1
74.0	1 845	1 731	7.7	7.2
76.0	1 870	1 756	7.8	7.3
78.0	1 900	1 781	7.9	7.4
80.0	—	1 805	—	7.5
82.0	—	1 830	—	7.7
84.0	2 000	1 855	8.4	7.8

Annex 5

SOME VALUES OF ENERGY EXPENDITURE IN EVERYDAY ACTIVITIES

The Committee has drawn attention to the fact that energy expenditure varies with the type of activity performed and has suggested that the recommendations on energy requirements might be adjusted according to observed customary patterns of activity. In the following table, the average expenditure of energy in a specified activity is given on the basis of the values assembled in Durnin, J.V. G. A. & Passmore, R. (1967) *Energy, work and leisure*, London, Heinemann. These values refer to the expenditure of energy during the actual performance of the activity and do not take into account any rest period. The values are based on body weights of 65 kg for a man and 55 kg for a woman, the reference weights used in this report. For certain of the activities, particularly those involving movement of the body as part of the activity, body weight is an important variable in energy expenditure. Other factors, such as training and efficiency of movement, also contribute to individual variability.

To apply these figures it is necessary to use as a base a diary of typical activities, including the actual times spent on individual tasks and rest periods. Thus, while an African woman farmer may expend 4.8–6.8 kcal (20.1–28.4 kJ) per minute when hoeing, it is unlikely that she would actually work at hoeing for a full hour at a time in the field.

TABLE 34. ENERGY EXPENDITURE IN SPECIFIED ACTIVITIES: MAN

	kcal per min	kJ per min
In bed asleep or resting	1.08	4.52
Sitting quietly	1.39	5.82
Standing quietly	1.75	7.32
Walking 3 miles/hour (4.9 km/hour)	3.7	15.5
Walking 3 miles/hour (4.9 km/hour) with a 10-kg load	4.0	16.7
Office work (sedentary)	1.8	7.5
Domestic work		
Cooking	2.1	8.8
Light cleaning	3.1	13.0
Moderate cleaning (polishing, window cleaning, chopping firewood, etc.)	4.3	18.0
Light industry		
Printing	2.3	9.6
Tailoring	2.9	12.1
Shoemaking	3.0	12.6

TABLE 34 (*cont.*)

	kcal per min	kJ per min
Light industry (*cont.*)		
Garage work (repairs)	4.1	17.2
Carpentry	4.0	16.7
Electrical industry	3.6	15.1
Machine tool industry	3.6	15.1
Chemical industry	4.0	16.7
Laboratory work	2.3	9.6
Transport		
Driving lorry	1.6	6.7
Building industry		
Labouring	6.0	25.1
Bricklaying	3.8	15.9
Joinery	3.7	15.5
Decorating	3.2	13.4
Farming (tropical)		
Grass cutting (with cutlass)	4.5	18.8
Clearing bush	6.2	25.9
Planting	3.6	15.1
Weeding (Africa)	3.8–7.8	15.9–32.6
Ridging, deep digging (Africa)	5.5–15.2	23.0–63.6
Tree felling (Africa)	8.4	35.1
Head planning, 20–35-kg loads (Africa)	3.2–5.6	13.4–23.4
Mowing (India)	5.1–7.9	21.3–33.0
Watering (India)	4.1–7.5	17.1–31.4
Weeding, digging, and transplanting (India)	2.3–9.1	9.6–38.1
Farming (European, mechanized)		
Driving tractor	2.4	10.0
Forking	7.8	32.6
Loading sacks	5.4	22.6
Feeding animals	4.1	17.2
Repairing fences	5.7	23.8
Forestry		
In nursery	4.1	17.2
Planting	4.7	19.7
Felling with axe	8.6	36.0
Trimming	8.4	35.1
Sawing — hand saw	8.6	36.0
power saw	4.8	20.1
Mining		
Working with pick	6.9	28.9
Shovelling	6.5	27.2
Erecting roof supports	5.6	23.4
Armed services		
Cleaning kit	2.7	11.3
Drill	3.7	15.5
Route marching	5.1	21.3
Assault course	5.8	24.3
Jungle march	6.5	27.2
Jungle patrol	4.0	16.7

TABLE 34 (*cont.*)

	kcal per min	kJ per min
Recreations		
Sedentary	2.5	10.5
Light (billiards, bowls, cricket, golf, sailing, etc.)	2.5–5.0	10.5–21.0
Moderate (canoeing, dancing, horse-riding, swimming, tennis, etc.)	5.0–7.5	21.0–31.5
Heavy (athletics, football, rowing, etc.)	7.5 +	31.5 +

TABLE 35. ENERGY EXPENDITURE IN SPECIFIED ACTIVITIES: WOMAN

	kcal per min	kJ per min
In bed asleep or resting	0.90	3.77
Sitting quietly	1.15	4.82
Standing quietly	1.37	5.73
Walking 3 miles/hour (4.9 km/hour)	3.0	12.6
Walking 3 miles/hour (4.9 km/hour) with 10-kg load	3.4	14.2
Office work (sedentary)	1.6	6.7
Domestic work		
Cooking	1.7	7.1
Light cleaning	2.5	10.5
Moderate cleaning (polishing, window cleaning, chopping firewood, etc.)	3.5	14.6
Light industry		
Bakery work	2.3	9.6
Brewery work	2.7	10.0
Chemical industry	2.7	11.3
Electrical industry	1.9	7.9
Furnishing industry	3.1	13.0
Laundry work	3.2	13.4
Machine tool industry	2.5	10.5
Farming		
Threshing (Europe)	3.8–5.5	15.9–23.0
Binding sheaves (Europe)	3.0–4.9	12.6–20.5
Hoeing (Africa)	4.8–6.8	20.1–28.4
Recreations		
Sedentary	2.0	8.3
Light (billiards, bowls, cricket, golf, sailing, etc.)	2.0–4.0	8.3–16.7
Moderate (canoeing, dancing, horse-riding, swimming, tennis, etc.)	4.0–6.0	16.7–25.1
Heavy (athletics, football, rowing, etc.)	6.0 +	25 +

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